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Factors Affecting the Natural Regeneration of *Taxus contorta* Griff. in Temperate Forests, North-western Himalaya Region, India

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***Abstract*:** The assessment of ecological factors on the occurrence of *Taxus contorta* Griff. forest helps in understanding the regeneration dynamics of the species and formulating a policy to make out the species from endangered rank. The study was undertaken at temperate forests in the north-western Himalayan region. In four forests, a total of 96 random plots were laid, of each plot area was 0.16 ha i.e., (40x40 m^2). Each forest had laid 24 plots, considering 6 plots on each geographical region (North, Northeast, Southwest, and southeast. The study aimed to assess the effect of local factors i.e. edaphic factor (pH, soil moisture, and bulk density), photosynthetic active radiation (PAR), canopy closure, soil compaction, and phytosociological attributes on regeneration process of an endangered plant species in *Taxus* occurrence forests. There were significant differences in stand diversity, soil moisture, and bulk density between the northern and southern geographical directions in all studied forests. Among all, Himri forest was found in "Good regeneration" category of *T. contorta* occurrence geographical directions while other forests were in "No regeneration" category for this species. The adult's population and their vitality were high and satisfied in all studied forests which resulted in high chance of return back of this endangered species. For returning and protection of this species, an appropriate conservation strategy should be undertaken immediately, especially in the northern slope exposure. The northern geographical directions are more suitability for this endangered species because it is grown at high moisture and humidity environment, low temperature slope exposure directions with association of thorny fleshy-fruited shrubs.

Keywords: Biodiversity, Endangered species, Influence factors, Returning, Shrub habitat

Taxus contorta Griff. (known as West Himalayan yew) an endangered species, is mainly distributed from Afghanistan to the central part of Nepal usually in small, localized, and patchy population. It is likely to be less than 2,000 km^2 in the whole Hindu-Kush Himalayan region i.e., less than 1% forest area. This species is different from other conifers in the sense of that it has colloid fleshy fruit with dense branches, evergreen leaves, foliage, needles distichous 1-1.5 inches long, dioecious, and rarely monoecious plant (Lanker et al 2010). Local people of the Himalayan region use this species as a medicinal plant from ancient times and present time (Chandra et al 2021) it is illegally or overused for extraction of anticancer drug "Taxol" thus its population is declining up to 90% (Poudel et al 2013). Furthermore, number of local factors are responsible for the poor seed regeneration of this species (Quinn et al 2002, Chettri et al 2010). The regeneration was found difficult under the mother tree due to toxic production from its roots, habitat fragmentation, and disturbance factors (Farris and Filigheddu 2008). All above-mentioned factors were found to negatively affect the regeneration of this species, its genetic impoverishment, formation of healthy seeds, and increase population in its potential habitat (Thomas and Polwart 2003). Thus, low recruitment of the species are due to the effects of local factors in its poor seed germination (8-10%) in natural conditions (Linares 2013). All these local factors and disturbances have led this species to become an endangered plant or extinction in near future from this region (Iszkulo et al 2012). The finding, outcomes of the research as, like deeply shaded thorny fleshy fruited shrub habitat, certain species composition, undistributed forest patch, moist and humid geographical directions were found some hope for its successful regeneration and sustainable conservation (Jensen et al 2021). From the above statement, it is well known that various environmental factors could become the most powerful triggers for its ecological decline in the Himalaya region forests (Wang et al 2019) but however the future perspective of its regeneration returning has some positive sign due to its conservation practises and awareness (Mownika et al 2021). The local factors have affected a significant role in the regeneration alteration of its occurrence forests (Kirby et al 2016) with negative impacts on the anatomy, physiology, and behavioural peculiarities of this species (Chybicki et al 2011). Thus, the assessment of factors affecting the regeneration of *T. contorta* in temperate forests information will be a milestone on the current status of its returning ecology. Thus, the present study aims to address the effect of the local factors (canopy closure, PAR, pH, moisture, bulk density, species composition) on regeneration in natural habitat.

MATERIAL AND METHODS

Study area: At the base of occurrence information from the Department of Forest Office Shimla, Himachal State, India, we have selected four forests i.e., area of occupancy (AOO) of this species. The average annual precipitation, average minimum, and maximum temperature were 2,000mm, 7^0C, and 19^0C respectively. The main dominant tree species composition in *Taxus* forests are found *Abies pindrow* (Royle ex D.Don) Royle, *Cedrus deodara* (roxb. Ex D.Don) G.Don, *Picea smithiana* (Wall.) Boiss. etc.

Survey, sampling, and identification: The study forests were declared from the district forest office (DFO), Shimla, Himachal State, India. The field survey and vegetation samplings were conducted in October and November 2020. Species were identified with the help of various floras books and research papers (Rana and Rawat 2017). For the study purposes, 40m × 40m unit plots were laid concerning the slope error correction. The plots were divided into 16 equal subplots of the 10m × 10m unit for adults and saplings and 5m × 5m unit for seedlings enumeration. Total 96 plots were laid in four studied forests. 24 random sampled plots were laid in each study forests with 6 plots in each studied geographical directions i.e., North, Northeast, Southwest, and Southeast respectively. Soil samples (BD, pH, SOC), and litter were collected from only one side diagonal subplots of 40×40 m^2. The soil samples represented by 0-10cm, 10-20cm and 20-30cm depth of defined steel corer [inner(r) =2.04cm]. The aspect of geography is measured by clinometer (Sunnto PM-5/360 PC Clinometer). The size and numbers of quadrats were determined (and Indian forest survey guide for coniferous forest. The height of all seedlings, saplings and adults were measured using the altimeter TP360 instrument.

Methods: Major phytosociological attributes such as species density, frequency, basal area, importance value index (IVI), species diversity indices (i.e. Simpson index, Shannon-diversity index ($_{H'}$), bulk density (BD) and Soil Organic Carbon (SOC) were calculated by using the formulae are shown in Table 2. Shrubs and herbs biomass was calculated by using the non-destructive method i.e., Reference Unit Method (RUM).

Table 1. Geographic distribution of research sites

Forests	Spatial identification	Altitude (m amsl) of *Taxus* occurrences range
Himri	Lat.: 31.2079°- 31.2217° Lon.:77.2785°- 77.2868°	2200-2400
Narkanda	Lat.:31.2465°- 31.2548° Lon.:77.4738°-77.5344°	2700-3000
NanKhari	Lat.: 31.2624^0 - 31.2611^0 Lon.:77.5976^0- 77.6105^0	2839-3010
Pabbas	Lat.: 30.9906° - 31.005^0 Lon.:77.4738°- 77.5017^0	2500-2700

The fresh soil samples were collected from the field, brought to the laboratory and sieved. Then, the samples were kept at 105°C for 24 to 48 h up to a constant weight <0.05 g in the hot chamber. Soil BD was calculated depth-wise as the differences in mass of fresh and dry soil (Alshammary et al 2020). For moisture calculation, the dry soil was weighted in the presence of the desiccators and calculated depth-wise (Dangal et al 2017). The fresh weight of the litter biomass was weighted in the field, then heated in lab at 75°C for 48 h in hot air oven, and calculations were made using the method given by Qin et al (2020). The soil pH was determined given method by Ghazali et al 2020 for upper soil layer (0-10 cm depth). Depth wise soil organic carbon (SOC) was determined the method given by Sharma et al 2018. Soil compaction and Photosynthetic Active Radiation (PAR) was measured from all 16 subplots (centre and 1m, 2m and 3 m and 5m apart diagonally) by adopting the method given by Tanioka et al (2020). Densiometer (Spherical concave) was used to take canopy closure in all Subplots (Bassett et al 2020).

Regeneration category: The seedlings, saplings, and adult density patterns were given by the information in the regeneration category; Good, Fair, Poor, No, and Not regeneration. RC was created to know the regeneration potential of each species (Shankar 2001).

Good regeneration (GR): If number of seedlings > saplings> adult

Fair regeneration (FR): If number of seedlings> or < saplings< adult,

Poor regeneration (PR): No seedlings (saplings may be <, > or = adults)

No regeneration (NR): If individuals of species are present only in adult form

Not abundant (NA): If the species occupy only in seedling or sapling

Importance Value Index (IVI), Abundance and Frequency ratio (A/F), and distribution pattern: IVI was calculated by summing relative density, relative frequency, and relative basal area. A/F was calculated according to exhibit the species distribution pattern (i.e. <0.025-regular, 0.025 to 0.05-random, >0.05-contagious distribution).

Analysis of data: The plant species was sampled at three different growth levels, determined by the circumferences at breast height (CBH, 1.37m from the ground), adult/tree (≥31. 5 cm), sapling (≥10. 5 to <31.5 cm), and seedlings (<10.5 cm) (Brokaw and Thompson 2000). Tukey's shrub density test was used to test differences among means while F–test was significant (P≤0.05). For determining population structure and dynamics, we used static life tables and survival curves. We used DBH size class in the analysis of wood stand in interval of 10 units, i.e., size I: (0<3.344)cm = seedlings, [II: (3.35<6.369 cm) and III: (6.37- 9.984 cm) = saplings], IV: (9.985–15.929 cm), V: (15.93–22.289 cm), VI: (22.29–28.659 cm), VII: (28.66–35.029 cm), VIII: (35.03–41.369 cm), IX: (41.37–47.769 cm), and X: >47.7cm (Zhang and Ru 2010).

RESULTS AND DISCUSSION

The decline of *T. contorta* in the north-western Himalaya region is attributed to climate change (climatic dryness) and invade of invasive species like *Pinus sylvestris* L (Su et al 2018, Kumar et al 2021). But mainly, it was observed that declining started in its habitat, due to owing to human influence consequences in habitat fragmentation and loss of shrub habitat (Iszkulo et al 2012). The natural distribution of this species has been further blurred by extensive planting for its high economical value and extraction of bark for anticancer drug "Taxol" (Hai et al 2020). Despite the many uses is unlikely that *T. contorta* has remained in a patchy forest and rapidly declined. But some hopes is shown by this research finding at Himri forest for its conservation model site. *T. contorta* are almost wholly confined in patchy forest especially favourable in northern geographical directions than southern geographical direction in the Himalaya region (Qin et al 2020).

Soil pH: In all studied forests, northern aspect has found higher acidic pH value than southern geographical directions. It was found north aspect has highest pH and southeast has almost neutral pH value. The results were showed that *T. contorta* occurrence geographical directionshas high pH than non-occurrence slope exposure in all studied forests, mentioned in Table 3. An endangered plant species were more widespread in alkaline soils noticed from all studied forests.

Soil moisture: There was no significant difference between the northern and southern geographical directions for soil moisture in 0-10cm depth while significantly different between north to southeast (p=0.0004) and north to southwest (p=0.0007) in 10-20cm and 20-30 cm north and southeast (p=0.0261) in Himri forest. Similarly, 10-20cm and 20-30cm depth significant difference between north to southeast aspect (p=0.0017) in Narkanda forest. In Pabbas forest, northeast and southeast aspects only found significant differences (p=0.0076) in 0-10 cm depth. In Nankhari forest, there was found significant differences between north and northeast aspects (p=0.0021) in 0-10cm depth and 20-30 cm depth (Table 4).

Bulk Density: Soil bulk density varied significantly between

Table 2. Procedure for analysis in study forest

Formula	References
$D = \frac{\text{Total number of individual of a species}}{\text{Total number of plant studied} \times \text{area of each quadrat}} \times 100$	Sharma et al (2018)
$RD = \frac{\text{Total number of individual of a species in all quadrat}}{\text{Total number of individual of all species in all quadrat}} \times 100$	Sharma et al 2018)
$F = \frac{\text{Number of quadrat in which a particular species occurs}}{\text{Total number of all quadrat}} \times 100$	Sharma et al (2018)
$RF = \frac{\text{Number of quadrat in which a particular species occurs}}{\text{Total number of all species in all quadrat}} \times 100$	Sharma et al (2018)
$BA = \frac{\Pi \times DBH^2}{4}$	Sharma et al (2018)
$RBA = \frac{\text{Basal area of a particular species in quadrat}}{\text{Total basal area of all species in quadrat}} \times 100$	Sharma et al (2018)
IVI = RD + RF + RBA	Dhakal et al (2021)
$H' = -\sum_{i=1}^{N} Pi \ln Pi$	Sharma et al (2018)
$C = \sum (Pi)^2$	Dhakal et al (2021)
$BD = \frac{\text{Oven dry mass}}{\text{Core volume} - \frac{\text{Mass of coarse fragments}}{\text{Density of rock fragments}}}$	Alshammary et al (2020)
Soil organic carbon = soil bulk density × soil depth × ha. conversion unit	Sharma et al (2018)

Abbreviation: D = Density, RD = Relative Density, F = Frequency, RF = Relative Frequency, BA = Basal Area, RBA = Relative Basal Area, IVI = Importance Value Index, H' = Shannon Diversity Index, S = Total number of species, N = Total number of all species, Pi = individual value of species, C = Dominance, BD = Bulk Density.

the northern and southern aspects. For example, in Himri, north to southeast (p<0.001) and north to southwest (p=0.05), similarly northeast to southeast (p<0.001) and northeast to southeast (p=0.0001) in 0-10cm depth. In Narkanda, north to southeast (p<0.0001) and north to southwest (p=0.001) and northeast to southeast (p=0.0001), and northeast to southeast (p=0.001) in 0-10cm depth. While 10-20cm depth and 20-30cm depth no evidence. In Pabbas, north and northeast aspects found southeast aspect significantly different (p<0.0001 and p=0.0008) respectively in 0-10cm depth (Table 5).

The bulk density and organic carbon content are strongly correlated to *T. contorta* occurrence geographical directions and non-occurrence geographical directions (Sheikh et al 2020). Bulk density assessment consider both topographic position and *Taxus* occurrences geographical directions as key variables in ordering the seedling germination factors along a forest complex factors relationship for endangered plant species (Zhou et al 2021).

Photosynthetically Active Radiation: PAR during the day in October morning at 8 to 8:15 a.m. was measured and for Himri, Narkanda, Pabbas, and Nankhari forest (Table 6). The PAR value has based on main geographical directions (N, NE, SW, and SE) and habitats [seedling, sapling, adult (*T. contorta*), and non-*Taxus* (no presence of *T. contorta* in the plot).

Table 3. Soil pH in study forests

Forests	North	Northeast	Southwest	Southeast
Himri	5.9	5.8	6.1	6.5
Narkanda	6.4	6.2	6.6	6.8
Pabbas	6.4	6.4	6.7	6.8
Nankhari	6.1	6.0	6.4	6.8

Soil compaction: Soil compaction is a major concern during forest management activities. The low value of soil compaction significantly promotes germination and plant regeneration while the reverse is true in case of high soil compaction (Table 7).

The higher value of soil compaction also induces changes in the amounts and balances to stress hormones in plants, especially increases in abscisic acid and ethylene, thus effects on seed germination (Abha Manohar et al 2022). Soil compaction was found higher in the southern aspect than in the northern aspect (Sheikh et al 2020). Moreover, the soil compaction has comparatively very low in seedling and sapling occurrences habitat rather than non-occurrence aspect (Mittal et al 2020). Especially, north and northern aspect of Himri was found significantly lower soil compaction than other forests. The lower soil compaction supports the germination of endangered species in their habitat (Pers-Kamczyc et al 2019).

Soil organic carbon: Plant functional types significantly affected the vertical distribution of SOC (Table 8). The role of percentage of SOC (in 30cm) was found significantly for germination process especially in endangered plant species. In shrub lands, the amount of SOC found higher than in other habitats.

Soil organic carbon (SOC) has a significant positive correlation (r=0.77) with organic matter deposition. This decaying phenomena was related with geographical direction, for e.g., northern direction was found higher than southern directions in all studied forests. The organic matter was higher in the northern aspect than the southern aspect in the study forest. The soil organic carbon of studied forests were varied forests wise and each forest geographical direction wise may be associated with some uncertainties like roll of decay factor, litter mass etc (Pattnayak et al 2021).

Table 4. Soil moisture (% by volume) in studied forests

Forests	Depth (cm)	North	Northeast	Southwest	Southeast
Himri	0-10	39.51±26.68^{a}	43.67±8.43^{a}	38.6±12.61^{a}	34.23±4.51^{a}
	10-20	33.54±14.09^{a}	30.01±5.06^{ac}	26.14±4.98^{bc}	25.85±10.52^{bc}
	20-30	32.96±17.51^{a}	27.76±11.52^{ac}	26.58±2.15^{bc}	23.02±11.56^{ac}
Narkanda	0-10	81.27±12.28^{a}	80.6±19.54^{a}	77.21±35.52^{a}	75.07±10.31^{a}
	10-20	51.01±24.65^{a}	73.33±18.56^{bc}	59.68±29.89^{a}	74.72±8.01^{ac}
	20-30	45.02±31.78^{a}	70.8±37.35^{bc}	59.76±33.07^{a}	42.12±26.95^{ac}
Pabbas	0-10	59.56±29.21^{a}	73.09±64.35^{ab}	47.91±10.22^{ac}	38.51±14.38^{a}
	10-20	54.37±15.95^{a}	51.45±19.35^{a}	43.47±21.07^{bc}	36.8±13.24^{ac}
	20-30	36.89±6.94^{a}	44.06±36.65^{a}	36.62±14.61^{a}	30.75±24.93^{a}
Nankhari	0-10	15.49±6.66^{a}	27.84±19.67^{b}	15.77±9.35^{a}	11.16±4.13^{a}
	10-20	14.99±9.71^{a}	24.52±17.04^{b}	10.97±4.42^{a}	11.29±4.43^{a}
	20-30	14.43±5.31^{a}	19.34±15.74^{ab}	7.57±3.75^{a}	13.19±6.45^{ac}

Table 5. Bulk density in study forests

Forests	Depth (cm)	North	Northeast	Southwest	Southeast
Himri	0-10	0.40±0.05^{a}	0.35±0.09^{a}	0.49±0.16^{b}	0.53±0.08^{b}
	10-20	0.46±0.12^{a}	0.41±0.08^{a}	0.57±0.04^{b}	0.65±0.18^{b}
	20-30	0.59±0.04^{a}	0.44±0.08^{ab}	0.67±0.33^{a}	0.82±0.21^{ac}
Narkanda	0-10	0.17±0.02^{a}	0.17±0.06^{a}	0.22±0.05^{b}	0.23±0.03^{b}
	10-20	0.22±0.04^{a}	0.23±0.13^{a}	0.25±0.01^{a}	0.25±0.05^{a}
	20-30	0.18±0.02^{a}	0.18±0.06^{a}	0.18±0.09^{a}	0.19±0.07^{a}
Pabbas	0-10	0.50±0.20^{a}	0.51±0.14^{a}	0.59±0.08^{bc}	0.67±0.11^{ac}
	10-20	0.47±0.20^{a}	0.52±0.07^{ac}	0.51±0.14^{bd}	0.83±0.24^{a}
	20-30	0.56±0.26^{a}	0.61±0.14^{ac}	0.58±0.14^{bd}	0.77±0.25^{a}
Nankhari	0-10	0.65±0.17^{a}	0.654±0.15^{a}	0.68±0.11^{a}	0.68±0.14^{a}
	10-20	0.69±0.18^{a}	0.68±0.21^{a}	0.77±0.35^{a}	0.82±0.21^{a}
	20-30	0.76±0.16^{a}	0.75±0.12^{a}	0.81±0.34^{a}	0.79±0.31^{a}

Table 6. Photosynthetically Active radiation (PAR) (µmol photons m^{-2} s^{-1}) at studied forests

	North				Northeast				Southwest				Southeast			
	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan
M	4.58	17.42	55.58	66.34	11.58	27.08	56.25	56.7	null	43.3	null	null	null	null	null	null
	8.83	15.58	41.67	63.8	18.33	23.25	54.92	51.4	null	54.2	null	null	null	null	null	null
	6.33	17	28.3	54.3	15.08	29.08	65	55.5	null	61.5	null	null	null	null	null	null
Sa	7.42	null	null	null	16.25	null	null	null	null	null	null	null	null	null	null	null
	13.33	null	null	null	12.33	null	null	null	null	null	null	null	null	null	null	null
	12.4	null	null	null	20.92	null	null	null	null	null	null	null	null	null	null	null
Se	9.58	null	null	null	24.25	null	null	null	16.25	null	null	null	null	null	null	null
	11.67	null	null	null	17.75	null	null	null	14.42	null	null	null	null	null	null	null
	11.8	null	null	null	21.65	null	null	null	22.08	null	null	null	null	null	null	null
NT	38.58	42.92	60.67	70.7	30.12	42.92	110.67	110.7	10.42	40.58	88.3	105.5	70	110.58	128.7	138.6
	37.58	55.67	62.4	76.8	33.4	48.7	98.6	106.5	12.83	71.23	98.5	111.3	79.67	201.4	146.5	140.8
	40.7	54.7	65.7	80.4	32.5	43.7	107.4	120.5	13.5	67.8	101.2	101.4	71.58	109.7	156.8	144.6

Abbreviation: M= Mother Tree habitat, Sa= Sapling habitat, Se= Seedling habitat, NT= Non_ *Taxus* habitat, Hi= Himri forest, Nar= Narkanda forest, Pab= Pabbas forest, Nan= Nankhari forest

Table 7. Soil compactionat studied forests

	North				Northeast				Southwest				Southeast			
	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan
M	70.06	73.33	95.83	118.9	83.89	98.89	108.17	112.7	null	84.17	null	null	null	null	null	null
	94.17	117.36	185.56	117.7	70.56	106.44	177.5	132.7	null	98.8	null	null	null	null	null	null
	90.56	145.56	152.5	145.1	75.17	112.22	143.89	140.8	null	110.8	null	null	null	null	null	null
Sa	66.39	null	null	null	52.06	null	null	null	null	null	null	null	null	null	null	null
	62.78	null	null	null	55.28	null	null	null	null	null	null	null	null	null	null	null
	70.21	null	null	null	48.47	null	null	null	null	null	null	null	null	null	null	null
Se	68.33	null	null	null	48.89	null	null	null	84.89	null	null	null	null	null	null	null
	62.78	null	null	null	45.7	null	null	null	90.14	null	null	null	null	null	null	null
	66.13	null	null	null	43.3	null	null	null	99.72	null	null	null	null	null	null	null
NT	133.06	150.28	153.61	160.8	110.12	122.2	121.94	132.5	129.28	173.61	181.94	187.8	173.08	195	193.61	189.7
	145.67	160.5	167.6	167.8	121.4	189.7	167.8	154.6	130.97	187.5	191.39	180.6	190.56	196.6	190.97	190.7
	155.56	168.78	180.7	165.7	126.5	190.7	187.9	155.6	130.3	210.9	220.8	179.6	185.56	200.8	212.8	201.5

See Table 6 for details

Canopy closure: It refers to the amount and organization of above-ground plant materials, including the size, shape, and orientation of plant organs such as leaves steams. Performances of seedlings and saplings were poor in lower value of canopy closure (Table 9).

T. contorta once established can continue growing slowly in non-shade space (Linares 2013, Jensen et al 2021). Saplings can persist and grow very high for dense canopy (Garcia et al 2000). This is consistent with the hypothesis that regeneration declines progressively as *T. contorta* forest develops without an appropriate canopy (Castro et al 2004). An important factor appears to be low levels of seedling recruitment found absent of seedlings and saplings in all studied forests due to less canopy closure (Coughlan et al 2020). This suggests that lack of suitable microsites beneath scrub vegetation is limiting factor in *T. contorta* occurrence forest (Thomas and Polwart 2003). It can survive its formidable shade and family groups of trees. All studied forests, shade-grown *T. contorta* is higher than less shade habitat. Lower than of 25 μmol m^{-2} s^{-1} (Photosynthetic Photon Flux Density) had found high seedling density indicated of shade-tolerant plants (Cai et al 2020). *T. contorta* can assimilate CO_2 down to 2–3 klux (PPFD of 75 μmol m^{-2} s^{-1}). *T. contorta* also showed that the maximum summer rate of photosynthesis at 10 klux (PPFD of 300 μmol m^{-2} s^{-1}) and 7 mg CO_2 g DW^{-1} h^{-1} whereas the maximum winter rate is 5.5 mg CO_2 g DW^{-1} h^{-1} (Wei 2011). The optimum temperature range was found 14–25°C which is higher than in other species of conifer for photosynthesis (Adhikari et al 2020).

Litter Biomass: The aboveground living biomass of leaves,

Table 8. Soil organic carbonin study forests

Forests	Depth (cm)	N	NE	SW	SE
Himri	0-10	5.25±.32	7.95±3.3	6±1.7	7.35±3.5
	10-20	4.92±.16	7.8±.39	5.52±2.2	6.84±3.9
	20-30	4.4±.11	8.2±3.6	5.9±2.1	5.9±3.4
Pabbas	0-10	2.55±.5	8.85±5.1	7.5±1.5	7.65±3.15
	10-20	9.96±2.52	6.12±1.44	5.64±2.76	6.24±2.76
	20-30	6.4±2.8	5.8±.9	5.6±3.2	6.1±3.1
Narkanda	0-10	2.56±.89	3.13±.47	1.8±.53	3.04±.92
	10-20	2.73±1.32	2.08±.79	1.19±.24	1.56±.92
	20-30	1.61±.57	1.99±.58	1.7±.78	1.44±.42
Nankhari	0-10	11.1±7.5	9.75±3.15	8.7±5.1	10.05±3.5
	10-20	8.16±2.5	8.16±2.5	9.24±3.96	9.84±3.84
	20-30	7.5±3.2	7.3±5.6	8.1±43	7.9±1.9

Table 9. Canopy closure (crown cover %) at studied forests

	North				Northeast				Southwest				Southeast			
	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan	Hi	Nar	Pab	Nan
M	84.79	51.56	59.43	56.6	95.83	51.25	54.64	56.5	null	51.77	null	null	null	null	null	null
	82.45	64.33	51.67	54.3	91.93	58.33	56.2	60.3	null	56.7	null	null	null	null	null	null
	81.41	77.34	51.2	52.1	93.23	55.89	60.05	62.5	null	55.4	null	null	null	null	null	null
Sa	91.93	null	null	null	94.79	null	null	null	null	null	null	null	null	null	null	null
	91.27	null	null	null	96.09	null	null	null	null	null	null	null	null	null	null	null
	89.6	null	null	null	94.27	null	null	null	null	null	null	null	null	null	null	null
Se	92.32	null	null	null	92.19	null	null	null	90.36	null	null	null	null	null	null	null
	93.63	null	null	null	94.27	null	null	null	91.93	null	null	null	null	null	null	null
	92.7	null	null	null		null	null	null	91.93	null	null	null	null	null	null	null
NT	64.01	42.9	40.89	44.4	76.9	38.54	39.9	40.5	62.97	47.76	47.76	44.3	42.19	31.61	32.45	36.5
	66.56	45.5	41.6	46.8	66.8	40.8	44.6	45.7	62.71	46.56	43.07	45.7	41.15	32.81	34.01	30.6
	60.6	44.8	42.7	47.8	68.7	42.5	40.8	44.3	59.84	51.2	41.2	45.9	41.41	29.7	28.7	33.7

See Table 6 for details

reproductive parts, and small branches, and trash was estimated as the cumulated fine litter fall over the year.

Litter biomass (Table 10) was a controlling factor to species regeneration through their effects on litter cover through many mechanisms, including shading, alteration of germination cues, direct physical interference, sheltering invertebrate seed predators, and encouraging pathogens.

Shrub biomass: The presence of shrub vegetation is very significant in temperate forest ecosystems. However, the difficulty involved in shrub management and the lack of information about the behaviour of this vegetation means that these areas are often left out of spatial planning projects. The dominant species was determined most characteristic species of the shrub biomass calculation.

Shrub biomass was highest in Himri forest (Table 11) and differed strongly between aspect and habitat types. To date, very few studies have estimated shrub biomass in intemperate forests, especially along with endangered species regeneration (Lanker et al 2010). The, herbaceous understorey growth was stronger in the northern aspect than southern aspect where herbaceous vegetation reached heights of 1.2 m and somewhere equal to the biomass of the shrub layer. The herbs compete with an endangered juvenile for light in the dark understorey, the strong herb layer might explain the relatively low fleshy-fruited shrub biomass (Bargali 2021). Herbaceous biomass was inversely related to the regeneration aspect, a pattern that seems largely due to reduced nutrients and invasion under closed canopies. This may be due to the relatively open canopy of forests, which allows for extensive growth.

Phytosociological attributes: Tree species diversity in forests varies greatly from place to place mainly due to variation in biogeography, habitat, and disturbance. There are differences in species composition at all scales. The diversity of trees is fundamental to total forest biodiversity because trees provide resources and habitats for almost all other forest species. The number of trees per hectare with a diameter at breast height (dbh≥1.3m) was about 300–700 individuals in the study forests. The factors controlling tree density include the effects of anthropogenic disturbance and soil condition. These results are expected to be helpful to improve the consequence of the change of forest structure and in biodiversity conservation.

North geographical direction (GD): This GD had highest diversity (H') 1. 53± with 4.7 ENS and 0. 71D. The average density of adult trees, saplings and seedlings were 657.29, 435 and 2667, respectively. Corresponding values of species richness for these life forms were 12, 10 and 8. The community in this GD was *C. deodara* and *Q. floribunda* of 48.5% IVI. The dominant species (ind.ha^{-1}) of adults were *C. deodara* (179) followed by *Q. floribunda*, *Q. semecarpifolia* , *P. wallichiana*, *and T. contorta* . The density of saplings was highest of *Q. dilatata* (114.58) followed by *R. barbatum*, *T. contorta*, *C. deodara*, *Q. floribunda* (933) was wiht highest seedling density followed by *R. barbatum* , and *T. contorta* and *C. deodara* in the seedling stage (Table 1). The endangered species - *T. contorta* was found in 8% in adults, 16% in saplings, and 14% in *the* seedling stage of total population occurrences in the north aspect. *T. contorta*, *Q. leucotricophora*, *Q. dilatata* and *R. barbatum* species were found "Good Regeneration" category is shown in (Fig. 1.). The *C. deodara* is found highest TBA (90.23 m^{2}ha^{-1}) and *T. contorta* was in 19.98 m^{2}ha^{-1} with IVI 26.94. Among the total 12 species, *T. contorta* rank in TBA and IVI value was in the fifth position.

Northeast geographical direction: This GD was the second-highest diversity (H') 1.2±0.19 with 10 species. The community of this aspect was *Q. floribunda* with 50.5%

Table 10. Litter biomass (gm/m^2) in studied forests

Forests	Northeast	North	Southwest	Southeast
Himri	1106.31^a (54.19)	1339.87^{ab} (68.34)	1203.65^a (144.201)	1014.97^{ac} (190.75)
Narkanda	1064.68^a (674.76)	957.35^a (489.53)	692.01^a (415.31)	619.02^a (218.22)
Pabbas	1084.16^a (316.39)	886.06^a (241.52)	848.84^a (171.56)	935.50^a (201.73)
Nankhari	997.56^a (167.78)	778.71^a (189.6)	646.67^a (167.75)	676.45^a (167.45)

Table 11. Shrub biomass (kg ha^{-1}) in studied forests

Forests	Northeast	North	Southwest	Southeast
Himri	654.88±76.49	643.93±133.96	203.05±147.46	154.77±125.66
Narkanda	541.78±472.86	157.78±114.95	317.94±249.43	326.88±187.63
Pabbas	690.82±225.69	292.82±304.62	67.01±156.72	38.51±93.28
Nankhari	429.12±233.67	321.34±111.23	287.56±193.23	111.23±134.56

Table 12.1. Phytosociological attributes in Himri forest

Aspect	Species	Density (ind. ha^{-1})			IVI	H'
		Seedlings	Saplings	Adults		
N	*Aesculus indica* (Wall. ex Cambess) Hook.	0	0	1.04±0.42	1.23	1.53±0.33[a]
	Cedrus deodara (Roxb. Ex D.Don) G.Don	20.83±40.05	56.25±74.5	179.17±144.36	79.21	
	Picea smithiana (Wall.) Boiss.	29.17±36.8	11.46±14.4	22.92±28.14	15.42	
	Pinus wallichiana A.B.Jacks.	41.67±90.37	19.79±14.4	65.63±81.85	28.94	
	Quercus floribunda Lindl. ex A. Campus	933.33±273.25	43.75±55.7	139.58±137.03	61.59	
	Quercus leucotrichophora A. Campus	29.17±60.03	5.21±12.76	1.04±0.42	0.71	
	Quercus semecarpifolia Sm.	null	35.42±23.2	77.08±68.34	35.44	
	Rhododendron arboretum Sm.	null	null	3.13±5.23	3.79	
	Quercusdilatate A.Kern.	150±273.86	114.58±87.	30.21±26.64	13.89	
	*R*hododendron *barbatum* Wall. ex G. Don	479.17±410.31	73.96±71.1	52.08±43.78	20.55	
	Taxus contorta Griff.	283.33±140.31	69.79±90.4	52.08±58.18	26.94	
	Populus ciliate Wall. ex Royle	null	5.21±12.76	33.33±51.79	12.32	
NE	*Cedrus deodara*	8.33±20.41	4.17±10.21	30.21±53.97	20.24	1.2±0.19[ac]
	Picea smithiana	62.5±130.14	15.21±14.5	39.58±46.21	35.22	
	Pinus wallichiana	8.33±20.41	53.17±79.8	77.08±147.3	30.97	
	Quercus floribunda	1150±908.43	33.33±70.1	288.54±98.62	135.7	
	Quercus leucotrichophora	8.33±20.41	60.42±38.0	14.58±22.94	8.13	
	Rhododendron arboreum	null	null	9.38±11.01	7.3	
	Quercusdilatata	395.83±969.56	31.25±49.8	14.58±22.59	6.39	
	Rhododendronbarbatum	645±551.53	17.71±17.4	9.38±9.48	5.39	
	Taxuscontorta	382.5±288.78	136.46±12	82.29±50.22	46.95	
	Populus ciliate	null	1.04±2.55	6.25±10.46	3.75	
SW	*Cedrus deodara*	25±50	1.04±2.55	2.08±3.22	2.19	0.79±0.44[bc]
	Picea smithiana	45.83±90.02	25±55.34	29.17±60.03	12.69	
	Pinuswallichiana	41.67±78.53	120.83±233	60.42±123.78	24	
	Quercusfloribunda	450±367.76	5±5.23	46.88±48.21	27.74	
	Quercusleucotrichophora	25±61.24	6.25±3.95	364.58±173.15	195.4	
	Quercus semecarpifolia	null	2.08±3.23	58.33±107.21	29.64	
	Quercus dilatata	75±183.71	3.13±5.23	1.04±2.55	0.97	
	Rhododendronbarbatum	66.67±97.04	2.08±3.23	5.21±12.57	3.26	
	Taxuscontorta	62.5±97.15	5.21±12.76	1.04±2.55	0.55	
	Millettia pinnata (L.) Panigrahi	null	2.5±5.6	7.29±11.54	2.98	
	Pyrus pashia Buch.-Ham. ex D.Don	null	null	1.04±0.04	0.57	
SE	*Cedrus deodara*	29.17±60.03	4.17±7.6	35.42±66.46	25.64	0.50±0.11[b]
	Pinuswallichiana	16.67±30.28	7.29±17.86	1.04±0.43	1.91	
	Quercusfloribunda	137.5±156.33	15.63±24.2	28.13±19.67	23.15	
	Quercusleucotrichophora	70.83±161.57	23.96±22.1	429.17±108.30	248.2	
	Rhododendronarboreum	16.67±20.41	1.04±2.55	1.04±2.55	1.06	
	Millettia pinnata	null	null	1.04±2.55	0.03	

abundance. The density of sapling (136.46) was led by endangered species - *T. contorta*. The endangered species - *T. contorta* was found 14.39% in adults, 46.76% in saplings, and 14.44% in seedling of the total populations. *T. contorta, Q. dilatata* and *R. barbatum* were found GR category is shown in Table 12.1.

Southwest geographical direction: This GD was found diversity (H') 0.79 with a total of 11 species richness at adult stage. The dominant adults were *Q. leucotrichophora* (IVI 195.41) and *T. contorta* has occurred the least value of IVI 0.55, with low density 1.04.

Southeast geographical direction: This GD found the lowest diversity (H') 0.5±. The *Q. leucotricophora* with IVI (248.23) occupied 86.73%, followed by *C. deodara* with IVI (25.64). *T. contorta* was absent in this aspect.

Phytosociological attributes in Narkanda forest: The diversity between N and NE geographical directions were with significant differences (p=0.0448) but other aspects had found no evidence. Shrub density found significant differences (p=0.0172) between NE and SE geographical directions. Very few species were found in the 'good regeneration' category, while *T. contorta* was found 'no regeneration' category in this forest. Some species were found 'new recruits' category (Table 12.2).

T. contorta is an occasional and sometimes prominent associate in species mainly *C. deodara*, *A. pindrow*, *P. smithiana*, and *Quercus* spp. Here it forms part of a sub canopy shade-tolerant trees being especially prominent in areas from Afghanistan to the central part of Nepal.

Diameter distribution class: It was classified as 10 cm interval unit 0-10 cm, 10-20 cm to a maximum diameter of an adult tree presence) on study aspects. In Himri forest, *T.*

Table 12.2. Phytosociological attributes in Narkanda forest

Aspect	Species	Density (ind. ha^{-1})			IVI	H'
		Seedlings	Saplings	Adults		
N	*Picea smithiana*	162.76±142.81	14.5±4.91	3.13±7.65	4.43	0.22±0.21[a]
	Abies pindrow	240.89±34.92	null	104.17±72.31	201.04	
	Quercus semecarpifolia.	52.08±27.58	null	22.92±40.63	32.25	
	Taxus contorta	null	null	23.96±26.64	44.09	
	Aesculus indica	null	null	5.21±12.76	17.80	
	Pinus wallichiana	65.10±6.74	null	null		
	Quercus floribunda	32.55±9.75	null	null		
NE	*Picea smithiana*	136.72±20.41	12.5±11.91	20.833±28.69	27.23	0.46±0.12[bc]
	Abies pindrow	260.42±80.98	null	112.5±44.72	186.13	
	Pinus wallichiana	45.57±3.81	null	1.04±2.55	1.06	
	Quercus semecarpifolia	26.04±1.89	null	12.5±17.72	19.27	
	Aesculus indica	null	null	5.21±12.76	11.34	
	Taxus contorta	null	null	35.42±17.53	48.97	
	Cedrus deodara	null	null	7.29±17.86	5.99	
SW	*Abies pindrow*	1191.41±864.51	112.5±111.91	147.92±108.52	181.35	0.32±0.14[ac]
	Quercus semecarpifolia	625±57.39	12.5±2.91	82.29±56.1	85.09	
	Picea smithiana	310.33±04.33	null	29.167±59.38	26.66	
	Taxus contorta	null	null	7.29±10.01	6.84	
	Quercus floribunda	45.57±1.68	null	null		
SE	*Quercus semecarpifolia*	943.36±562.19	2.5±2.91	337.5±147.37	200.73	0.30±0.09[ac]
	Picea smithiana	325.52±225.98	16.3±5.91	104.17±15.63	43.68	
	Pinus wallichiana	221.35±298.17	6.3±7.91	8.33±17.53	14.76	
	Quercus floribunda	45.57±93.80	3.3±4.91	2.08±5.10	2.35	
	Abies pindrow	390.63±33.58	null	33.33±75.69	36.92	
	Quercus dilatata	null	null	8.33±2.55	1.60	
	Cedrus deodara	6.51±15.95	null	null		

contorta was absent in southeast aspect. In the occurrence aspects, there were seemed reverse J-shaped pattern for the population distribution structure is shown in Figure 1. *T. contorta* diameter distributions were found in three aspects that are north, northeast, and southwest. The minimum and middle diameter distribution classes are seemed absent in all 3 aspects. The northeast aspect has seemed right-skewed distribution in Narkanda forest. In Pabbas, southeast and southwest aspects were seemed absent for *T. contorta* regeneration. The shape of diameter distribution of *T. contorta* for two aspects has seemed like unimodal shape. The minimum and middle diameter distribution classes were seemed absent in all 3 aspects. All aspects seemed uniform distribution for *T. contorta* regeneration in Nankhari forest.

Survivorship curve of *T. contorta* in studied forests: The survivor individuals and estimated survival rates were different among studied forests. For this, all individuals of *T. contorta* in all plots in each forest reserve were pooled to make static lifetables (Fig. 5). The inferred mortality rate (qx) varied among the different size classes (DBH) in the forest; size classes I had the highest mortality rate, and size classes VII had the lowest mortality. Establishing growth and mortality rates for large trees needs further study (Naithani et al 2018). It is possible that mortality rates increase for juveniles that are growing slowly, but not for large trees. In addition, large trees have significant energy reserves to use in defence against diseases and other disturbance activities. But for the juveniles, the effect on their germination and growing process also due to various local factors. They are likely to die or destruct quickly if they are attacked by mechanical activities, pathogens, deficient nutrients, etc

Table 12.3. Phytosociological attributes in Pabbas forest

Aspect	Species	Density (ind. ha^{-1})			IVI	H'
		Seedlings	Saplings	Adults		
N	*Picea smithiana*	625±35.53	256.25±212.3	362.5±180.34	59.76	0.66±0.14[a]
	Taxus contorta	null	null	331.25±220.67	60.50	
	Abies pindrow	null	62.5±45.45	637.5±267.98	120.48	
	Pinus wallichiana	75±34.56	25±13.34	168.75±201.34	40.64	
	Cedrus deodara	null	null	50±54.67	11.23	
	Quercus floribunda	null	null	12.5±17.75	1.81	
	Quercus semecarpifolia	75±56.34	31.25±23.89	37.5±16.87	3.82	
	Quercus floribunda	null	6.25±3.25	6.25±3.45	0.88	
	Quercus dilatata	null	6.25±8.34	6.25±5.67	0.88	
NE	*Picea smithiana*	850±647.45	81.25±46.9	418.75±379.56	103.89	0.57±0.10[a]
	Abies pindrow	100±45.56	null	300±201.67	116.78	
	Taxus contorta	null	null	206.25±145.89	33.70	
	Pinus wallichiana	375±129.94	18.75±20.34	212.5±187.98	34.02	
	Quercus semecarpifolia	75±67.45	50±48.95	18.75±22.67	2.85	
	Cedrus deodara	50±51.26	12.5±18.67	81.25±36.87	8.76	
SW	*Quercus semecarpifolia*	null	null	6.25±3.45	6.28	0.35±0.19[b]
	Cedrus deodara	Null	343.75±135.8	123.5±249.57	232.35	
	Pinus wallichiana	25±16.34	6.25±3.57	50±34.78	34.95	
	Quercus floribunda	null	null	81.25±45.45	14.98	
	Abies pindrow	null	null	25±36.67	5.32	
	Millettia pinnata (L.)	null	null	12.5±12.67	1.44	
	Picea smithiana	null	6.25±4.23	18.75±9.34	4.68	
SE	*Cedrus deodara*	null	143.75±122.9	343.75±78.99	254.78	0.20±0.07[b]
	Picea smithiana	null	43.75±45.89	75±56.76	14.84	
	Abies pindrow	null	null	6.25±3.45	1.39	
	Pinus wallichiana	100±56.89	18.75±19.56	156.25±145.89	27.75	
	Quercus dilatata	null	null	6.25±3.34	1.23	

(Lau et al 2017). More likely, after a prolonged period of stress (local factor effects) during which growth rate decreases, juveniles will eventually decline and die absolutely (Kumar et al 2020) is shown in Narkanda, Pabbas, and Nankhari (Fig. 5).

Possible techniques for propagation - a step towards conservation and restoration: Considerable effect of local factors in the studied forests and extremely slow-growing nature of this endangered species indicate the tendency of very slow recovery in its habitat (Lanker et al 2010). Therefore, some measures are mandatory for conservation, and returning activities of this species in the northern slope

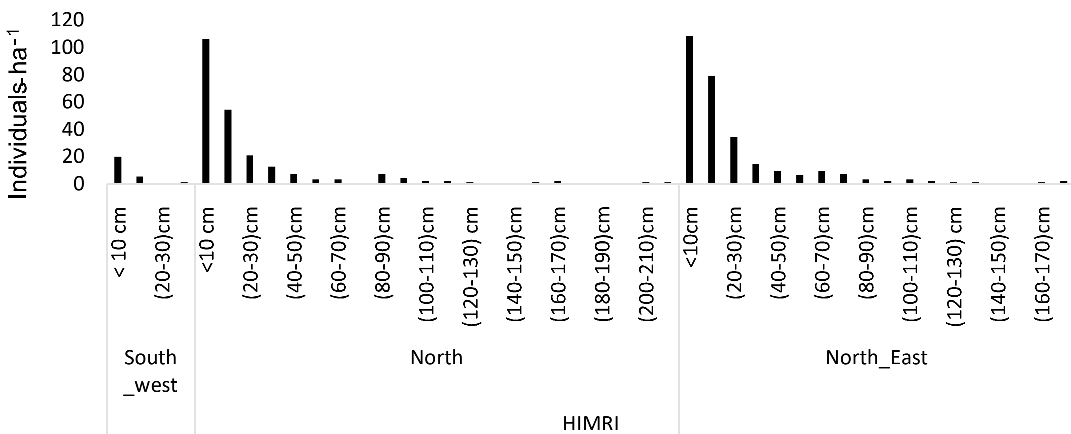

Fig. 1. Diameter distribution classes (cm) of *T. contorta* in Himri forest

Table 12.4. Phytosociological attributes in Nankhari forest

Aspect	Species	Density (ind. ha^{-1})			IVI	H'
		Seedlings	Saplings	Adults		
N	*Juglans nigra L.*	208.33±510.3	29.17±71.44	37.51±15.81	68.59	0.54±0.30
	Taxus contorta	null	null	17.71±12.13	32.98	
	Aesculus indica	null	null	14.58±7.22	29.35	
	Abies pindrow	null	null	62.5±59.69	112.54	
	Picea smithiana	null	null	34.38±30.94	47.42	
	Pinus wallichiana	null	null	6.25±2.24	9.12	
NE	*Juglans nigra*	279.51±125	44.72±20	36.07±46.25	41.38	0.57±0.17
	Picea smithiana	104.17±255.2	37.5±62.75	27.08±15.65	43.75	
	Abies pindrow	null	8.33±20.41	41.67±21.89	85.39	
	Taxus contorta	null	null	28.13±20.98	38.74	
	Quercus semecarpifolia	null	null	16.67±9.55	33.79	
	Pinus wallichiana	360.84±312.5	37.5±31.7	10.93±5.98	18.22	
	Aesculus indica	null	null	9.38±4.42	38.71	
SW	*Quercus semecarpifolia*	232.81±269.8	98.32±80.63	40.63±40.34	61.77	0.45±0.21
	Pinus wallichiana	216.51±187.5	62.5±82.92	9.38±3.61	48.86	
	Picea smithiana	52.08±127.58	16.66±40.82	22.92±10.95	75.9	
	Abies pindrow	null	null	153.13±145.8	90.29	
	Taxus contorta	null	null	32.25±1.4	26.07	
SE	*Quercus semecarpifolia*	212.81±249.8	80.63±98.33	62.5±40.08	101.45	0.34±0.27
	Pinus wallichiana	265.63±179.5	62.5±82.92	17.19±13.86	61.68	
	Abies pindrow	null	null	5±3.45	45.67	
	Picea smithiana	null	null	40.34±36.24	91.2	

exposure. Active conservation activities such as “applied nucleation” will be the best techniques for sustainable conservation (Garcia et al 2000). The northern geographical directions has favoured or suitable microclimatic conditions, but not sufficient to ensure active regeneration of this endangered populations in studied forests. This study suggests that patterns of regeneration are strongly governed by the presence of fleshy-fruited shrub habitat. Considering a fine spatial scale, fleshy-fruited shrubs act as establishment microhabitats for seedlings and saplings especially of this species (Joshi et al 2021). This study explored the presence of fleshy-fruited shrubs that serve as nurse plants and shelter for avian dispersers for seed dispersal (Martinez and Garcia 2017). Not only that, due to the dense structure of shrubs, it protects from physical damage by herbivores and protects against summer drought during the juvenile stage. Because of these scenarios four main management guidelines can be suggested; 1) Prohibited restricted any kinds of human disturbances, 2) the conservation of fleshy fruited shrubs habitat and their avian disperse community 3) the assessment of local ecological factors in its probable microenvironment before planning restoration of this species and 4) the promotion of indigenous knowledge, practices, and religious aspects to enhance the conservation of this species.

Legal and social aspects of conservation: Although Department of forest (DFO) Government of India and state forest department has included *T. contorta* in a list of endangered species with “negative” export activities (Ahmadi et al 2020). But continued cutting of adult for timber due to its high economic value in furniture and removal of the

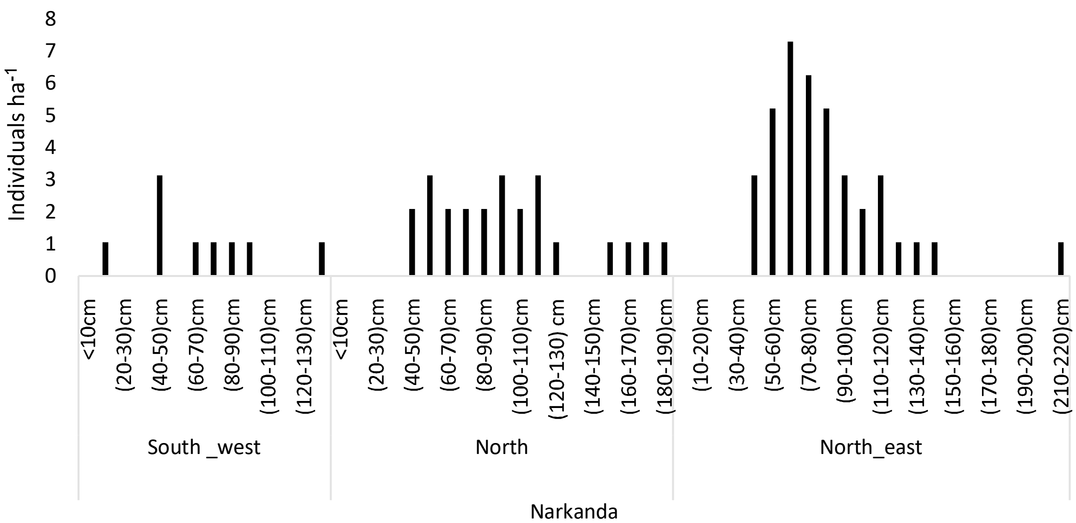

Fig. 2. Diameter distribution classes (cm) of *T. contorta* in Narkanda forest

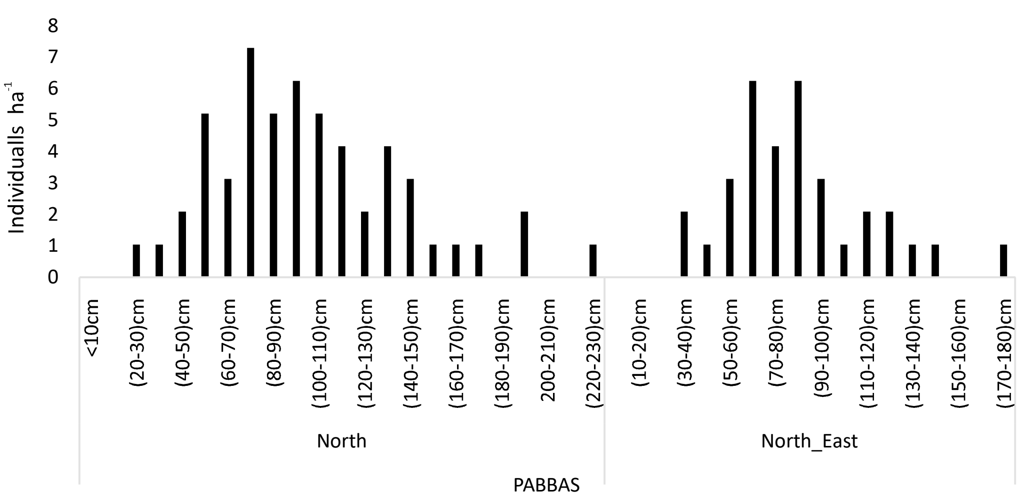

Fig. 3. Diameter distribution classes (cm) of *T. contorta* in Pabbas forest

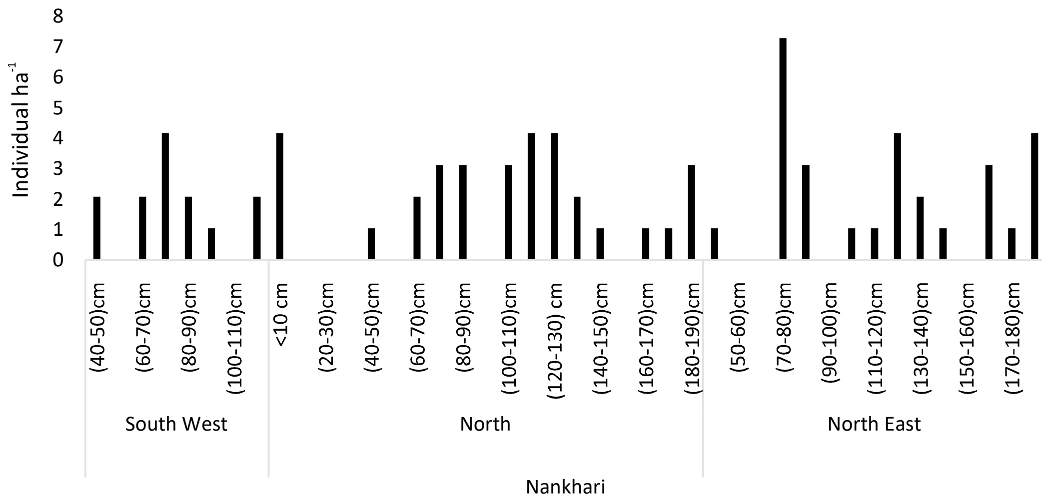

Fig. 4. Diameter distribution classes (cm) of *T. contorta* in Nankhari

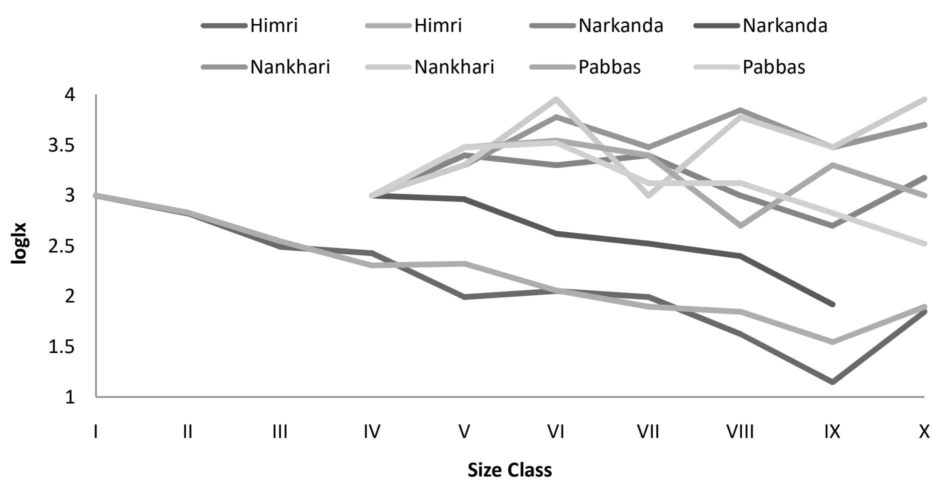

Fig. 5. Log lx and the number of dead trees of *T. contorta* in study forests

bark activities of this species for medicinal purpose is attracting attention (Iqbal et al 2020). The restrictions may be effective in Himri site by the awareness of local people, zero disturbances of cattle grazing and remoteness of this area leads to conservation but other forests are closer to settlement area, highly signed of cattle grazing, cuted stems of this species lead to alter the microhabitat of this species (Sharma and Garg 2015). More stringent laws and future restrictions is need to be imposed. Non-government organizations, village communities, and voluntary bodies should be encouraged to undertake conservation by planting and clonally propagated in their natural habitats (Nayak and Sahoo 2020). The specific microsites with recorded tree associations are maintained for proper recruitment of seedlings and plantations to ensure better growth, survival and sustainability of this endangered plant species (Poudel et al 2012).

CONCLUSIONS

T. contorta has become locally reduced, categorized "no regeneration", small and isolated populations with an in-proportion of seedlings, saplings and adults in most of the studied forests except Himri forest. Several causes have been put forward for the decline of *T. contorta* that leads to change in microclimate due to over-exploitation by human activities. *T. contorta* population has, however, been seen probability to expand where conditions are favourable i.e., the northern geographical directions of the western Himalayan region. It is recommended that applied nucleation in fleshy-fruited shrub habitat can help for its sustainable regeneration and probability of returning in degraded forest for its population conservation. Finally, in the face of unpredicted climate change scenarios, *T. contorta* is highly at risk in its distribution range in the Himalayas region.

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Effects of Light Availability on Survival and Growth of Seedling and Sapling of Tropical Dry Deciduous Forest Tree Species in Ballavpur Wild Life Sanctuary, West Bengal, India

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Abstract: Seasonal variation of available light under tree canopy could impact growth and survival of tree seedlings and saplings in tropical dry forest. Different species responds differentially to such natural traits. The seedling and sapling growth and survival of six dry forest tree species under two different canopy conditions were studied inside the Ballavpur Wild Life Sanctuary. Light intensity significantly differed under open and closed canopy stands. Seedling survival varied for different species and ranged from 60-100%. No seedling and sapling of *Butea monosperma* and *Terminalia arjuna* were available under closed and open canopy respectively. The seedling survival was independent of the canopy condition but significantly varied for different species. Relative growth rate in height (RGRH) of tree seedlings differed significantly among different species.The seasonal rainfall in the dry deciduous forest promoted the relative growth of tree seedlings. The present study emphasized that species specific response plays very important role in governing the seedling survival and growth of tropical dry deciduous tree species.

Keywords: Dry deciduous forest, Canopy condition, Light availability, Relative growth, Seedling and sapling survival

Canopy cover is the layer formed by the branches and crowns of plants or trees. The cover can be continuous, as in primary forests, or discontinuous - with gaps. The forest canopy is a structurally complex and ecologically important subsystem of the forest. Forest canopy is an important ecological parameter of forest ecosystem for its relationship with natural regeneration and species richness (Zollner and Crane 2003). Due to its primary importance in photosynthesis, light limits the tree-seedling recruitment under various forest canopies (Way and Pearcy 2012). The early establishment phase in the life cycle of trees is influenced by the presence and abundance of understorey (Rodríguez-García et al 2011).The influence of light on the tree seedlings growth in tropical ecosystem has been well documented (Turner 2001, Vieira and Scariot 2006a, Tripathi and Raghubanshi 2014). Seasonal variation in understorey light availability has a vital role in shaping the establishment and growth of tree seedlings in tropical dry forest (Tripathi and Raghubanshi 2014). In tropical dry forests understorey light levels are relatively high, due to a more open and lower canopy compared to moist forests (Holbrook et al 1995, Murphy and Lugo 1986, Coomes and Grubb 2000). Seedlings generally grow slowly under high canopy or deep shade relatively utilizes less or no added nutrients to the soil (Baker et al 2003a). In India the influence of canopy cover on vegetation in *Pinus* dominated forests in Uttrakhand were studied by Arya and Ram (2016). Singh et al (2008) studied the impact of different tree species canopy on diversity and productivity of understorey vegetation in Indian desert. Tripathi et al (2020) showed the effects of light availability on seedling growth in a tropical dry forest of Uttar Pradesh. Effect of canopy cover on understory invasive alien species in the Wayanad Wildlife Sanctuary, Kerala was studied by Najar and Rahim (2018). Though several studies have been done in other parts of India, only a few remote sensing forest canopy estimations are available from West Bengal (Bera et al 2021, Pal et al 2018). Studies on seedling and sapling growth under different canopy conditions are also lacking. So this work has been undertaken to study the growth of seedlings and saplings of few selected dry deciduous tree species under different canopy conditions.

MATERIAL AND METHODS

Study area: This study was carried out in the Ballavpur Wildlife Sanctuary of Birbhum district in West Bengal. This sanctuary is managed within the jurisdiction of Bolpur Range under Birbhum Forest Division of South East circle. It extends between 23°39'25"N latitude and 87°41'39"E longitude (Fig. 1). It represents the Bio-geographic zone 7BChhotonagpur Plateau. During the summer, the temperature can shoot well above 40 °C (104 °F) and in winter it can drop to around 10 °C (50 °F). The annual average rainfall is 1,212 millimetres (47.7

in), mostly in the monsoon months (June to September). The sanctuary has natural Sal forests. In 1954-55 Acacia, Sissoo, Cashew nut and other trees were planted to green the barren land. Sanctuary has three water bodies (locally called Jhils) which attract large number of winter migratory birds.

Measurement of light intensity: The selection of species was done as par with method of Nag and Gupta (Joshi) (2020). Two stands differing in light conditions (open and closed canopy) were selected in the Ballavpur WLS. Digital Lux Meter (Model LX-101A, Taiwan) was used to measure light intensity below the tree canopy (Tripathi et al 2020). The light intensity was measured four times in a year at interval of three months from November 2018 to August 2019. Light intensity was measured at the same time of the day in both open and close canopy stands.

Estimation of relative growth rate in terms of height (RGRH): Variable numbers of natural regenerations (1 to 16 seedlings and saplings depending upon their availability) were identified and tagged for the six selected species under both stands in November 2018. Each stand was visited at the end of three months corresponding to three seasons (winter, summer and rainy), and the number of tagged seedlings and saplings surviving for each species were counted and their growth in heights was measured by a meter tape. Relative growth rate in terms of height (RGRH) was estimated as:

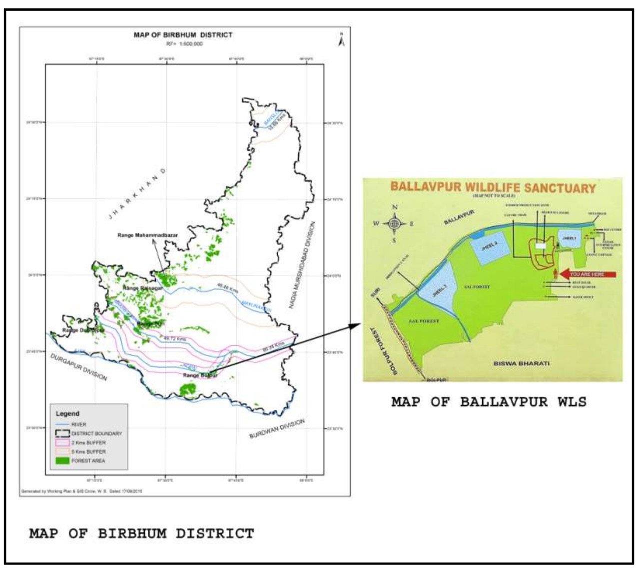

Fig. 1. Study area (Source: www.westbengalforest.gov.in)

$$RGRH = Log \frac{\text{Final height}}{\text{Initial height}} \div \text{Time intervals in days}$$

Statistical analysis: Chi-square test of independence was done to find whether there is significant association between seedling survival and canopy condition. Chi-square tests for goodness of fit were done to find whether seedling survival varied among the six species and under the two canopy conditions. Variations in light intensity and RGRH were analysed with SPSS, version 20.

RESULTS AND DISCUSSION

Light Intensity under open and closed canopy: The light intensity ranged from 9500 to 72100 lux under open canopy condition and from 610 to 11100 lux under close canopy condition (Table 1). Highest light intensity was recorded in May under open canopy and lowest value in February. In closed canopy highest and lowest light intensity were in August and February, respectively. Light intensity was significantly different under open and closed canopy conditions. However, light intensity did not vary significantly in different seasons. Interaction of canopy condition and seasons was also not significant. In the dry tropical environments the survival and growth of the tree seedlings are intensely determined by light availability (Poorter 2001, Khurana and Singh 2006, Tripathi and Raghubanshi 2014).

Seedling and sapling survival under open and closed canopy: Seedling survival varied for different species and ranged from 60-100% (Fig. 2). A single seedling of *Butea monosperma* was tagged under open canopy condition while maximum number of seedlings and saplings (16) were tagged for *Terminalia arjuna* under closed canopy condition. No seedling and sapling of *Butea monosperma* and *Terminalia arjuna* were available under closed and open canopy respectively. All the tagged seedlings and saplings of *Buchanania lanzan* and *Terminalia arjuna*under closed canopy and of *Butea monosperma* under open canopy survived throughout the study period. Lowest survival was noticed for *Terminalia bellirica* under closed canopy with 6 out of 10 seedlings surviving through the study period.

A Chi-square test of independence revealed that seedling survival of selected species was independent of canopy condition and varied significantly among different species when both canopy conditions were combined. However,

Table 1. Light intensity range under open and close canopy in different time periods

Canopy condition	Light Intensity (Lux)			
	November	February	May	August
Open canopy	10900-45000	9500- 53600	19600- 72100	10200- 51000
Close canopy	760- 6200	610- 9410	1100- 7300	900- 11100

when all the species were combined, the seedling survival did not vary under two canopy conditions. Out of the six selected species, seedlings of light demanding *Butea monosperma* were absent under close canopy while of shade tolerant *Terminalia arjuna* were absent under open canopy; rest four species survived under both open and closed canopy conditions. This indicates that different species respond differently to the canopy condition in terms of regeneration. The seedling survival also indicates the overall regeneration status of the species. Good seedling survival of *Terminalia arjuna* and *Buchanania lanzan* in Ballavpur WLS correlates with their good regeneration status in our previous study on population and regeneration status (Nag and Gupta (Joshi) 2020).

Many studies observed higher seedling survival under open and partially open conditions than under closed canopy condition (Nanda and Mohanty 2010, Castro-Marin et al 2011). Promoting effect on seedling survival by canopy gaps benefited light demanding species more than the shade tolerant species (Lu et al 2018). Low light intensity, poor spectral quality, increased fungal attack through increased humidity, physical damage due to litterfall, concealment for seedling predators, soil and microsite conditions, etc., are cited for reduction in seedling survival under close canopy (Castro-Marin et al 2011, Tripathi and Raghubanshi 2014). Contrary to the above, many studies reported better growth of seedlings under close canopy due to certain advantages given by the adult trees – allowing the access to higher soil moisture for longer periods to the understory tree seedlings Phillips and Barnes 2002, Bertacchi et al 2016) due to hydraulic lift (Ludwig et al 2004). Competition by grasses may also suppress the tree-seedling growth under open canopy (Kambatuku et al 2011). These might be the reasons for our observation on survival and growth of *Terminalia arjuna* seedlings and saplings under close canopy only. *Terminalia arjuna* is a shade-tolerant late successional species with large seeds having reduced germination in canopy openings (Khurana and Singh 2004).

RGRH under open and closed canopy: *Phyllanthus emblica* showed better RGRH under open canopy than under closed canopy in all the seasons whereas *Pterocarpus marsupium* showed better RGRH under closed canopy in all the seasons (Fig. 3). All the species had highest RGRH in the rainy season under both open and close canopy.

Relative growth rate (RGRH) differed significantly among different species but did not vary significantly under open and closed canopy. However interaction of species and canopy conditions on relative growth rate was significantly different. *Phyllanthus emblica* showed higher RGRH under open than under closed canopy while *Pterocarpus marsupium* showed

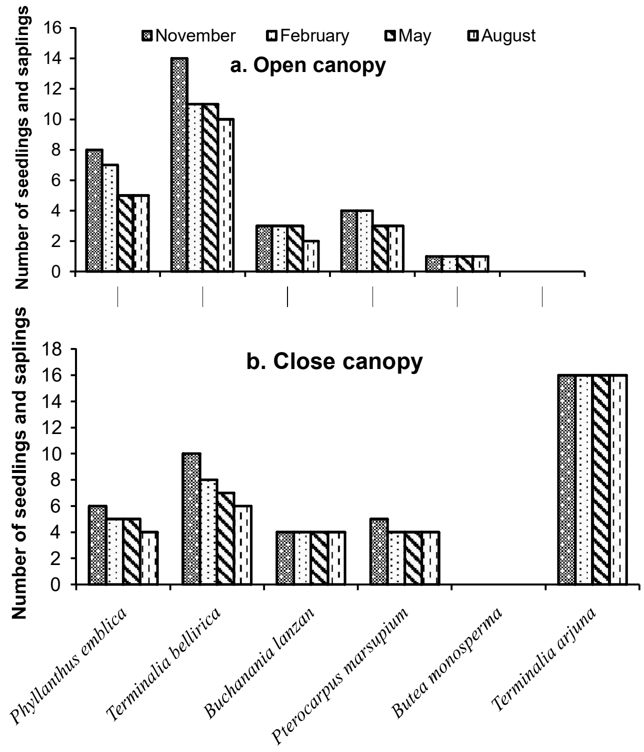

Fig. 2. Survival of seedlings and saplings of different species under (a) open and (b) closed canopy conditions

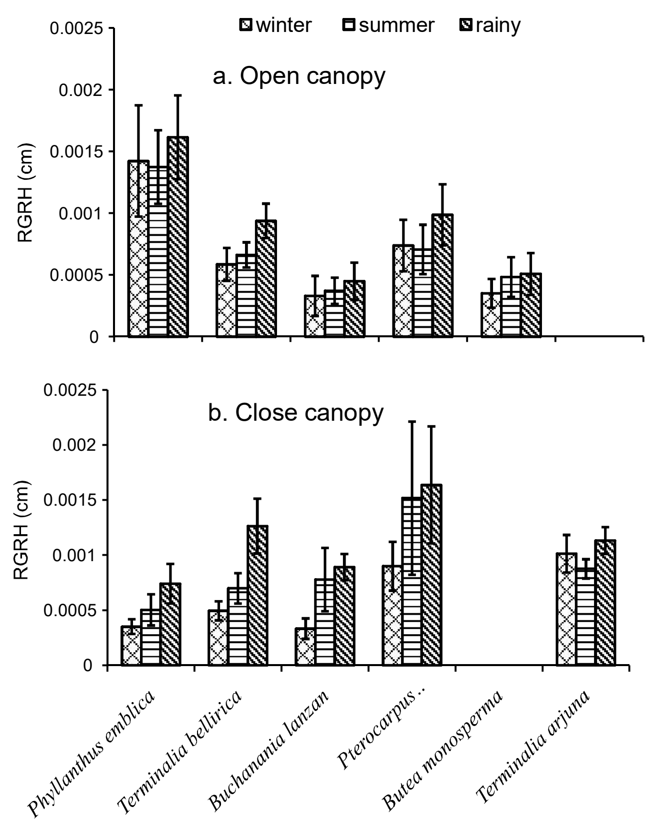

Fig. 3. RGRH of different species in different seasons under (a) open and (b) closed canopy conditions

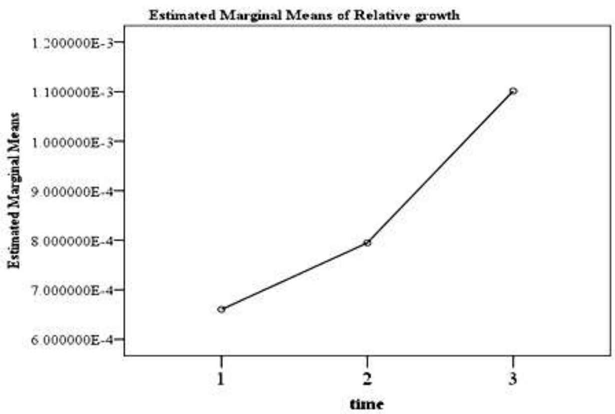

Fig. 4. Estimated marginal means of RGRH at three different time periods

higher RGRH under closed than under open canopy. *Buchanania lanzan* and *Terminalia bellirica* also had higher RGRH under closed canopy in at least one or two seasons. Under favourable growing conditions the relative growth rate of plant species varies considerably. Sapkota and Oden (2009) reported positive effects of canopy opening on relative growth in weight, height and radial growth due to reduced competition for light and space. Chacon and Armesto (2005) found six times greater RGR of seedlings under tree fall gap than under closed canopy.

Mean RGRH differed significantly at different time points or seasons (Fig. 4). In summer season (time 2) RGRH increased only slightly from winter season (time 1). However, a significant increase was noticed in rainy season (time 3) when RGRH increased to 0.00110127 cm. The availability of soil moisture is directly determined by pronounced seasonality of rainfall in the dry deciduous forests and plays a significant role in the germination, survival, and growth of tree seedlings (Khurana and Singh 2001, McLaren and McDonald 2003, Marod et al 2004). In the present investigation the relative growth rates of seedlings and saplings of all the six selected species were highest during the rainy season. The seedlings faced growth constraints in rainy seasons due to lower light availability under close canopy habitat in tropical dry forest resulting in decline in the physiological traits and RGR of light demanding pioneer species (Tripathi et al 2020). They also observed promotion in seedling survival under shady habitats in the dry deciduous forest during the driest summer season. Their observation can be linked with the survival of all the seedlings of *Terminalia arjuna* in the shaded area throughout the study period in the present study.

CONCLUSION

The results of present study emphasized that the species specific response plays a very important role in governing the seedling survival and relative growth of tropical dry deciduous tree species under variable canopy condition. The seasonal rainfall in the dry deciduous forest was another influencing factor that promoted the relative growth of tree seedlings. Large gaps in the forest are created due to commercial exploitation for timber; cutting and lopping for fuelwood creates small gaps; these gap formation favours the regeneration and survival of pioneer species. Seedlings of light demanding *Butea monosperma* survived only under open canopy while of shade tolerant non-pioneer *Terminalia arjuna* were restricted to the closed canopy areas. The environmental effects induced by canopy opening must be linked with the forest management. Long term study including more species could generate a thorough understanding of species specific strategy for survival and growth of tropical dry forest species in relation to canopy openings.

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Herpeto-faunal Diversity Study: Analysis and Critical Observations from South-eastern Rajasthan, India

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Abstract: Herpeto-fauna provides an important array to wildlife and also tangible and intangible ecosystem services. The diversity of Herpeto-fauna in a specific area solely determines the qualitative as well as quantitative rapid data analysis of habitat modifications because of its resilient nature. The present investigation deals with the amphibians and reptile survey conducted between years 2017-2019 at Jhalawar District of Rajasthan. Random plots were selected along with relevant habitats were surveyed and observed for amphibians and reptiles. Relevant habitats include streams, floodplains, mountain meadows, caves, cliffs, bogs and manmade structures. A total of amphibians and reptiles, representing 45 species, using area-constrained searches of random plots and specialized habitats, placement of artificial cover boards, night driving and incidental observations. The regress survey revealed that species belonging to 18 families included 20 snakes, 8 lizards, 5 turtles and tortoise, and 12 amphibians. In lizards, a species was recorded first time from the south-eastern Rajasthan, i.e. Indian Chameleon (*Chamaeleo zeylanicus*) new distribution record in Rajasthan and Short-tailed Agama (*Calotes minor*) was re-reported after 20 years from South-eastern Rajasthan. In the present study observation and data recorded will serveline information among the students, researchers and nature lovers.

Keywords: Amphibian, Diversity, Habitats, Jhalawar, Rajasthan, Reptiles

Amphibians and reptiles being cold-blooded animals and found all over the world, excluding the regions with extreme cold. In India, three orders of amphibian *viz*. Anura, Caudata and Gymnophiona are found, and in reptiles also have a representative from all three living orders *viz*. Crocodylia, Testudines and Squamata. Approximately 472 species of amphibians and 610 species of reptiles are found, and almost 50% have reported endemic to the Indian region. In India, amphibians are relatively less studied with few dedicated and comprehensive resources on their taxonomy, biology and conservation (Gosavi et al 2021,Khandekar et al 2021). The updated checklist of amphibians 405 species in India, including 3 orders and 15 families (Dinesh et al 2017). Aengals et al (2018), documneted 572 species of reptiles, which includes lizards (231 species), turtles and tortoises (34 species), crocodiles (3 species), and snakes having 36 families (304 species)in India.In the South-eastern Rajasthan primarily, faunal diversity comprises various species of carnivores and herbivores. It also provides a suitable habitat for the growth of the different medicinal plants. Hadauti region contains one of the finest forests in Rajasthan as indicated by the presence of Mosses and Ferns which require necessary moisture for their growth. This area is most rich in avian biodiversity estimated more than 400 birds reported this area. Fortunately, this part of Rajasthan is taming closely very threatened herpes from their entire representative. Reptiles and amphibians are plays vital roles in ecosystems as predators, prey, herbivores and commensal taxa (Hopkins 2007, Böhm et al 2013, Ingle 2020). The present survey was undertaken to document the Herpeto-fauna of the Jhalawar district which acts like an ecotone between Rajasthan and Madhya Pradesh states.

MATERIAL AND METHODS

Study area: The study area Jhalawar lies at the edge of the Malwa plateau, The south-east corner of Rajasthan. It is surrounded by dense green forests and natural landscapes. The district is situated between 23°45'20" and 24°52'17" north latitudes and 75°27'35" and 76°56'48" east longitudes. It has an average elevation of 312 m. . The climate is very similar to the Indo-Gangetic plain. The annual maximum rainfall reported (Average-900mm) in Rajasthan. The habitat types were identified and sampled during the survey were home gardens, cultivated fields, riverine forests, grasslands, road sides, rock-outcrops, shrublands or woodlands, small pond, streams and tanks are characterized by the very modest undulations at the west side, while a fertile area on the east, which is expanding over an area near about 150-180 sq. km. This division of forest exclusively falls in the territory (24°37" to 24°46" N and 76°02" to 76°11" E) which is extending from the Gagron fort (24°37' 41.5" N, 76°10'52.6" E) along with the western bank of Kalisindh River up to the Khanpura village. Far off that study area it forms the peculiar stripes which ultimately join the Mukundara Hill National Park in the north-west, formed stripes width have been recorder of an average 10 km. The high temperature generally around 40°C and can exceed 45°C during summer and fall up to 1°C in winter. In the state of Rajasthan, Jhalawar district receive 890 mm precipitation annually, which is a key factor in maintaining and keeping the environment cool, gentle and sustainable ultimately supporting the diversity of flora and fauna.

Methodology: Field observations were started from April 2017 up to July 2019 with a total of 70 field days (6 hrs/day) covering both the wet and dry seasons. A combination of methods was adopted to study the diversity of herpeto-fauna associated with all of the representative habitats and micro-habitats types in the Jhalawar district of Rajasthan. This includes methods viz. litter cleaning methods (LCM), Digging loose soil method (DLS) and Visual encounter surveys (VES) with utmost efficacy. During the study, avoided the Pitfall trap exclusively as this practice is associated with Herpeto-faunal mortality, predation and also a hindrance in the active process of forest regeneration. All specimens collected from the study area were examined carefully and recorded. They were released back to their original place of capture after identification without harming. Basic environmental parameters such as temperature and humidity were also recorded from the nearest weather station, where specimens were observed. Roadkills were examined, but not collected because most of the roadkills were extensively damaged and thus are not included as could not be identified to the species level. The specimens were identified through the use of field guides and identification keys given by Whitaker and Captain (2004) and Das and Das (2018).

RESULTS AND DISCUSSION

During survey of two years recorded 45 species of batrachofauna and ophiofauna. Amphibians include both frogs and toads whereas, reptiles include venomous and non-venomous snakes, lizards, geckos, turtles and tortoise. In lizards, Indian Chameleon (*Chamaeleo zeylanicus*) was reported first time from the South-eastern Rajsathan earlier it's known from the South-western Rajasthan (Sharma and Koli 2018) and Short-tailed Agama (*Calotes minor*) was also reported first time from the Jhalawar district, but Vyas and Singh (1998) reported from the Baran district of South-eastern Rajasthan (Khan and Kumar 2010). Chauhan and Kavita (2012) reported 6 reptiles and two amphibian species

Table 1. Identified snake species location of Jhalawar District, Rajasthan, India

Common name	Scientific name	Family
Brahminy Worm Snake	*Ramphotyphlops brahminus* (Daudin 1803)	Typhlopidae
Common Sand Boa	*Gongylophis conicus* (Schneider 1801)	Boidae
Red Sand Boa	*Eryx johnii* (Russell 1801)	Boidae
Spectacled Cobra	*Naja* (Linnaeus 1758)	Elapidae
Common Krait	*Bungarus caeruleus* (Schneider 1801)	Elapidae
Saw Scaled Viper	*Echis carinatus* (Schneider 1801)	Viperidae
Russell's Viper	*Duboia ruselli* (Shaw and Nodder 1797)	Viperidae
Indian Rock Python	*Python molurus* (Linnaeus 1758)	Pythonidae
Common Trinket	*Coelognathus helena helana* (Daudin 1803)	Colubridae
Banded Kukri	*Oligodon arnensis* (Shaw 1802)	Colubridae
Russell's Kukri	*O. taeniolatus* (Jerdon 1853)	Colubridae
Common Bronzeback Tree Snake	*Dendrelaphis tristis* (Daudin 1803)	Colubridae
Common Wolf Snake	*Lycodon aulicus* (Linnaeus 1758)	Colubridae
Barred Wolf Snake	*L. striatus* (Shaw 1802)	Colubridae
Checkered Keelback	*Xenocrophis piscator* (Schneider 1799)	Colubridae
Striped Keelback	*Amphiesma stolatum* (Linnaeus 1758)	Colubridae
Common Cat Snake	*Boiga trigonata* (Schneider 1802)	Colubridae
Green Vine Snake	*Ahaetulla nasuta* (Lacépède 1789)	Colubridae
Rat Snake	*Ptyas mucosa* (Linnaeus 1758)	Colubridae
Ornate Flying Snake	*Chrysopelea ornate* (Shaw 1802)	Colubridae

from the Jhalawar. Sen and Nama (2013) concluded that out of 19 species of snakes belonging to 6 different families have so far been reported from the study area, excluding amphibian fauna. Overall, 45 species of herpeto-fauna were recorded belonging to 34 genera and 18 families from Jhalawar district during the study period (Fig. 1). Out of which, 20 species of snakes (4 highly venomous, 1 mildly venomous and 15 non-venomous) belonging to 18 genera in six families (Fig. 2, Table 1, Plate 1); 8 species of lizards belong to 5 genera in five families (Table 2, Plate 2); 5 species of turtles and tortoise with 5 genera in three families (Table 3, Plate 3) and 12 species of amphibians belonging to 6 genera in four families (Table 4, Plate 4). Among the snakes, the Colubridae family represents a maximum number of species (12 species). In the case of lizards of Gekkonidae (3 species), turtles of Trionychidae and Geomydidae (2 species each) and amphibians of Dicroglossidae (7 species) represented the maximum number of species which also shows their frequency distribution in the area. High forest diversity influences associated factors and bring seasonal variations and a variety of forest ecosystems offer available resources for better development, growth, feeding and breeding, environmental gradients are of utmost importance in establishing the Pray-Predator relationship, which lies on the plant species composition. The pattern of distribution in herpeto-fauna was much varied among different habitat of Jhalawar. The present herpeto-faunal diversity may be proven as a vital indicator to predict the quality of biotic interference in the forest ecosystems, diversity of herpeto-

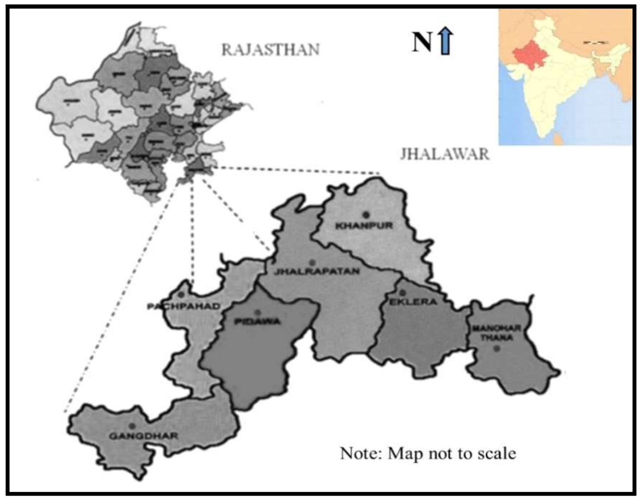


Fig. 1. Map of study area Jhalawar district, South-eastern Rajasthan, India

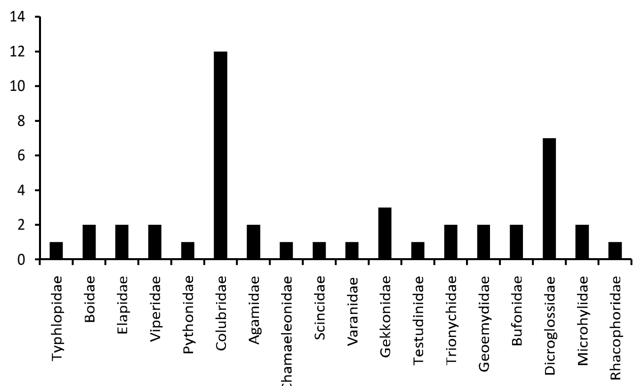


Fig. 2. Herpeto-faunal species distribution in families

Table 2. Identified lizard species location of Jhalawar District, Rajasthan, India

Common name	Scientific name	Family
Oriental Garden Lizard	*Calotes versicolor* (Daudin 1802)	Agamidae
Hardwicke's Bloodsucker/Dwarf Rock Agama	*C. minor* (Hardwicke & Gray 1827)	Agamidae
Indian Chameleon	*Chamaeleo zeylanicus* (Laurenti 1768)	Chamaeleonidae
Bronze Grass Skink/Bronze Mabuya	*Eutropis macularia* (Blyth 1853)	Scincidae
Bengal Monitor Lizard	*Varanus bengalensis* (Daudin 1802)	Varanidae
Termite Hill Gecko/Dakota's Leaf-toed Gecko	*Hemidactylus triedrus* (Daudin 1802)	Gekkonidae
Brooke's House Gecko/Spotted House Gecko	*H.brookii* (Gray 1845)	Gekkonidae
Northern House Gecko	*H. flaviviridis* (Ruppell 1835)	Gekkonidae

Table 3. Identified testudines' species location of Jhalawar District, Rajasthan, India

Common name	Scientific name	Family
Indian Star Tortoise	*Geochelone elegans* (Schoepff, 1795)	Testudinidae
Indian Flapshell Turtle	*Lissemys punctata punctata* (Bonnaterre, 1789)	Trionychidae
Indian Softshell Turtle	*Nilssonia gangetica* (Cuvier, 1825)	Trionychidae
Three-striped Roofed turtle	*Batagur dhongoka* (Gray, 1832)	Geoemydidae
Indian Tent Turtle	*Pangshura tentoria* (Gray 1834)	Geoemydidae

Brahminy Worm Snake
Ramphotyphlops brahminus (Daudin, 1803)

Common Sand Boa
Gongylophis conicus (Schneider, 1801)

Red Sand Boa
Eryx johnii (Russell, 1801)

Spectacled Cobra
Naja naja (Linnaeus, 1758)

Common Krait
Bungarus caeruleus (Schneider, 1801)

Saw Scaled Viper
Echis carinatus (Schneider, 1801)

Russell's Viper
Duboia ruselli (Shaw and Nodder, 1797)

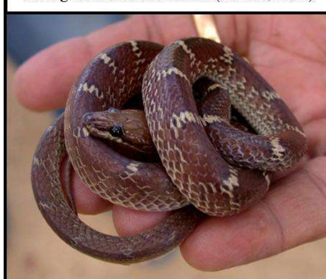
Indian Rock Python
Python molurus molurus (Linnaeus, 1758)

Common Trinket
Coelognathus helena helana (Daudin, 1803)

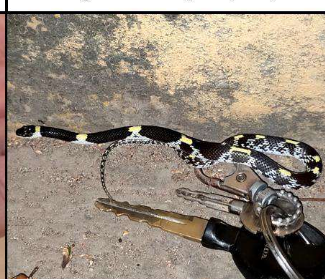
Banded Kukri
Oligodon arnensis (Shaw, 1802)

Russell's Kukri
Oligodon taeniolatus (Jerdon, 1853)

Common Bronzeback Tree Snake
Dendrelaphis tristis (Daudin, 1803)



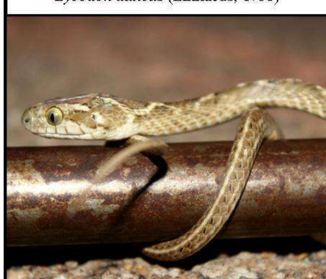
Common Wolf Snake
Lycodon aulicus (Linnaeus, 1758)



Barred Wolf Snake
Lycodon striatus (Shaw, 1802)

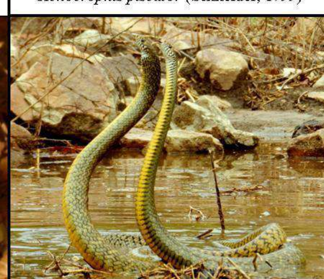
Checkered Keelback
Xenocrophis piscator (Schneider, 1799)

Striped Keelback
Amphiesma stolatum (Linnaeus, 1758)

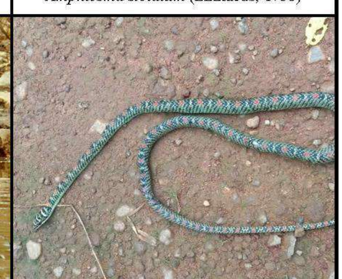


Common Cat Snake
Boiga trigonata (Schneider, 1802)

Green Vine Snake
Ahaetulla nasuta (Lacépède, 1789)



Rat Snake
Ptyas mucosa (Linnaeus, 1758)



Ornate Flying Snake
Chrysopelea ornata (Linnaeus, 1758)

Plate 1. Snakes of Jhalawar district, South-eastern Rajasthan, India

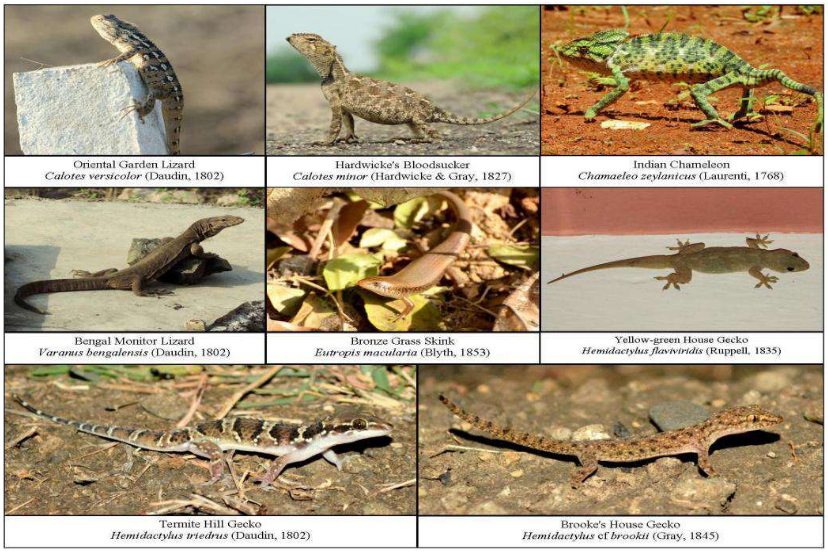


Plate 2. Lizards of Jhalawar district, South-eastern Rajasthan, India

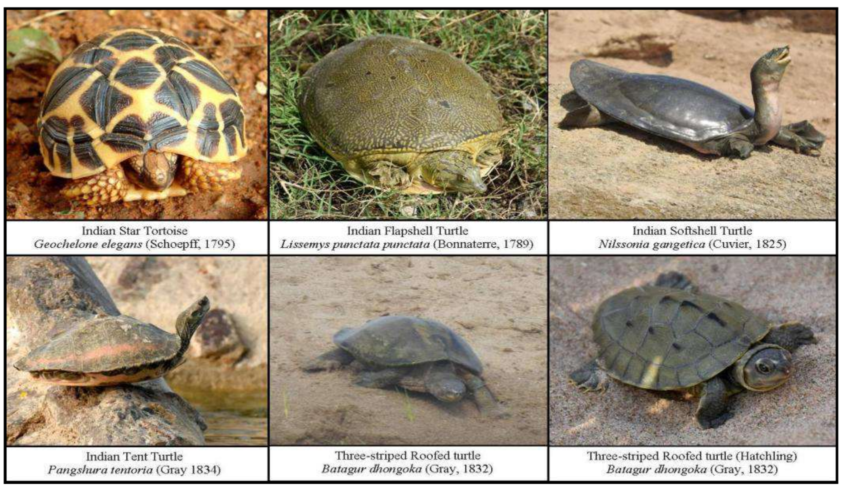


Plate 3. Turtles and tortoise of Jhalawar district, South-eastern Rajasthan

Table 4. Identified anuran species location of Jhalawar district, Rajasthan, India

Common name	Scientific name	Family
Asian Common Toad	*Duttaphrynus melanostictus* (Schneider 1799)	Bufonidae
Indian Marbled Toad	*D. stomaticus* (Lutken 1864)	Bufonidae
Indian Skipper/Skittering Frog	*Euphlyctis cyanophlyctis* (Schneider 1799)	Dicroglossidae
Asian Grass/Rice Field Frog	*Fejervarya cf limnocharis* (Gravenhorst 1829)	Dicroglossidae
Indian Cricket Frog	*Minervarya spp.1*	Dicroglossidae
Cricket Frog	*Minervarya spp.2*	Dicroglossidae
Cricket Frog	*Minervarya spp.3*	Dicroglossidae
Cricket Frog	*Minervarya spp.4*	Dicroglossidae
Indian bullfrog	*Hoplobatrachus tigerinus* (Daudin 1803)	Dicroglossidae
Marbled Balloon Frog	*Uperodon systoma* (Schneider 1799)	Microhylidae
Painted Baloon Frog	*Uperodon cf taprobanicus* Parker 1934	Microhylidae
Indian Tree Frog	*Polypedates maculatus* (Gray 1830)	Rhacophoridae

* = Species not confirmed

Plate 4. Amphibians of Jhalawar district, South-eastern Rajasthan, India

fauna in intermediate forest habitats is mainly due to the presence of different microhabitats, including human-altered habitats that are providing favourable conditions to amphibians and reptiles for their survival.

CONCLUSIONS

The present study communicates that the reptile diversity of the Jhalawar and its surroundings, it's an important location in terms of herpeto-faunal diversity. Awareness education should be providing, on schools and university level to increase acquaintance of the natural habitats of the area. The present survey exhibits that the dominant families were Colubridae in snakes and Dicroglossidae in amphibians represented 12 and 7 species respectively whereas, 7 families namely Typhlopidae and Pythonidae in snakes, Chamaeleonidae, Scincidae and

Varanidae in lizards, Testudinidae in tortoise and Rhacophoridae in amphibians represented only single species which requires ecological conservation and scientific management study. This conducted study will support in compiling a complete distribution list of amphibian and reptiles species and also assist in determining the conditions of the different species within the region. This paper will serve as baseline data and also to enhance the current knowledge of the herpeto-faunal diversity within the area studied.

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Evaluating Leaf Litter Decomposition Rate of Multipurpose Tree Species using Litter Bag Technique

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Abstract: For nonlegume crop production, legume leaves utilized as green manure could be a viable alternative to commercial N fertilizers. The experiment's main purpose was to assess the rate of decomposition of leaf litter from ten tropical trees utilizing evaluation measures such as mass loss, decomposition rate, and relative decomposition rate. The decomposition of legume litter selected for this experiment was *Peltophorum ferrugineum, Albizia lebbek*, *Gliricidia sepium*, *Delonix regia, Leucaena leucocephala*, *Pongamia pinnata, Senna siamea, Acacia nilotica, Prosopis juliflora* and the non-legume of *Azadirachta indica* which was evaluated by litter bag technique. Among all the ten tree species *Acacia nilotica* tree leaf litter showed the highest mass loss% (55.36%), decomposition rate, and relative decomposition rate throughout the decomposition period of 7 weeks and closely followed by *Prosopis juliflora* (55.04%). The decomposition rate is mainly influenced by meteorological factors, soil parameters (soil moisture and soil temperature), and also the chemical composition of the leaf litter and its lignin content.

Keywords: Decomposition, Decomposition rate, Leaf litter bag Technique, Mass loss, Relative decomposition rate

Nutrient-rich tropical tree species are protecting soil and improving crop productivity in heavily weathered soils of the humid and sub-humid tropics. Perennial trees serve an important role in nutrient cycling and energy transfer in soil-plant systems that are being developed sustainably (Soni et al 2020). The addition and breakdown of leaf litter is an important biological process of nitrogen cycling and soil formation that supports the activity of microfauna (Nivethadevi et al 2021b). Organic matter enhances nutrient uptake and also improves soil properties. Organic matter is provided by adding the leaf litter which improves the water holding capacity, microbial activity, and organic carbon content (Ngoran et al 2006, Shailendra Bhalawe et al 2012). In agricultural environments, more diversified soil fauna community causes faster decomposition but has minimal effect on the overall rate of decomposition. The amount of nutrients recycled is based upon the element which is available in the litter and the release of nutrients from litter depends upon the rate of decomposition. The litter addition and decomposition paves way for the immobilized nutrients in the litter to be mineralized and utilized by the roots of crops and plants in due course of time. The decomposition rate of leaf litter is influenced by C: N ratio (Joon Sun Kim 2007), leaf litter composition (Prescott et al 2004) and also environmental factors such as maximum temperature, relative humidity, and soil parameters (soil moisture and soil temperature) (Saryldiz 2003).

The litterbags method is the most commonly employed to measure the rates of decomposition of biomass in an agroforestry system since it allows for field-based decomposition tests. This method involves placing a specified amount of tree biomass in bags with appropriate mesh sizes and depositing it on the soil surface.

MATERIAL AND METHODS

Study site and species: The evaluation of legume leaf litter decomposition was carried out in Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai from January 10 - February 2022, geographically presented at 9° 96' N latitude, 78° 5' E longitude, and at an altitude of 147 m above sea level. The type of soil was sandy clay loam. In several tropical and subtropical countries, the species chosen for the study are widely grown or distributed naturally. During the peak season of leaf shedding, leaf litter was collected from plantations, which included both natural and planted trees (November-March). The experiment was laid out in completely randomised block design and the treatments comprised of T_1=*Peltophorum ferrugineum*, T_2=*Albizia lebbek*, T_3=*Gliricidia sepium*, T_4=*Delonix regia*, T_5 =*Leucaena leucocephala,* T_6=*Pongamia pinnata,* T_7=*Azadirachta indica,* T_8=*Senna siamea,* T_9=*Acacia nilotica,* T_{10}=*Prosopis juliflora.* All the tree species selected for decomposition were belongs to Leguminosae family except *Azadirachta indica* (Meliaceae).

Litter bag technique: Initially, leaf litter was air-dried and brushed to remove the adhering soil particles. Here, 25 grams of leaf litter for each species were taken and replicated in four nylon bags made of 2mm mesh and 20x20 cm size. The litter bag technique was used to study leaf litter decomposition (Mason 1977, Singh and Gupta 1977). The method was used to determine the litter mass loss in the field and then examine the leftover material chemically and biologically (Nivethadevi et al 2022). Furthermore, this technique is extensively used to collect information on simultaneous comparisons of various species, particularly in field conditions. The nylon bags were arranged in the soil such that the lower surface is in complete contact with the soil and the upper surface of the bag was exposed to the sunlight. Powers et al (2009) found that the decomposition of buried litterbags was faster than that of surface litterbags in drier tropical forests. The perforations of nylon bags were sufficiently large enough to facilitate aerobic microbial activity and prevent invertebrates from entering. A total of 40 samples were placed in a cultivated field with optimum moisture in the soil to promote decomposition. Each week, the litter bags were retrieved from the field and cleansed of ingrown roots, debris, and foreign matter, and observations were recorded on weight loss per individual bag, and soil characteristics promoting decomposition such as soil moisture, soil temperature, and environmental factors (maximum temperature, sunshine hours, and relative humidity). I calculated the decomposition rate and relative decomposition rate from the litter samples. A different fresh leaf litter sample was taken to the laboratory for each species to estimate the moisture content of leaf litter on an oven-dry weight basis by using the following formula.

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight– Dry weight}}{\text{Fresh weight}} \times 100$$

Decomposition rate (k): The following formula was used to calculate the decomposition rate (Makkonen et al 2012).

$$(k) = -\ln(M_t / M_0) / t$$

Where M_t = final litter mass, M_0 = initial litter mass, and t = time in weeks.

Relative Decomposition Rate (RDR): The mean relative decomposition rate (RDR) was estimated as per Singh et al (1999).

$$\text{RDR (g/g/day)} = \ln(W_1\text{-}W_0) / (t_1\text{-}t_0)$$

Where W_0 - the mass of litter present at time t_0, W_1 - the mass of litter at time t_1 and t_1-t_0 - sampling interval (days).

The loss in weight [mass loss (%) and remaining mass (g)] of all leaf litter was observed continuously for seven weeks from the estimated oven-dry weight of the litter samples collected every week.

$$\text{Mass loss (\%)} = \frac{\text{Initial weight– Final weight}}{\text{Initial weight}} \times 100$$

Likewise, during the study period, monitoring of soil moisture and temperature was made regularly. Soil temperature was estimated regularly at 2.00 pm using a conventional mercury bulb thermometer at 15-20 cm soil depth, while soil moisture was estimated regularly at 7.00 am using a soil moisture sensor at 15 cm soil depth. After the fifth week, water was applied to promote the decomposition rate of litter and a light rainfall of (7.4 mm) was received before the first week of decomposition, which influences the rate of decomposition of leaf litter in the first few weeks. The data generated were statistically with DMRT and besides correlation studies (Dafaallah 2017).

RESULTS AND DISCUSSION

The data generated in the decomposition study of nine legumes and one non-legume (*Azadirachta indica*) of tropical tree species. The moisture content of tree species ranges from 52 to 59.5% which is greater than the fifty percent weight of fresh leaf litter (Table 1). The highest moisture content in *Acacia nilotica* (59.5%) reflected the decomposition rates and relative decomposition rates of tropical tree species.

Climate, soil moisture, and soil temperature: Time-course of study decomposition of leaf litter mass % indicated widely varying decomposition of leaf litter in ten multipurpose trees (Table 2). The maximum mean weight loss of leaf litter was in *Acacia nilotica* (32.39%) during the first week to the seventh week of the litter bag study and followed by *Prosopis juliflora* (31.94%). Decomposition of leaf litter in *Pongamia pinnata* was the least in all weeks (24.82%) (Fig. 4). Suguna and Swaminathan (2012) showed evidence that incorporating *Pongamia pinnata* leaf litter enhances soil fertility and has a positive effect on crop growth by influencing yield of barnyard millet (*Echinochloa frumentaceae*), when a 45-day decomposition interval was allowed. Among different times of

Table 1. Initial moisture content of leaf litter of different tree species

Treatments	Fresh weight (g)	Dry weight (g)	Moisture content after drying (%)
Peltophorum ferrugineum	100	44.1	55.9
Albizia lebbek	100	43.5	56.5
Gliricidia sepium	100	45.5	54.5
Delonix regia	100	46.6	53.4
Leucaena leucocephala	100	42.5	57.5
Pongamia pinnata	100	46.5	53.5
Azadirachta indica	100	45.4	54.6
Senna siamea	100	48.0	52.0
Acacia nilotica	100	40.5	59.5
Prosopis juliflora	100	41.1	58.9

sampling, the seventh week recorded significantly the highest mean weight loss percentage (51.47%) of all the tree species due to the presence of optimum soil moisture and temperature. The maximum weight loss percentage was in *Acacia nilotica* in the seventh week (55.36%) and followed by *Prosopis juliflora* (55.04%). The differences in mass loss% of leaf litter starting from the first week to the seventh week of decomposition decrease by 10.64, 7.69 4.62, 4.5 and 3.95 percent respectively due to winter conditions. In winters, low temperature and rainfall may have resulted in the low activity of decomposers. The correlation coefficient of four environmental factors (maximum temperature, sunshine hours, relative humidity morning and evening relative humidity) with leaf litter weight loss (%) was analyzed (Fig. 1). The rate of litter mass loss in different species was separately positively correlated with mean values of maximum temperature (r=0.631), relative humidity (morning) (r=0.853*), relative humidity (evening) (0.941**), and sunshine hours (r=0.356).

Soil temperature, moisture, and other factors also influence leaf litter decomposition. These are the primary elements that accelerate litter decomposition. During the decomposition process, data on these characteristics were collected for seven weeks in the topsoil (15 cm). Variations in soil temperature and moisture content were observed during the decomposition of leaf litter and revealed a variable tendency. It ranged from 38.5 to 45.8°C. The temperature during the fifth week blunted due to the intermittent irrigation given for hastening the decomposition. The mass loss of all the tree species is correlated with weekly mean of soil temperature (r=0.521). Bothwell et al (2014) reported the similar results k values are positively correlated to temperature. The mean soil moisture content for the decomposition of leaf litter varies every week and ranges from 9.8 to 19.8%. The soil moisture peaked during the third week due to the intermittent irrigation given for increasing the decomposition rate. The mass loss of all the tree species was positively correlated with the weekly mean valves of soil moisture (r=0.836*). Amongst all selected variables, soil moisture was the best predictor of mass loss, explaining variability in mass loss. The correlation between mass loss, relative humidity, and soil moisture suggest that the decomposition rate in tree species is influenced by these two factors. The meteorological parameters are significantly correlated with mass loss of tree species (Table 3).

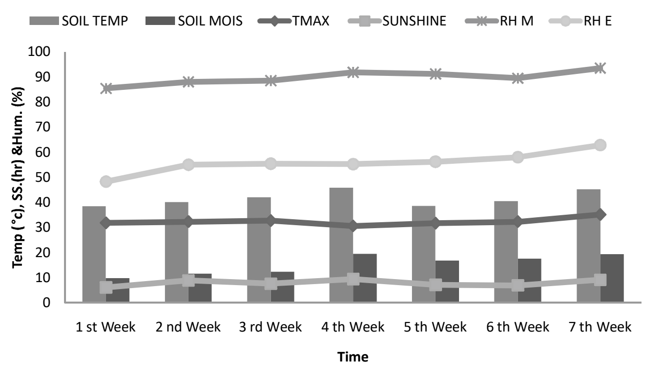

Fig. 1. Meteorological data and soil data recorded during decomposition (January- February 2022)

Table 2. Effect of time of sampling on weight loss in different multipurpose tree species (%)

Tree species	Week							
	1st	2nd	3rd	4th	5th	6th	7th	Mean (%)
Peltophorum ferrugineum	11.28	19.36	23.28	27.4	31.28	39.04	51.68	29.04[bc]
Albizia lebbek	7.32	15.44	19.4	23.52	27.04	34.32	47.76	24.97[d]
Gliricidia sepium	11.04	19.2	22.4	27.2	31.12	38.72	51.44	28.73[bc]
Delonix regia	11.84	19.92	23.76	27.92	31.96	39.84	51.92	29.59[b]
Leucaena leucocephala	11.44	15.52	23.68	27.84	31.84	39.68	51.76	28.82[bc]
Pongamia pinnata	7.04	15.52	19.36	23.44	27.52	33.92	46.96	24.82d
Azadirachta indica	11.32	18.32	21.6	26.32	30.56	38.64	51.28	28.29[c]
Senna siamea	11.2	19.28	23.2	27.6	31.2	39.12	51.52	29.02[bc]
Acacia nilotica	11.96	20.8	27.2	31.68	35.84	43.92	55.36	32.39[a]
Prosopis juliflora	11.92	19.96	25.6	31.6	35.68	43.76	55.04	31.94[a]
SD	1.849	2.059	2.451	2.756	2.856	3.264	2.632	
Mean	10.64	18.33	22.95	27.45	31.40	39.09	51.47	28.76
SEd	0.132	0.267	0.231	0.352	0.541	0.432	0.631	
CD (p=0.05)	0.271	0.546	0.474	0.719	1.104	0.882	1.288	

Means followed by the different alphabets significantly differ in DMRT

Decomposition rate and relative decomposition rate: The weekly percent decomposition rate (k/week) for leaf litter varied between 7.3% (*Pongamia pinnata*) and 11.5% (*Acacia nilotica*) among legumes and 12.1% to 8.1% for non-legume, *Azadirachta indica*. The leaf litter decayed in a steady phase starting from the first week till the end of the study. The mean weekly decomposition rate (k) for legumes leaf litters started in the first week (11.2%) and in the last week rate of decomposition progressively decreased. *Acacia nilotica* significantly showed a higher rate of decomposition from the beginning till the end of the study with the maximum litter decomposed at the seventh week followed by *Prosopis juliflora* and *Pongamia pinnata* with least decomposition rate (9.1%) (Fig. 2**)**. It indicates the faster disintegration of the litter and decomposition, which is an ideal phenomenon in selecting green leaf manure for crop production.

The relative decomposition rate (RDR) of different litter species was maximum in *Acacia nilotica* (0.375 g/g/day). The mean RDR of different multipurpose trees ranged from 0.137 to 0.363 g/g/day starting from the first week to the seventh week of the decomposition period (Fig. 3). Comparatively, the rate of decomposition of leaf litter showed a slow but gradual progressive trend was observed in the subsequent weeks. The decomposition rate progressed steadily, further lynching towards complete decomposition during a later stage indicating patterns of decomposition (Semwal et al 2003). However, a further decrease in the mass loss in this study may be attributed to the release of cellulose, lignin, and

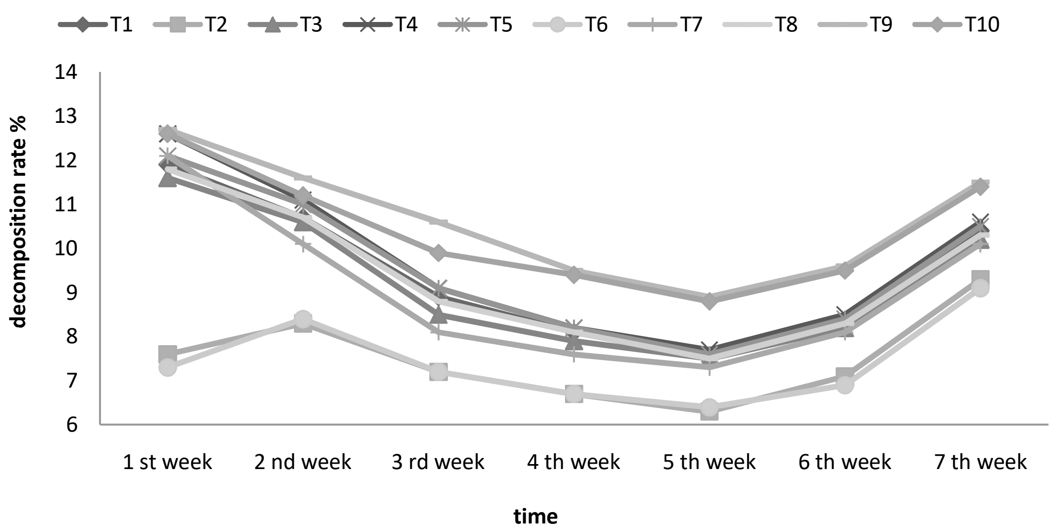

Fig. 2. Weekly decomposition rate (k) on weekly basis (Makkonen et al 2012)

Table 3. Correlation matrix: Effect of meteorological parameters on mass loss %

Tree species	Correlation coefficient					
	Maximum temperature (°C)	Sunshine (Hrs)	Soil temperature (°C)	Soil moisture (%)	Relative humidity morning (%)	Relative humidity evening (%)
Peltophorum ferrugineum	0.647	0.364	0.521	0.828*	0.850*	0.946**
Albizia lebbek	0.654	0.379	0.534	0.828*	0.856*	0.949**
Gliricidia sepium	0.642	0.367	0.519	0.831*	0.852*	0.944**
Delonix regia	0.641	0.359	0.515	0.829*	0.848*	0.945**
Leucaena leucocephala	0.613	0.305	0.518	0.843*	0.846*	0.916**
Pongamia pinnata	0.643	0.38	0.527	0.833*	0.863*	0.951**
Azadirachta indica	0.649	0.344	0.505	0.823*	0.839*	0.935**
Senna siamea	0.64	0.367	0.525	0.832*	0.852*	0.946**
Acacia nilotica	0.597	0.354	0.523	0.852*	0.863*	0.944**
Prosopis juliflora	0.583	0.346	0.518	0.862*	0.864*	0.934**
Mean	0.631	0.356	0.521	0.836*	0.853*	0.941**

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed) and NS- Non significant

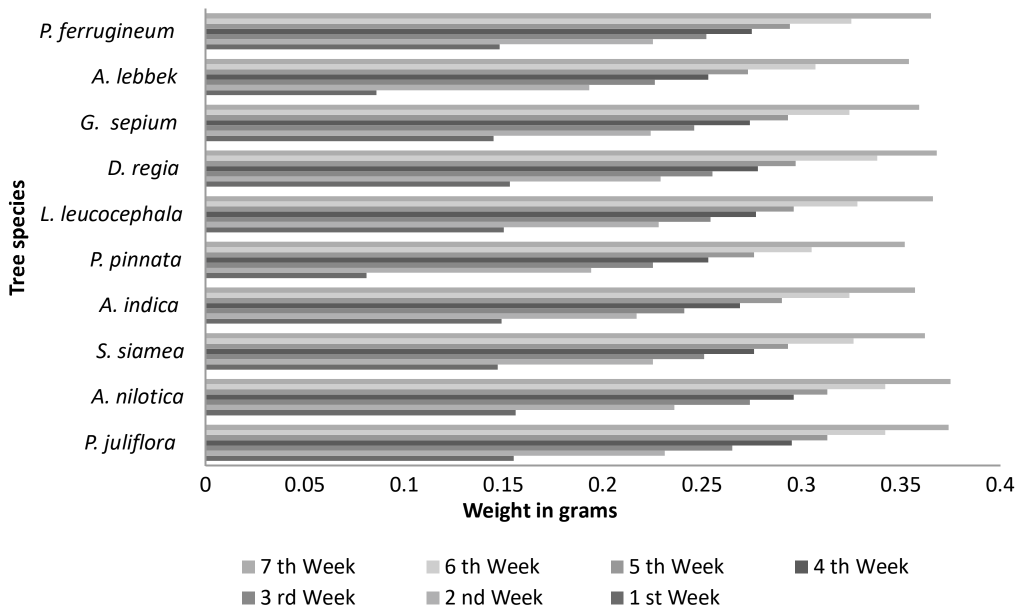

Fig. 3. Relative decomposition rate (g /g /day)

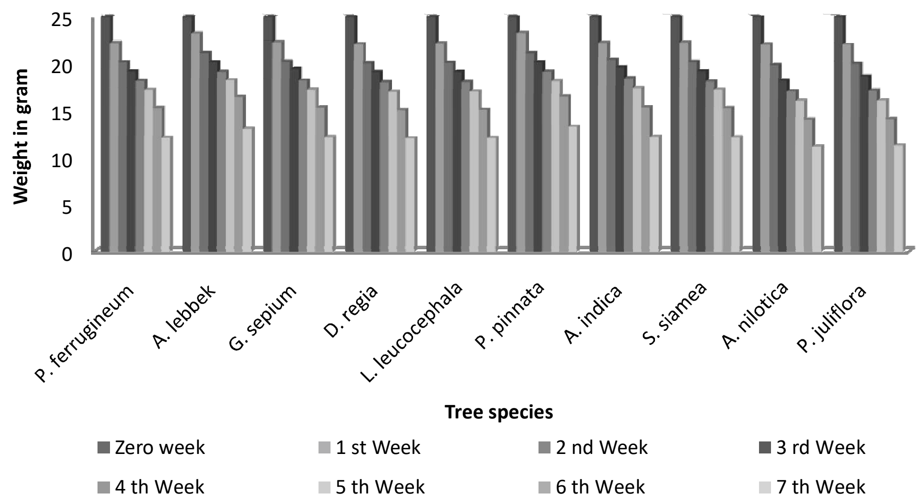

Fig. 4. Remaining mass (g) of decomposing leaf litter over time

tannin at the advanced stage of leaf litter decomposition. All the leguminous tree species showed comparatively quicker mass loss as observed in multipurpose tree species of the central Himalayas (Semwal et al 2003) and the possible variation in mass loss between legume and non-legume might be due to the litter quality, climatic conditions (Jairo et al 2017, Petit-Aldana et al 2019). Many studies observed difference in leaf decomposition rates between species is heavily influenced by litter quality. The higher decay rate of *Melia azedarach* litter could be an indicator of superior litter quality when compared to other species (Mahmood Hossain et al 2011). This study was taken up in winter and the occurrence of summer baking of leaf litter and availability of adequate moisture due to rain or artificial application of water would result in rapid mass loss of semi-decomposed materials that ensures complete break-down of litter at a rapid rate.

CONCLUSION

The rate of decomposition varies significantly by tree species. *Peltophorum ferrugineum, Albizia lebbek, Gliricidia sepium, Delonix segia, Leuceana leucocephala, Pongamia pinnata, Azadirachta indica, Senna siamea, Acacia nilotica, and Prosopis juliflora* leaf litter decomposition was observed for up to seven weeks. The rate of decomposition was significant in leaf litter nylon bag methods. Meteorological and soil characteristics have the greatest impact on the decomposition process. The amount of nutrients released by leaf litter into the soil is determined by litter quality, climatic circumstances, individual nutrient levels, and their interactions during the decomposition process. The added minerals may aid in the maintenance of soil fertility, which is becoming increasingly important in agroforestry systems. Among the studied tree species, *Acacia nilotica* have the highest decomposition rate.

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Taxonomic Census of Riparian Vegetation Near Kangsabati River Basin in Purulia Region, India

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Abstract: The floristic study was undertaken at Kansai basin and its adjoining area near Purulia town, West Bengal during the year 2020-21 in the monsoon season. A total of 170angiosperms were documented systematically on the basis of Angiosperm Phylogeny Group IV (APG IV) classification out of which 137 species are dicots, 1 species belong to sister group of eudicots and 32 species are monocots. Along with terrestrial plants, free-floating, marshy and submerged aquatic plants were also observed. Only 64 plant species are classified under IUCN conservation status (on global scale), out of which 62 species are in the least concern category, 1 near threatened and 1 data deficient, while most of the species are not evaluated till date.

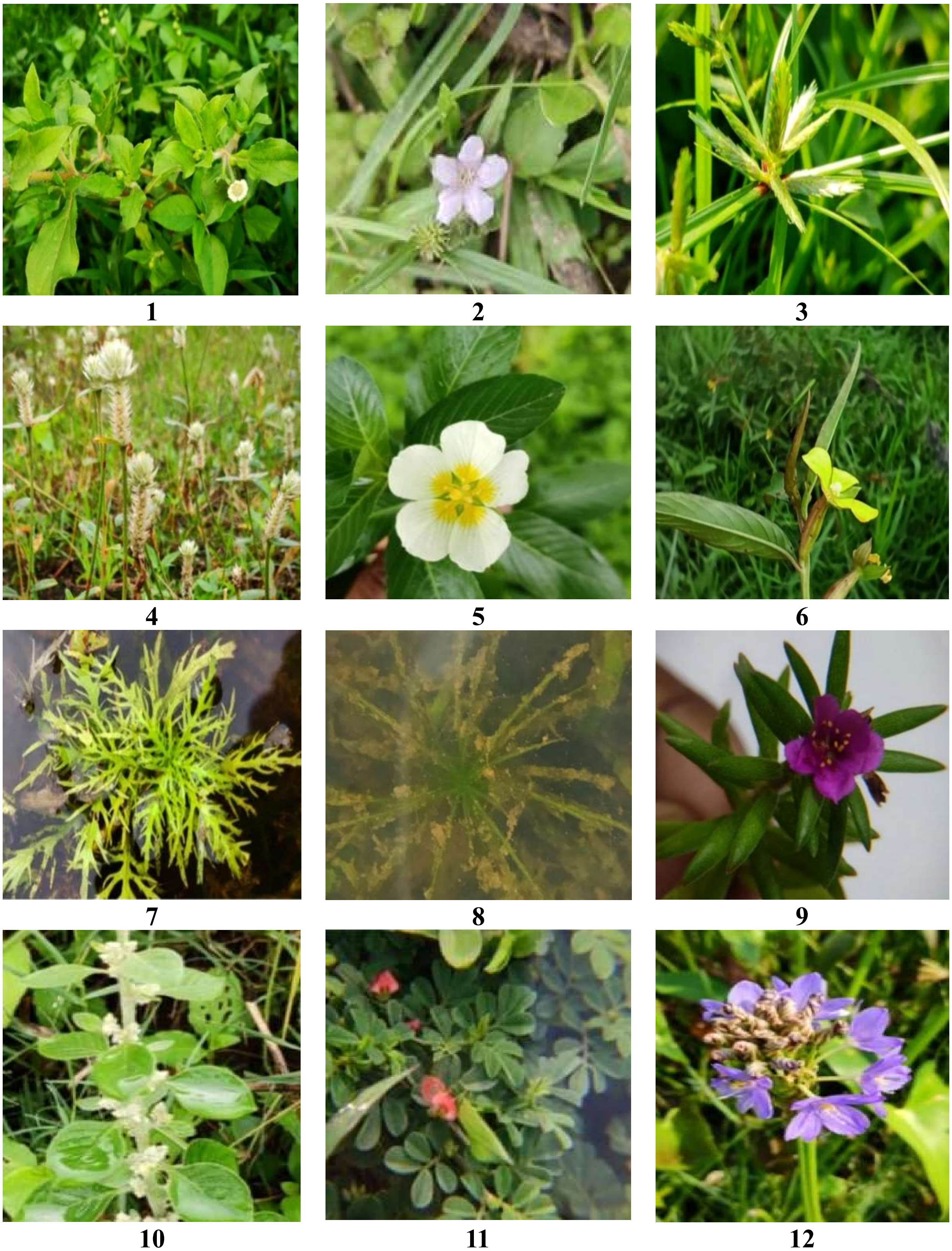
Keywords: Basin of Kansai River, Purulia, Floristic study, APG IV classification, IUCN red list

Riparian vegetation encompasses plant communities that grow adjacent to rivers, streams and some other water bodies. They have multiple adaptations in order to persist in these variable and dynamic habitats. The importance of riparian vegetation in preventing soil erosion, minimizing floods and other ecosystem services is well known in the scientific world. This type of vegetation is highly influenced by water and forms a critical component of terrestrial landscape. Anthropogenic activities such as deforestation practices for agricultural use, transformation into pastures etc. along with climate change, are the main threats to the riparian ecosystems (Sunil et al 2016).The rapid loss in riparian floristic diversity and changing pattern of vegetation due to various biotic and abiotic factors have necessitated the documentation of the floristic diversity of such vegetation. Kangsabati River (also known as Kansai) rises from JaborPahar, Chota Nagpur plateau in Jharkhand district and passes through the three districts of West Bengal viz., Purulia, Bankura and Paschim Medinipur before finally draining into the Bay of Bengal. It is one of the most important rivers of Purulia district (Bhave et al 2013). The river banks of Kangsabati harbour conspicuous wealth of floristic diversity and constitute one of the main riparian zones in Purulia. However, only one study related to the role of some riverine plants in prevention of soil erosion near Kansai basin has been conducted so far (Dey et al 2020). The vegetation distribution pattern, communities, and population dynamics in riparian areas of Purulia have seldom given the due attention and are hence poorly understood. Therefore, a comprehensive study in the riparian landscape was undertaken to evaluate the vegetation composition and prepare a taxonomic census, and assess the existing conservation status of plants as per IUCN along a stretch of the basin of river Kangsabati in Purulia.

MATERIAL AND METHODS

Study area: The Kangsabati river basin with an area of 5796 km^2, is a part of the lower Ganga basin that lies mostly within West Bengal state between coordinates 87°32'E and 85°57'E, 22°18'N and 23°28'N. Due to variations in annual rainfall and temperature, this basin is vulnerable to climatic extremes such as drought and floods. It passes through drought-prone Purulia district that has highly gullied lands and eroded residual hills prone to high run-off and consequently soil erosion (Bhave et al 2013). For the present investigation, both sides of the Kangsabati River bank covering 60 acres area (approximately) near Purulia town was selected as the study site (Fig. 1). Cultivation of various crops was observed in the adjoining areas.

Methodology: Regular floristic surveys were carried out in the study site during 2020-21, covering the monsoon season (May-July). The plant specimens were collected randomly throughout the site from various habitats and identified following the methodologies of Roy (2020). Post identification, the plants were arranged according to Angiosperm Phylogeny Group IV (APG IV) classification (2016), and a taxonomic census was prepared accordingly. Habit analysis was also performed. The existing conservation status of each taxon provided is based on IUCN criteria on global scale (ver. 4).



Images 1-12: 1. *Eclipta prostata* 2. *Dyschoriste radicans* 3. *Cyperus compressus* 4. *Gomphrena celosiodes* 5. *Jussaea repens* 6. *Ludwigia perennis* 7. *Hottonia palustris* 8. *Ceratophyllum demersum* 9. *Portulaca Pilosa* 10. *Aerva lanata* 11. *Indigofera spicata* 12. *Monochoria hastata*

Fig. 3. Important plant species in the study site

Table 1. An enumeration of the flowering plants on the basis of APG IV classification (2016)

Clade	Order	Family	Name of the species	Conservation status as per IUCN on Global scale (2021)
Tracheophytes Angiosperms	Nymphaeales	Nymphaeaceae	**Nymphaea rubra* Roxb. ex. Salisb.	LC
			**Nymphaea alba* L.	LC
			**Nuphar lutea* (L.) Sm.	-
Tracheophytes Angiosperms Magnoliids	Mangoliales	Anonnaceae	****Annona squamosa* L.	LC
			****Polyalthia longifolra* (Sonn.) Thwaltes	-
Tracheophytes Angiosperms Monocot Commelinids	Arecales	Arecaceae	****Pheonix dactylifera* L.	-
	Poales	Cyperaceae	**Cyperus microiria* Stedu.	-
			**Cyperus compressus* L.	LC
			**Cyperus rotundus* L.	LC
			**Cyperus longus* L.	LC
			**Cyperus esculentus* L.	LC
			**Fimbristylis dichotoma* (L.)Vahl.	LC
			**Kyllinga brevifolia* Rottb.	LC
			**Scirpus microcarpus* J.Phesl & C.Phesl	-
		Poaceae	**Setaria pumila* (Poir) Roem & Schult	-
			**Chloris barbata* (L.) Sw.	-
			**Glyceria maxima* (Hartm.) Holmb.	LC
			**Eleusine indica* (L.) Gaertn.	LC
			**Agrostis capillaris* L.	-
			**Saccharum spontaneum* L.	LC
			**Eragrostis tenella* (L.) Roem & Schult	-
			**Cynodon dactylon* (L.) Pers	-
			**Dactyloctenium aegyptium* (L.) Willd.	-
			**Digitaria ciliaris* (Retz.) Koeler	-
			**Paspalidium distichum* L.	-
			**Echinochloa colona* (L.) Link	-
			****Bambusa bamboos* (L.) Voss.	-
	Commelinales	Commelinaceae	**Commelina benghalensis* L.	LC
			**Commelina diffusa* L.	-
			**Commelina erecta* L.	LC
			**Cyanotis axillaris* (L.) D.Don ex. Sweet	LC
		Pontederiaceae	**Eichhornia crassipes* (Mart.) Solms	-
			**Monochoria hastata* (L.) Solms	LC
Tracheophytes Angiosperms Monocot	Alismatales	Aponogetonaceae	**Apongeton undulatus* Roxb.	LC
		Araceae	**Colocasia esculenta* (L.) Schott.	LC
			**Alocasia macrorrhizos* (L.) G.Don	-
		Hydrocharitaceae	**Ottelia alismoides* (L.) Pers.	LC
Tracheophytes Angiosperms	Ceratophyllales	Ceratophyllaceae	**Ceratophyllum demersum* L.	LC
Tracheophytes Angiosperms Eudicots	Ranunculales	Papaveraceae	**Argemone mexicana* L.	-
Tracheophytes Angiosperms Eudicots Rosids	Fabales	Fabaceae	**Desmodium triflorum* (L.) DC.	-
			**Stylosanthes biflora* (L.) ritton & al.	-
			**Alysicarpus monilifor* (L.) DC.	-
			**Indigofera spicata* Forrsk.	-
			**Indigofera linifolia* (L. f.) Retz.	LC

Cont...

Table 1. An enumeration of the flowering plants on the basis of APG IV classification (2016)

Clade	Order	Family	Name of the species	Conservation status as per IUCN on Global scale (2021)
Tracheophytes Angiosperms Eudicots Rosids	Fabales	Fabaceae	****Butea monosperma* (Lam.) Taub.	LC
			****Albizia lebbeck* (L.) Benth	LC
			****Pongamia pinnata* (L.) Pierre	LC
			****Dalbergia sissoo* DC.	LC
			****Vachellia nilotica* (L.) P.J.H. Hurter & Mabb.	LC
			***Tephrosia purpurea* (L.) Pers.	-
			****Acacia auriculiformis* Benth.	LC
			***Phaseolus vulgaris* L.	LC
			**Crotalaria pallida* Aiton	-
			***Senna obtusifolia* (L.) H.S.Irwin & Barneby	LC
			***Senna occidentalis* (L.) Link	-
			****Delonix regia* (Hook.) Raf.	LC
			**Clitoria ternatea* L.	-
			***Mimosa pudica* L.	LC
	Rosales	Moraceae	****Ficus religiosa* L.	-
			****Ficus benghalensis* L.	-
			****Ficus hispida* L.	LC
			****Ficus racemosa* L.	LC
			****Streblus asper* Lour.	LC
		Rhamnaceae	****Zizapus oenoplia* (L.) Mill.	-
		Utricaceae	**Utrica dioica* L.	-
	Cucurbitales	Cucurbitaceae	**Cucumis prophetrum* L.	-
			**Diplocyclos palmatus* (L.) C. Jeffrey	-
			**Bryonia cretica* L.	-
	Oxalidales	Oxalidaceae	**Oxalis corniculata* L.	-
	Zygophyllales	Zygophyllaceae	**Tribulus terrestris* L.	LC
Tracheophytes Angiosperms Eudicots Rosids	Malpighiales	Euphorbiaceae	***Jatropha gossypifolia* L.	LC
			**Acalypha indica* L.	-
			**Croton bonplandianus* Baill.	-
			**Euphorbia hirta* L.	-
			***Euphorbia lactea* L.	-
			**Phyllanthus simplex* Retz.	-
			**Tragia involucrata* L.	-
Tracheophytes Angiosperms Eudicots Rosids	Malpighiales	Phyllanthaceae	****Bridelia retusa* (L.) A. Juss	LC
Tracheophytes Angiosperms Eudicots Rosids	Malpighiales	Violaceae	**Hybanthus enneaspermus* (L.) F.Muell.	-
	Mytrales	Mytraceae	****Syzygium cumini* L. Skeels	LC
		Onagraceae	**Jussiaea repens* L.	-
			**Ludwigia perennis* L.	LC
Tracheophytes Angiosperms Eudicots Rosids	Mytrales	Combretaceae	****Terminalia arjuna* (Roxb. ex. DC.) Wight & Arn.	-
Tracheophytes Angiosperms Eudicots Rosids	Malvales	Malvaceae	**Urena lobata* L.	LC
			**Sida acuta* Burm f.	-
			**Sida cordata* (Burm. f.) Borss. Waalk	-
			**Melochia corchorifolia* L.	LC
			****Bombax ceiba* L.	LC
	Brassicales	Cleomaceae	**Cleome rutidosperma* DC.	-
			**Cleome viscosa* L.	-

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Table 1. An enumeration of the flowering plants on the basis of APG IV classification (2016)

Clade	Order	Family	Name of the species	Conservation status as per IUCN on Global scale (2021)
		Moringaceae	****Moringa oleifera* Lam.	LC
	Sapindales	Anacardiaceae	****Mangifera indica* L.	DD
		Meliaceae	****Melia azedarach* L.	LC
			****Azadirachta indica* A. Juss.	LC
		Rutaceae	****Aegle marmelos* (L.) Correa.	NT
		Simarobaceae	****Ailanthus altissima* (Mill.)Swingle	-
Tracheophytes Angiosperms	Caryophyllales	Molluginaceae	**Mollugo nudicaulis* Lam.	-
		Aizoaceae	**Trianthema portulacastruma* L.	-
		Nyctanginaceae	**Boerhaevia diffusa* L.	-
		Amaranthaceae	**Alternanthera sessilis* (L.) R. Br. ex. DC	LC
			**Alternanthera philoxeroides* (Mart) Griseb	
			**Aerva lanata* (L.) Juss.	-
			**Amaranthus viridis* L.	-
			**Amaranthus biltum* L.	-
			**Achyranthes aspera* L	-
			**Gomphrena serrata* L.	-
			**Gomphrena celosioides* Mart.	-
		Portulaceae	**Portulaca oleracea* L.	LC
			**Portulaca pilosa* L.	-
		Polygonaceae	**Polygonum hydropiper* L.	-
			**Polygonum barbatum* L.	-
			**Polygonum glabrum* L.	-
Tracheophytes Angiosperms Asterids	Cornales	Cornaceae	****Alangium salviifolium* (L.f.) Wangerin	LC
	Ericales	Primulaceae	**Hottonia palustris* L.	LC
Tracheophytes Angiosperms Eudicot Asterids	Asterales	Asteraceae	**Cyanthillium cinereum* (L.) H.Rob.	-
			**Ageratum conyzoides* (L.) L.	LC
			**Eclipta prostata* (L.) L.	LC
			**Synedrella nodiflora* (L.) Gaerth.	-
			**Parthenium hysterophorus* L.	-
			**Xanthium strumarium* L.	-
			**Pluchea indica* (L.) Less.	-
			**Tridax procumbens* L.	-
			**Tussilago farfara* L.	-
			**Acmella caulirhiza* Delile.	-
			**Matricaria discoidea* DC.	-
		Menyanthaceae	**Nymphoides indica* (L.) Kuntze	LC
Tracheophytes Angiosperms Eudicot Asterids	Solanales	Convolvulaceae	**Evolvulus alsinoides* (L.) L.	-
			**Evolvulus nummularius* (L.) L.	-
			***Ipomoea carnea* Jacq.	-
			**Ipomoea aquatica* Forssk.	LC
			**Ipomoea Purpurea* (L.) Roth.	-
			**Cuscuta reflexa* Roxb.	-
		Solanaceae	**Physalis angulata* L	LC
			**Solanum sisymbriifolium* Lam.	-
			**Solanum virginianum* L.	-
	Lamiales	Acanthaceae	**Rugia repens* (L.) Nees.	-
			**Hygrophila auriculata* (Schumach.) Heine.	LC
			**Hygrophila polysperma* Anderson	
			**Dyschoriste radicans* Nees.	LC

Cont...

Table 1. An enumeration of the flowering plants on the basis of APG IV classification (2016)

Clade	Order	Family	Name of the species	Conservation status as per IUCN on Global scale (2021)
		Lamiaceae	**Leucas aspera* (Willd.) Link.	-
			**Ocimum americanum* L.	-
			**Ocimum tenuiflorum* L.	-
			**Ocimum basilicum* L.	-
			**Elsholtzia ciliata* (Thunb.) Hyl.	-
			***Vitex negundo* L.	LC
			****Tectona grandris* L.	-
			***Clerodendrum infortunatum* L.	-
			***Leonotis nepetifolia* (L.) R. Br.	-
			**Hyptis suaveolens* (L.) Poit.	-
			**Anisomeles indica* (L.) Kuntze	-
		Lentibulariaceae	**Utricularia gibba* L.	LC
		Martyniaceae	**Martynia annua* L.	-
		Pedaliaceae	**Pedalium murex* L.	-
		Plantaginaceae	**Scoparia dulcis* L.	-
			**Mecardonia procumbens* (Mill) Small.	-
		Verbenaceae	***Lantana camara* L.	-
			**Phyla nodiflora* (L.) Greene	-
		Linderniaceae	**Lindernia antipoda* (L.) Alston	-
			**Lindernia crustaceae* (L.) F.Muell.	-
			**Lindernia procumbens* (Krock.) Philcox	-
			**Lindernia rotudifolia* (L.) Alston	
	Gentianales	Apocynaceae	***Cascabela thevetia* (L.) Lippold	LC
			***Tabernaemontana divaricata* (L.) R. Br. ex. Roem & Schult.	LC
			****Alstonia scholaris* (L.) R.Br.	-
			***Calotropis gigantea* (L.) Dryand.	-
		Rubiaceae	**Spermacoce hispida* L.	-
			**Dentella repens* (L.) J.R. Forst. & G. Forst.	LC
			**Oldenlandia corymbosa* L.	
	Boraginales	Boraginaceae	**Heliotropium indicum* L.	-
			****Cordia dichotoma* G. Forst.	LC
			*Herb; ***Shrub, ***Tree	

LC= Least concern, DD= Data Deficient, NT= Not Threatened

RESULTS AND DISCUSSION

Vegetation composition: A total of 170 plant species belonging to 139 genera and 54 angiosperm families was recorded from the study site along the river Kangsabati basin (Table 1). According to APG IV classification, the dicots are represented by 45 families, 113 genera and 137 species whereas monocots are represented by 8 families, 25 genera and 32 species in the study site. However, one member *Ceratophyllum demersum* L. belongs to the Ceratophyllales group which is a sister group of Eudicots and therefore, its position is between monocot and dicot. Members of Fabaceae (19 species), Poaceae (13 species), Lamiaceae (11 species), Asteraceae (11 species), Amaranthaceae (8 species), Cyperaceae (8 species), and Euphorbiaceae (7 species) were mainly distributed throughout the study site. Habit analysis revealed the majority of taxa to be herbs (124 species), followed by trees (31 species) shrubs (15 species). The reason behind dominance of herbs is that these have the capability to grow easily under varied environmental conditions in a given area (Roy 2020).

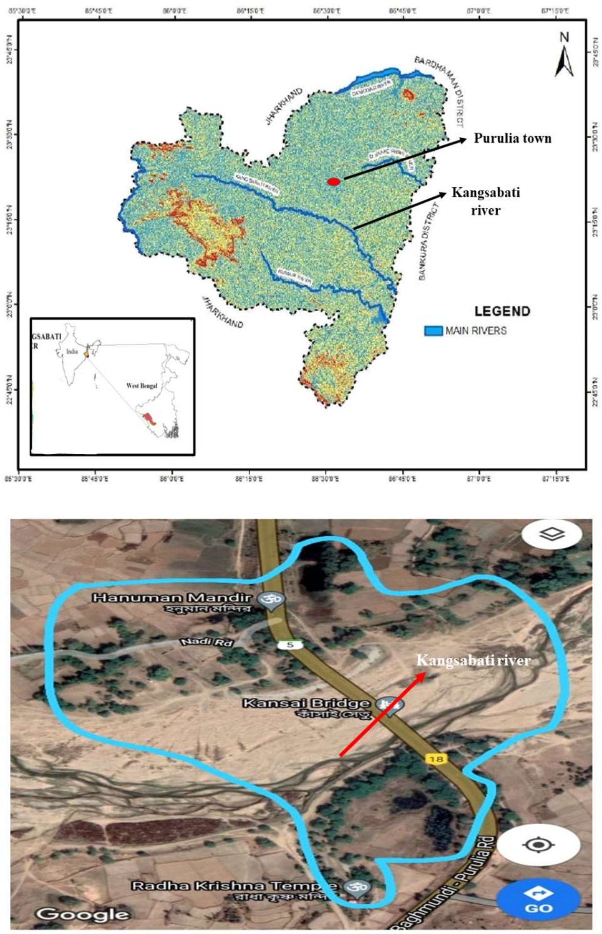

Fig. 1. Study site (The blue line in the Google earth image below indicated the area of study site)

Aquatic plants: A decent proportion of aquatic plants were also observed in the riparian zone. These plants could be categorised into different groups based on their habitats. Out of 26 aquatic plants, 23% were free-floating, 19.23% were submerged, while 57.69% were found in the marshes (Fig. 2).

Current conservation status of the existing flora: In order to understand the present conservation status of the recorded plant species, these were assessed as per IUCN categories. Out of 170 species, only 64 species were enumerated for conservation status at a global scale (Table 2). About 62 species fall under least concern category (LC), while 1 data deficient (DD) and 1 near threatened (NT) species are also observed.

CONCLUSION

This study confirms the presence of different plant groups in the riparian zone of Kangsabati river basin near Purulia region and is able to prepare a taxonomic census of the same. Riparian vegetation provides terrestrial habitat, supplies detritus, and food and habitat space for aquatic invertebrates. More elaborated studies related to riparian vegetation at a broader scale is extremely essential since besides agricultural activities, uncontrolled tourism activities especially during Makar Sankranti (also known as Tusu Parab) are also exerting pressure in the area, leading to decline in plant species and causing soil erosion, consequently affecting the overall biodiversity and ecology of the riparian zones.

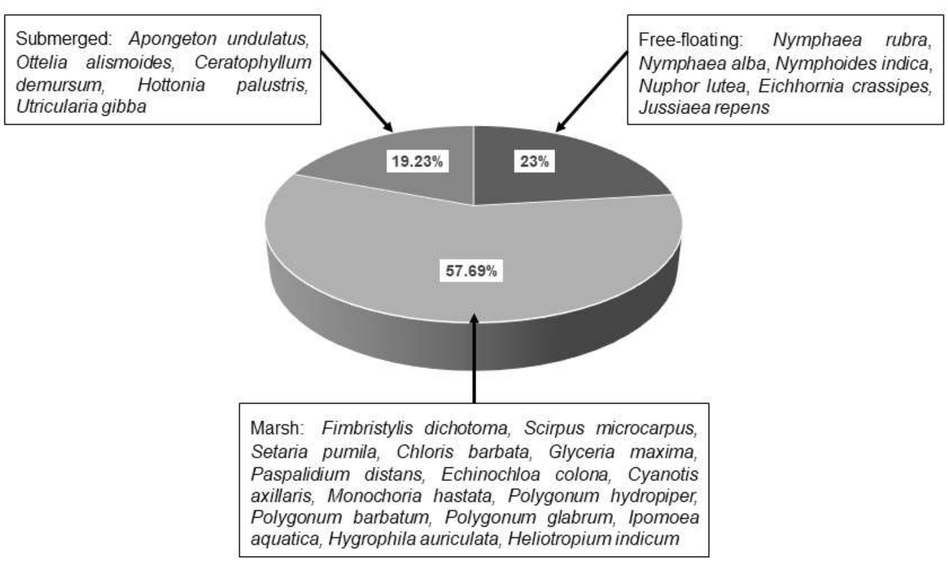

Fig. 2. Presence of different groups of aquatic plants in the study site

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Traditional Knowledge on Medicinal Plants used by the Tribal Communities from Adilabad, Telangana State, India

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Abstract: The ethnomedicinal knowledge practices of the tribal communities play a crucial role in providing a cure for temporary and long-standing illnesses. The objective of the study is to study and identify the ethnomedicinal plants used by the tribal communities of Adilabad, Telangana. The study identified 64 medicinal plant species belonging to 56 families through an exploratory method involving qualitative research methodology. The information was collected through focused group discussions followed by a personal interview with 486 respondents. The mode of utilisation of the medicinal plants majorly constitutes leaves/roots (32%), whole plant (22%) and bark (20%). The tribal communities from the Adilabad district have tremendous knowledge about the different variety of plant-based medicinal preparations which are freely available from nature in the form of sacred groves.

Keywords: Intellectual property, Indigenous knowledge, Folk medicines, Traditional practices, Sacred groves, Natural resources

The tribal communities play a vital role in the management, conservation and sustainable use of the medicinal plants which is learnt from their ancestors. They have tremendous knowledge of cultural adaptation processes for in-situ and ex-situ conservation of numerous plant varieties for medicinal and consumption related aspects in the form of sacred groves. Ethno-botanical use of plats has been known since time immemorial and several plants were used to cure diseases to maintain good health (Chaudhari et al 2010). Ethno-botanical medicines have a direct relationship between man and plants, as plants constitute a major source of world pharmaceuticals and folk-lore medicines, which are widely used to treat many diseases (Adhikari et al 2021). Plant-based indigenous medicinal practices provide health care facilities to more than three fourth of the world's population (Varma and Singh 2008). The World Health Organization estimated that more than 80 per cent of the indigenous communities depend on forest-based traditional ethnomedicinal plants for their cure to illnesses and diseases (Ragupathy et al 2008). In the present day, most of the modern pharmaceutical industry depends more on plant-based extracts to prepare formulations for life-saving drugs (Patwardhan and Datta 2021). It is estimated that more than 30 per cent of such medicinal formulations comes from plant-based products (Msomi and Simelane 2018). The intellectual property rights of the traditional and indigenous communities are being violated by multi-national companies by appropriating the traditional knowledge related to ethno medicines (Mposhi et al 2013). As per a study by the World Bank, it is estimated that more than 7500 plant species have medicinal properties which are documented today and there are more than 45000 plant species which is known to traditional communities for their medicinal properties but the use is not yet documented (Zahra et al 2020). The ethnobotanical approaches are being used to establish a close relationship between nature and people (Singh et al 2018).

The relationship between the indigenous people and the environment has always been an interest to researchers and academicians. The studies of historical ethnobotanical practices of the indigenous communities for the past few decades have become a source of wisdom for the sustainable maintenance of resources and conservation of the environment (Turner and Turner 2008). The report of the Brundtland Commission emphasised the potential scope of the traditional knowledge for the conservation of biodiversity in a sustainable manner (Nesshöver et al 2017). Indigenous knowledge is based on the principle that indigenous communities utilise proximal use of resources for subsistence which is contradictory to the intensive, isolated and single resources based pattern in industrialised communities (Mownika et al 2021). The indigenous communities live in an environment where they understand the interrelation of plants and animals, working ecosystem principles and the use of resources to sustain themselves (Gangadhar 2020). The system-wide understanding of the environment makes sustainable management of ecosystems and became a scope for the adaptation to present-day problems of climate change.

It is evident from the history of India that, many medicines are derived from plant extracts which can be seen in the *Patanjali's Ayurveda* (Telles et al 2013). Among nearly 45,000 plant species reported in India, about 7,000-8,000 species are considered medicinal and used by tribal communities (Nizar et al 2015). These plant-based crude extracts are used to ant-microbial, anti-fungal, anti-diarrheal, anti-inflammatory and antidote to insect, dog, snake and scorpion bites which are well documented by many ethnobotanists and ethno zoologists. In developing nations like India, the tribal and indigenous communities have a culturally adopted wisdom to practice ethnomedicinal knowledge. Medicinal plants act as a source of livelihood sustainability of the tribal communities for their symbiotic relationship with nature (Sharma et al 2020). Adilabad district is regarded as a place with large sections of tribal communities with are covering more than 50 per cent as reserve forest acts as a rich source of floristic diversity along with ethnomedicinal knowledge of plants. The ethnic communities of Adilabad district such as *Gonds, Andhs, Kolams, Pardhans, Thotis, Nayakpod* practising these traditional healing practices for ages. There is s scope to explore the rich diversity of tribal communities and document the ethnomedicinal plant species along with their preparation methodology and mode of operation for larger interest in the sector.

MATERIAL AND METHODS

The study is based on qualitative methodology involving exploratory research design. The exploratory research design, the information related to ethnomedicinal plants used by the tribal communities of Adilabad district. The study was conducted in the Boath block of Adilabad which has diverse villages of tribal communities from *Andhs, Gonds, Kolam, Thoti, Pardhans, Nayakpods* and *Lambadas*. The Boath block consists of 18 Gram Panchayats having 75 villages. To conduct research, 10 villages having a tribal population of more than 90 per cent according to the 2011 census were chosen to conduct research namely Anduru, Babera, Birlagondi, Ghanpur, Kantegaon, Lambaditanda, Nagapur, Sakera, Tiwiti and Wajjara. The data was collected from primary sources through individual open-ended questionnaires and focused group discussions which are further explored with secondary sources. To get required information 10 participant based focused group discussions with 10-12 adult members of the village comprising village head, traditional healers, public representatives, old age persons along with women to get familiar with the respondents for individual interviews. The data was collected from personal interviews involving 486 respondents during a period of seven months from June 2019 to December 2019 based on the availability of the respondents from the villages.

The Adilabad district derives its name from the then ruler of the area which is named after the ruler of Bijapur, Ali Adil Shah. The district is located towards the extreme northern part of the Telangana state, India. The geographical coordinates of the district are located at a latitude of 19° 40′ 12.00″ North and a longitude of 78° 31′ 48.00″ East. The Adilabad district is bordered by the Yavatmal district on the North, Chandrapur district to the Northeast, Asifabad district by the Eastside, Mancherial district to the Southeast, Nirmal district towards the Southern side and Nanded district of the Maharashtra state on the Westside. The district has a population of 708972 which forms 3.13 per cent of the total population of the Telangana State. The Utnoor division is dominated by the tribal population and has an Integrated Tribal Development Agency (ITDA) for the welfare of the indigenous communities. The Adilabad district comprises an area of 4,153 Square Kilometers with a density of population of 170 persons per sq. km. As per the 2011 census, the Scheduled Tribe population of the district is 224622 which accounts for 31.68% of the district and 7.06% scheduled tribe population of the Telangana state. The present study has been conducted in the villages Boath block, Adilabad district. The major tribal communities living in the district are *Gonds, Kolams, Pardhans, Thotis, Andhs, Nayakpod* and *Lambada* communities. The information related to ethnomedicinal plants which are used by the tribal communities for folk medicine has been studied.

RESULTS AND DISCUSSION

The study identified about 64 varieties of ethnomedicinal plant species belonging to 56 different families (Table 1). The age-wise category of respondents includes 27 % aged 18-40 years, 63 % aged 41-80 years and 10 % aged above 80 years. The study shows that 69 % of the respondents were male and 31 % of respondents were from the female category. The mode of transmission of knowledge from one generation to another includes that about 37 % of respondents learnt from ancestors, 38 % learnt from adult family members and the remaining 25 % learnt from the traditional healer of the same village or other. In females, 54 % of respondents learnt from their ancestors whereas in males it is only 27 %. The less diversity in females learning about medicinal plants may be due to the prevailing patriarchies in the tribal communities.

The use-value (UV) for the top three plant species are*Bauhinia, Ocimum tenuiflorum*, *millettia pinnata* and plant species with less UV value are*Acacia greggii, alangium*

Table 1. Ethnomedicinal plants used by tribal communities of Adilabad

Scientific name of the plant	Local name	Purpose	Preparation	Traditional medicinal use	Use value (UV)
Abrus precatorius	Gurivinda	Hair growth, Contraceptive	Paste	Seed paste directly used to apply and consume	0.03
Acacia farnesiana	Muriki tumma	Dog bite	Juice	Juice paste from fruit applied to the area affected	0.05
Acacia greggii	Muriki Thumma	Dog bite	Paste	Apply bark paste to the dog bite area to heal	0.03
Acacia nilotica	Nalla tumma	Burns	Paste	Paste from bark applied to burnt area	0.04
Achyranthes aspera	Uttareni	Normal delivery	Tied	Tie roots to the waist of the pregnant lady	0.05
Aegle marmelos	Maredu	Diarrhoea	Powder	Directly consume bark powder or paste	0.07
Aerva lanata	Pindi kura	Kidney stone	Leaves	Leaves are eaten directly or cooked as veggies for consumption	0.07
Agave americana	Kitta Narra	Skin diseases	Paste	Apply leaf paste to the affected area of the body	0.07
Ageratum conyzoides	Vishamusthti	Hypertension	Paste	Bark paste is consumed daily in the morning	0.11
Ailanthus excelsa	Peddamanu	Body Pains	Juice	Juice from bark and leaves are taken to relieve pain	0.09
Alangium salvifolium	Uduga Chettu	Baldness	Oil	Cure for hair fall and baldness problems	0.03
Albizia odoratissima	Chinduga chettu	Skin diseases	Paste	Apply bark paste to the affected area of the body	0.05
Ampelocissus latifolia	Adavi Draksha	Dental problems	Juice	Apply leaf juice to the toothache area	0.15
Andrographis paniculata	Nela Vemu	Fever	Powder	Dried plant powdered and taken with honey	0.07
Anogeissus latifolia	Thirumani	Stomach pain	Stem	Chewing the stem directly to cure	0.26
Aristolochia bracteolata	Gadida Gadapa	Menstrual pain	Paste	Apply plant paste with honey to area having pain	0.23
Azadirachta indica	Neem	Worms in stomach	Juice	Leaves juice taken directly along with sugar or honey	0.13
Bauhinia vahlii	Madapaku	Arthritis	Paste	Paste from leaves applied directly at the pain area	0.60
Calotropis gigantea	Tella jilledu	Earache	Juice	Juice from the plant is to be applied to the pain area	0.13
Calotropis gigantea	Jilledu chettu	Snakebite	Paste	Root paste applied directly at the snake bite area	0.16
Capparis sepiaria	Nalla uppi	Contraceptive	Fruits	Fruit is eaten directly for abortion	0.12
Capparis zeylanica	Adonda	Immunity	Fuits	Consume fuits for raising immunity	0.07
Cardiospermum halicacabum	Budda kakara	Hydrocele	Roots	Roots fresh or dried taken directly twice a day	0.22
Careya arborea	Budda darmi	Labour pains	Juice	Juice from the bark to be applied to pain area	0.25
Caryota urens	Adavi Jeelugu	Urinary problems	Juice	Juice from the plant consumed directly	0.23
Catharanthus roseus	Billa Gannenu	Blood pressure, Body swelling	Decoction	Soak the plant in water for a night and drink decoction the next day	0.18
Centella asiatica	Saraswati Aaku	Memory booster	Plant	Fresh plant or dried power consumed to boost memory	0.14
Cissus quadringularis	Anduatukula Teega	Bone fracture	Tied	The whole plant is crushed and bound to broken limbs	0.09
Coccinia grandis	Adavi donda	Painless delivery	Decoction	Root decoction is taken directly while giving birth	0.12
Cochlospermum religiosum	Konda gogu	Piles	Leaves	Leaves are to be taken directly two times a day	0.07
Corallocarpus epigaeus	Pamu donda	Snakebite	Tuber	The tuber is eaten directly in the required quantity as an antidote	0.14
Crinum asiaticum	Pinjari gadda	Snakebite	Paste	A paste made from tuber is applied at the snake bite area	0.16

Cont...

Table 1. Ethnomedicinal plants used by tribal communities of Adilabad

Scientific name of the plant	Local name	Purpose	Preparation	Traditional medicinal use	Use value (UV)
Cuscuta reflexa	Sitamma pogunalu	Bone fracture	Paste	Apply the paste directly to the fractured area and massage	0.05
Dalbergia lanceolaria	Chinduga chettu	Hairfall, Baldness	Powder	Dried bark powder consumed directly	0.04
Dalbergia latifolia	Jitregi	Stock ache	Juice	Bark juice is to be taken along with water or milk	0.03
Dodonaea viscosa	Puli vaili	Bone fracture	Tied	Bark tied to the broken area with bamboo sticks	0.04
Dregea volubilis	Bandi gurija	Tonsils	Plant	Plant part to be eaten directly or chewed twice a day	0.20
Eclipta prostrata	Bhringraj	Hairfall	Paste	Apply the paste directly on hairs before bathing	0.16
Ficus racemosa	Medichettu	Mums	Juice	Bark juice applied directly to the affected area	0.11
Gmelina arborea	Gummateku	Sperm count increase	Powder	Consume bark powder with sugar and water	0.14
Justicia gendarussa	Addasaramu	Tuberculosis	Decoction	Leaf decoction for direct consumption	0.07
Maerua oblongifolia	Boochakra gadda	Snakebite	Roots	Roots used to cure snake and scorpion bite	0.09
Millettia pinnata	Kanuga Chettu	Body pains, bone pains, muscle problems, general use	Oil	Oil extracted from seeds is used as a massage oil	0.34
Momordica dioica	Bodikakara	Abortion	Powder	The dried root powder is taken in palm juice	0.11
Ocimum sanctum	Adavi Tusali	Piles	Plant	Consume whole plant to cure piles	0.08
Ocimum tenuiflorum	Thulasi	Cold, Cough, Fever, General use	Leaves	Directly chewing leaves from the plant or taken with tea	0.35
Pergularia daemia	Guruti Chettu	Liver diseases	Plant	The plant used to cure liver-related diseases	0.07
Phyllanthus acidus	Thella Usiri	Snakebite	Paste	Apply root paste at the snake bite area	0.29
Phyllanthus acidus	Thella usiri	Snakebite	Paste	Paste from roots applied directly on the snake bite area	0.29
Phyllanthus niruri	Nela Usiri	Jaundice	Plant	Chewing bark with pepper	0.19
Plumbago rosea	Erra Chitramulamu	Piles	Paste	Apply root paste directly on piles	0.05
Prosopis juliflora	Nalla Thumma	Snakebite	Paste	Apply bark paste to the snake bite area to heal	0.14
Pulicaria wightiana	Adavi Chamanti	Abortion	Tied	Keeping small part of roots in the vagina	0.11
Selaginella bryopteris	Sanjivini	Irregular periods	Plant	Chewing plants to cure menstrual problems	0.10
Senna occidentalis	Advi chennangi	Rheumatism	Leaves	Leaves can be used to cook food and consume as veggies	0.11
Solanum virginianum	Tella mulaka	Fertility	Seeds	Seeds are eaten along with milk or water	0.07
Spondias dulcis	Adavimamidi	Irregular periods	Powder	Bark powder is taken with milk	0.05
Sterculia urens	Thapsi chettu	Dog bite	Powder	Consume bark powder directly with water	0.18
Strychnos nux-vomica	Mushti	Insect bite	Paste	Paste from seeds applied on area affected	0.11
Tinospora cordifolia	Dusseri teega	Kidney stone	Juice	Juice from the plant consumed directly	0.25
Tinospora cordifolia	Dusari Teega	Fever, stomach problems	Powder	Plant power taken with water to cure	0.06
Vernonia ceneria	Sahadevi	Irregular periods, mestrual pains, menstrual hygiene	Plant	Chewing plant for irregular menstrual cycle	0.03
Zingiber roseum	Adavi Allam	Tumours, swellings, healing agent	Paste	Root paste applied directly on tumours	0.13
Ziziphus mauritiana	Regu chettu	Scorpion bite, agent to store grains	Leaves	Directly chewing leaves from the plant and applied to the wound	0.22

salvifolium and *vernonia ceneria*. The various types of illness and diseases cured with the identified plant varieties includes for treatment of abortion, arthritis, baldness, blood pressure, body swelling, body pains, bone fracture, contraceptives, dental problems, dog bite, earache, hair fall, hydrocele, hypertension, boosting immunity, insect bite, irregular periods, jaundice, kidney stones, menstrual problems, mums, painless delivery, piles, rheumatism, scorpion bite, skin diseases, snake bite, increasing sperm count, stroke, stomach pain, tuberculosis, urinary problems and general fevers. The diagnosis of diseases amongst the tribal communities is based on both traditional and also modern methods, for serious illness, the people prefer going to the government and private hospitals. They use traditional healing practices for general health issues and which are of no threat to the health situations. If the person fell ill, they consult the traditional healer in the village, if the problem still prevails after two to three medications then the traditional healer and village head prefers them for sending to a nearby hospital in the district depending on the severity of the problem.

To prepare traditional forms of medicines to heal the illness and diseases different parts of the plant are used. From the study, 27 plant species were used for external application and 37 plant species are used for consumption based on the required quantity made by the tribal communities. To protect the traditional knowledge as requested by the respondents, the medical preparation related information was not documented on the issues of ethics and confidentiality. The mode of utilisation of the medicinal plants majorly constitutes the whole plant (22%) followed by the bark (20%). The majorly of 14 plant species are used completely as part of medication, followed by bark of 13 plants, leaves and roots constitute 10 species as identified by the study. The various routes of application and consumption of the medicinal plants involve preparation based on knowledge of the tribal communities which includes decoction, paste, juice, powder, leaves, oils, roots, seeds and other methods. The medical preparation of paste form (28%) is the most common process employed by the tribal communities followed by juice (16%), powder (13%) and the remaining were consumed or applied in the form of fruits, oils, roots, seeds, stems and tubers.

CONCLUSION

The indigenous knowledge of the tribal communities from the Adilabad district depends on various plant-based ethnomedicinal practices for healing the illness and diseases in their day to day life. There is a need for the government, universities, research institutions and civil society organisations to take part in research and developmental aspects related to the identification and bringing the medicinal practices through scientific evidence made available to the various sections of society. The problem of pharmaceutical companies for finding solutions to the variety of illnesses, diseases and epidemics can find solutions through the knowledge practices of these communities. There is a need for further research to authenticate the usage of ethnomedicinal practices with scientific and technological inventions for better knowledge adaptations.

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Invasive Succulents in Malabar Region of Kerala, India

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***Abstract*:** The present study identified a total of 49 invasive succulent species under 31 genera, belonging to 20 families have been recorded. Among these, dicotyledons were represented by 14 families, while monocotyledons were represented by 6 families. In terms of nativity, majority of invasive plants were reported from Mexico followed by Madagascar, North America and Central America, etc. Life form analysis reveals that herbs (36 species) were dominant followed by shrubs (11 species) and climbers (2 species). The outcome of the present study will be useful to make an understanding of invasive species diversity, life form and habitat in order to implement successful invasive species management.

***Keywords*:** Invasive succulents, Nativity, Malabar Region, Western Ghats, Kerala

The increased movement of humans around the world has facilitated the deliberate and accidental transfer of species away from their original ranges, often in a way that can facilitate invasions (Wilson et al 2009). Many of these introduced species have notable benefits to humans, but some have undesirable effects that can lead to significant financial costs and changes to entire ecosystems and social systems (Kumschick et al 2012). The threat to biodiversity due to invasive alien species is contributed second only to that of habitat destruction. They are serious hindrance to conservation and sustainable use of biodiversity. The impacts of bioinvasions are so widespread and significant and that they are a recognized component of global change. Invasive alien plants are a large and growing concern around the world, posing a threat to ecosystem integrity and the services they give to humans. Because of their aggressive nature, invasive plants thrive in disturbed soil in a short period of time, inhibiting the growth of native plants (Zhou et al 2020). Climate change, on the other hand, lowers the habitat's resistance to biological incursions. Invasive alien species must be incorporated into climate change policies. This has the potential to weaken natural habitats, agricultural systems and urban areas resilience to climate change. This includes biosecurity efforts to prevent them from spreading to new places as a result of climate change, as well as fast response methods to track and destroy alien species that may become invasive as a result of climate change (Mooney 2005). These invasive substances are widely distributed in all types of ecosystems around the world and include all categories of organisms (Singh 2005). Invasive plants have a greater capacity for efficient uptake of resources in low-resource environments than native plants (Funk and Vitousek 2007). Changes in plant communities caused by invasive plants are often caused by mechanisms that alter the recruitment rates of native species (Yurkonis and Meiners 2004). In India, there are about 40% of the flora are alien of which 25% are invasive. A variety of invasive plants have established themselves in India, and have serious environmental, socio-economic, and health consequences for the indigenous people. The analysis of taxonomical patterns among invasive plants could reveal stabilized trends that could then be used to suggest which plant groups or types of plants should be subjected to the greater level of surviving prior to allowing their importation to new geographical region. Comprehensive studies on invasive succulent species and succulent invasions are still lacking in Kerala. The current research aimed to document the invasive succulent species in Malabar region of Kerala.

MATERIAL AND METHODS

Study area: The Western Ghats, a hotspot that runs along Kerala's eastern border and creates a continuous mountain wall. The Malabar region of Kerala is located between the Western Ghats and the Arabian Sea. This includes the northern part of Kerala. Malabar region of Kerala comprises the districts of Kasaragod, Kannur, Wayanad, Kozhikode, Malappuram, and Palakkad. The Malabar region, which stretches from 74°30'E to 77°E longitude and 10°N to 12°30'N latitude, covers 17,461km^2. Kerala is bordered on the north by Karnataka, on the south and east by Tamil Nadu, and on the west by the Arabian Sea coastline.

Floristic analysis: Intensive field visits were conducted in the Malabar region of Kerala from 2019 to 2021 to document invasive succulent plants floristic diversity. Specimens were collected for scientific study, voucher specimen preparation and identified using appropriate floras, revisions, monographs and relevant literatures (Sasidharan 2004, Sasidharan 2013). Herbarium studies were also carried out to confirm the identity of species using specimens from the Bharathiar University Herbarium and the Madras Herbarium (MH). The voucher specimens were prepared according to the standard procedures (Jain and Rao, 1976) and deposited in the Bharathiar University Herbarium. The nativity of the invasive plants was recorded from the published literature (Maheswari and Paul 1975, Nayar 1977, Sharma and Pandey 1984, Hajra and Das 1982, Saxena 1991, Pandey and Parmer 1994, Reddy and Raju 2002, Murthy et al 2007, Negi and Hajra 2007). The International Plant Name Index (IPNI) and the World Checklist of Selected Plant Families were used to update botanical names.

RESULTS AND DISCUSSION

A total of 49 species distributed in 31 genera and 20 families were recorded as invasive succulent species in the Malabar region of Kerala (Table 1). Among these, the dicotyledons were represented by 14 families, 17 genera and 25 species whereas monocotyledons were represented by 6 families, 14 genera and 24 species. A total of 18 different geographic regions in terms of nativity are recorded in the present study. The analysis of the plant habitat reveals that all invasive succulent species were terrestrials. This can be compared with the results of Swapna and Joy (2016), as they recorded a total of 17 invasive species, out of which 11 were terrestrial invasive plants from the Arookkutty Panchayath of Kerala. Zingthoi and Prabhat (2021) recorded 68 species from 53 genera and 30 families of invasive plants from the moderately disturbed Patches of Hailakandi district in an Indo Burma Hotspot Region. The study also discovered that land use change has a substantial impact on the spread of invasive alien plants over the landscape and plays an important part in the spread of invasive alien species over the landscape.

Invasive succulents were most abundant in wastelands, cultivated fields, road sides, river banks and forest edges. This suggests that an infertile soil is a critical prerequisite for successful invasion by exotic species. Sharma et al (2005) reported that a habitat characterized by disturbance is more prone to invasion than an undisturbed habitat. The recorded exotic species were originated from range of countries with 12 succulent species are native to Mexico followed by 6 species are native to Madagascar, 4 species are native to North America and Central America each, 3 species are native to Brazil and South Africa each, 2 species are native to South America and Tropical Africa each and remaining geographical region represented by one species each (Fig. 1). The preliminary findings support that America is the primary geographical origin of invasive alien plant species in the study area. Liu et al (2006) also suggested that America was the primary geographical origin of most invasive alien species. China, Asia and North America share a wide range of similar environment and related biota, which may result in each region being more susceptible to each other's immigrant species than species from many other parts of the world. The Amaryllidaceae (9 species) is the dominant family followed by Asparagaceae (6 species), Euphorbiaceae (4 species), Apocynaceae, Araceae, Cactaceae, Crassulaceae, Commelinaceae, Portulacaceae (3 species each), Bromeliaceae (2 species) and remaining family with one species each (Figure 2). The genera with the highest number of alien invasive species is *Euphorbia* (4 species); *Hippeastrum, Kalanchoe, Plumeria, Portulaca, Tradescantia and Zephyranthes* (3 species each); *Ananas* (1 species) and the remaining genera with one species each (Table 1). The

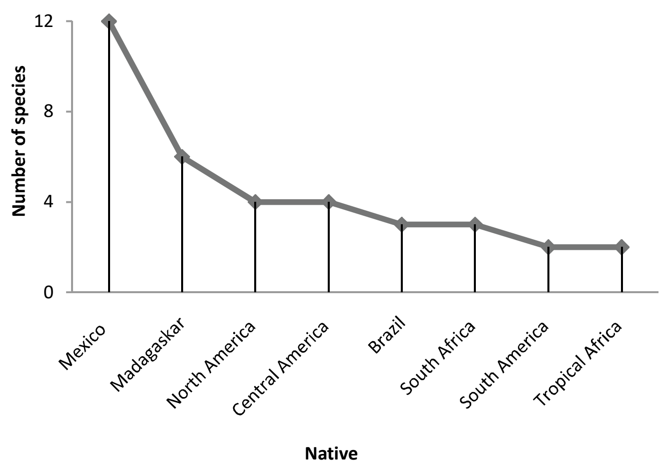

Fig. 1. Native of invasive succulent species

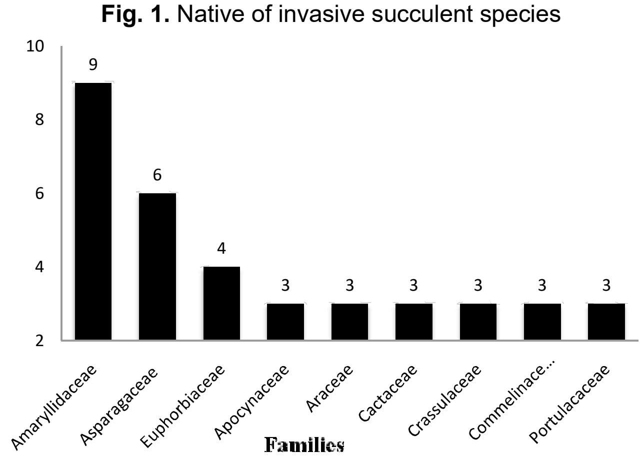

Fig. 2. Dominant families of invasive succulent species

Table 1. Invasive succulents in Malabar Region of Kerala

Binomial Name	Family	Habit	Habitat	Succulent part	Nativity
Agapanthus africanus (L.) Hoffmanns.	Amaryllidaceae	H	Te	Le	South Africa
Agave americana L.	*Asparagaceae*	S	Te	Le	South America
A.salmiana var. *ferox* (K.Koch) Gentry	*Asparagaceae*	S	Te	Le	Mexico
A.sisalana Perrine	*Asparagaceae*	S	Te	Le	Mexico
Alocasia macrorrhizos (L.) G.Don	Araceae	H	Te	Pl, Pe, Tu	Australia
Ananas comosus (L.)Merr.	Bromeliaceae	H	Te	Le	South America
A.comosus var. *microstachys* (Mez) L.B.Sm.	*Bromeliaceae*	H	Te	Le	Central America
Asparagus racemosusWilld.	*Asparagaceae*	C	Te	Tu	Tropical Africa
Begonia grandis Dryand.	Begoniaceae	H	Te	Pe, Pl	Central China
Caladium bicolor (Aiton) Vent.	Araceae	H	Te	Pe, Pl, Tu	Central America
Canna indica L.	Cannaceae	H	Te	St	Tropical America
Cereus pterogonus Lem.	Cactaceae	S	Te	St	Colombia
Chrysothemis pulchella (Donn ex Sims) Decne.	Gesneriaceae	H	Te	St	Mexico
Dracaena trifasciata (Prain) Mabb.	*Asparagaceae*	H	Te	Le	West Africa
Eclipta prostrata (L.) L.	Asteraceae	H	Te	St	North America
Euphorbia milli Des Moul.	Euphorbiaceae	H	Te	St	Madagascar
E.neohumbertii Boiteau	Euphorbiaceae	H	Te	St	Madagascar
E.tithymaloides L.	Euphorbiaceae	S	Te	St	North America
E.viguieri Denis	Euphorbiaceae	H	Te	St	Madagascar
Furcraea foetida (L.) Haw.	Asparagaceae	S	Te	Le	North America
Hippeastrum puniceum(Lam.) Voss	Amaryllidaceae	H	Te	Bu, Le, Pe	Tropical America
H.reginae (L.) Herb.	Amaryllidaceae	H	Te	Bu, Le, Pe	Peru
H.reticulatum (L'Hér.) Herb.	Amaryllidaceae	H	Te	Bu, Le, Pe	Brazil
Centella macrodus (Spreng.) B.L.Burtt	Apiaceae	C	Te	St	South Africa
Hymenocallis littoralis (Jacq.) Salisb.	Amaryllidaceae	H	Te	Bu, Le,Pe	Mexico
Impatiens walleriana Hook.f.	Balsaminaceae	H	Te	St	Kenya
Kalanchoe blossfeldiana Poelln.	Crassulaceae	H	Te	Le, St	Madagascar
K.delagoensis Eckl. &Zeyh.	Crassulaceae	H	Te	Le, St	Madagascar
K.pinnata (Lam.) Pers.	Crassulaceae	H	Te	Le, St	Madagascar
Leuenbergeria bleo (Kunth) Lode	Cactaceae	S	Te	St	Panama
Mirabilis jalapa L.	Nyctaginaceae	H	Te	St	Mexico
Opuntia cochenillifera (L.) Mill.	Cactaceae	S	Te	Le/ Cl	Mexico
Oxalis triangularis A.St.-Hil.	Oxalidaceae	H	Te	Pe, Pl	Peru
Peperomia pellucida (L.) Kunth	Piperaceae	H	Te	St	Tropical America
Pilea microphylla (L.) Liebm.	Urticaceae	H	Te	Le, St	Mexico
Plumeria alba L.	Apocynaceae	S	Te	St	North America
P. pudica Jacq.	Apocynaceae	S	Te	St	Panama
P. rubra L.	Apocynaceae	S	Te	St	Mexico
Portulaca grandiflora Hook.	Portulacaceae	H	Te	Le, St	Bolivia
P. oleracea L.	Portulacaceae	H	Te	Le, St	Europe
P. pilosa L.	Portulacaceae	H	Te	Le, St	Central America
Scadoxus multiflorus (Martyn) Raf.	Amaryllidaceae	H	Te	Bu, Pe	Tropical Africa
Tradescantia pallida (Rose) D.R.Hunt.	Commelinaceae	H	Te	St	Mexico
T. spathacea Sw.	Commelinaceae	H	Te	St	Mexico
T. zebrina Bosse	Commelinaceae	H	Te	St	Mexico
Xanthosoma sagittifolium (L.) Schott	Araceae	H	Te	Pe, Pl, Tu	Central America
Zephyranthes minuta (Kunth) D.Dietr.	Amaryllidaceae	H	Te	Bu, Pe, Le	Mexico
Z. candida (Lindl.) Herb.	Amaryllidaceae	H	Te	Bu, Pe, Le	Brazil
Z. robusta (Herb.) Baker	Amaryllidaceae	H	Te	Bu, Pe, Le	Brazil

Habit: **H** –Herb; **S**- Shrub; **C**- Climber; **Habitat**: **Te** –Terrestial; **Succulentpart**: **Le** – Leaf; **St**- Stem; **Bu** – Bulb; **Pe** – Peduncle; **Tu**- Tuber; **Pl**- Petiole; **Cl –** Cladode

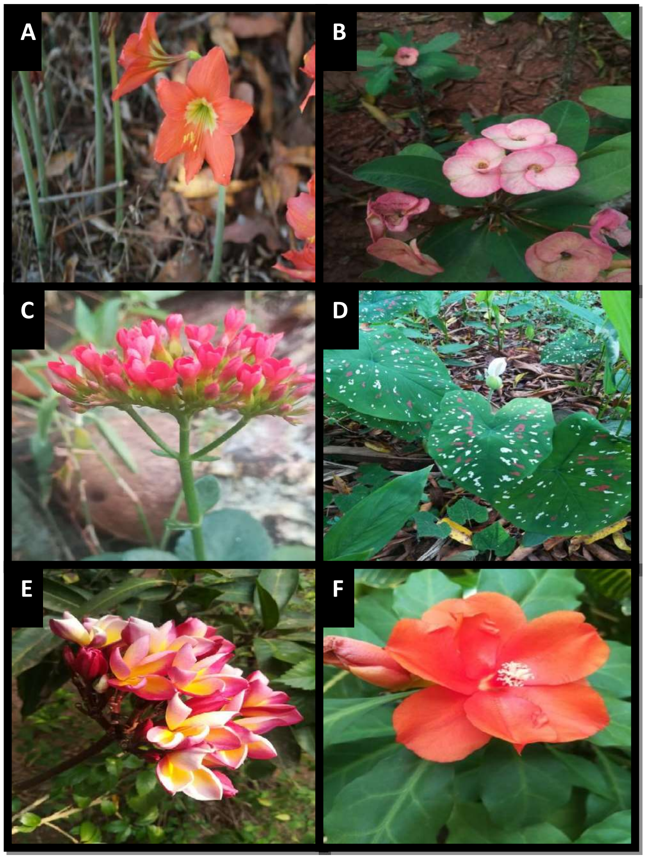

Fig. 3. A. *Hippeastrum puniceum*(Lam.) Voss B. *Euphorbia milli* Des Moul. C. *Kalanchoe blossfeldiana* Poelln. D. *Caladium bicolor* (Aiton) Vent. E. *Plumeria rubra* L.F. *Leuenbergeria bleo* (Kunth) Lode

Fig. 4. G. *Peperomia pellucida* (L.) Kunth H. *Scadoxus multiflorus* (Martyn) Raf. I. *Kalanchoe pinnata* (Lam.) P ers. J. *Opuntia cochenillifera* (L.) Mill. K. *Euphorbia tithymaloides* L. L.*Chrysothemis pulchella* (Donn ex Sims) Decne

plant growth form analysis indicates that herbs were represented by 36 species (74%) whereas shrubs were represented by only 11 species (22%) followed by two climbers (4%). The present study observed that invasiveness in cacti is closely linked to specific growth forms. Angled, cylindrical, flattened-padded, or sprawling are all characteristics of invasive cactus. The ability of taxa in these groups to grow vegetatively from cuttings, allowing for rapid spread, is likely the explanation for the high levels of invasiveness in these growth forms.

CONCLUSION

The current study on invasive succulents distributed in Malabar region of Kerala revealed that there are about 49 invasive succulents that were dominantly introduced from Mexico followed by Madagascar, North America and Central America. All invasive succulent species were terrestrials. The invasive succulent species were mostly found in wastelands, cultivated fields, road sides, river banks and forest edges. Therefore, creating adequate awareness to the public about potential invasive succulent plants and their management is crucial. The outcome of this research is important for defining strategies for preventing harmful invasive succulent species introductions and managing invasive succulent species.

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Disparity in Phytosociology, Biomass and Carbon Stock of Trees in Primary and Secondary Temperate Broadleaf Forest of Indian Himalayas

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Abstract: Estimation of carbon stocks in tree biomass is necessary to study climate change under UN Framework Convention on Climate Change. To understand diversity, community characteristics, biomass and carbon stock of trees in Indian Himalayas, two forests - primary (PF) and secondary (SF) temperate broadleaf forest were investigated in Arunachal Pradesh. Extensive field study was undertaken and 15 quadrats (20x20 m^2) each in the two study sites were laid randomly for the study. A total of 33 species of trees belonging to 26 genera and 17 families were recorded from the study sites. 26 species, 21 genera and 15 families were recorded from PF while 27 species, 20 genera and 13 families were recorded from SF. The study revealed higher biomass and higher Carbon stocks with good species richness, higher density and basal area in SF than PF. Forest clearing during *Jhum* may not be considered as deforestation but forest modification allowing forest regrowth during sufficient long fellow. It can be concluded that integration of indigenous knowledge can lead to the development of cost-effective, participatory and sustainable way to conserve biodiversity, to increase long term C sequestration in plants and to mitigate climate change.

Keywords: Arunachal Pradesh, Carbon sequestration, Climate change, Conservation, Jhum, Northeast India, Mitigation

The major concern which was highlighted in the Kyoto protocol was the ever-increasing carbon emission in the entire world (Parry et al 2017). One of the tangible solution for reduction of atmospheric carbon is through the mechanism known as carbon sequestration (Chavan and Rasal 2012). So, the forests play the major role as in sinks of greenhouse gases through changes in the overall carbon stocks of forests and supply of biomass which substitute the fossil fuel and energy-intensive material (IPCC 2006). In the healthy growing forest carbon sequestration act as the only known cost-effective option for mitigation of global warming and global climatic change overall. The study on climate change under UN Framework Convention on Climate Change has made mandatory to estimates carbon stocks and stock changes in tree biomass (Green et al 2007, Parry et al 2017). FAO (2006) estimated that the world's forest ecosystems store more carbon than the entire atmosphere. The role of forest in sequestration and storing of carbon is considered as the most significant in the present context for climate change mitigation strategies (Kishwan et al 2009). Natural forests possess high species diversity when compared with the plantation forests and they are increasingly recognized for their capacity to sequester atmospheric carbon (Baishya and Barik 2011). The sequestration potential varies with species level density change that leads to stratification of different carbon pools (Baishya and Barik 2011). Determination on the potentials of carbon sequestration by the terrestrial ecosystem through estimation of biomass is widely accepted and considered to be the most appropriate approach (Brown 1997). Northeast India represents only 8.0% of geographical area of India but accounts for nearly 25% of its forest cover of the country (FSI 2013). Northeast India is represented by a variety of forest ecosystems ranging from tropical rainforest to sub-tropical and temperate forests (Champion and Seth 1968). These forests are rich in biodiversity and fall into the Indo-Burma hot spot of the world biodiversity (Myers et al 2000). Temperate forests cover 767 million hectares worldwide and account for approximately 14 % of forest carbon storage (Pan et al 2011). The greatest potential for C storage in temperate forests is usually found within the tree biomass (Sonetal 2001, Peichl and Arain 2006). In India, including Northeast India, large areas of primary forests are degraded at to a varying extent and converted to other land uses including shifting cultivation (Behera and Misra 2006, Barik and Mishra 2008, FSI 2013). However, (Bhagawati et al 2015) claimed that contrary to modern belief, *Jhum* is carbon sink, maintains soil health, preserves biological diversity and sustains local climate. Many thorough studies on floral diversity and community characteristics of the temperate forests have been undertaken in Indian Himalayas including north eastern India (Mao et al 2009, Bharali et al 2011, Sharma et al 2014, Yam and Tripathi 2016, Thokchom and

Yadava 2017, Paul et al 2019). For effective C mitigation, it is pivotal to accurately quantify the C stocks of forests of NE India. However, only few studies have been reported on biomass and C stocks on forests of NE India (Thokchom and Yadava 2013, 2017, Waikhom et al 2018). Thus, this study was taken up to understand the tree diversity, community characteristics and to estimate the biomass and carbon storage of primary and secondary temperate broadleaf forest in Arunachal Pradesh, Indian Himalayas.

MATERIAL AND METHODS

The present study was conducted in Shi-Yomi district (newly created district) of Arunachal Pradesh, Indian Himalayas. Three major tribes *viz* Adi, Memba and Tagin inhabit the district. Two temperate broadleaf forests (with an altitude ranges from 1500-1900 m asl) were selected in the district - Gapo village forest (untouched community forest) (between latitude 28˚30´47.718´´ N and longitude of 94˚18´40.68´´E) as Primary forest (PF) and Kuak-Menying village forest (rejuvenated forest after *Jhum* cultivation in 1970s) (between latitude 28˚31´24.157´´ N and longitude of 94˚18´53.816´´E) as Secondary forest (SF). Extensive field survey was undertaken in these two forests in 2018-2019. Vegetation sampling of all the trees was done through random quadrats methods. A total of 15 quadrats (20 m x 20 m size) each were laid randomly in the selected plot for tree species and individuals with diameter at breast height (DBH) more than 5 cm where recorded directly using measuring tape. Trees with D<5 cm are excluded because such trees hold a small fraction of AGB in their habitat (Chidumayo 2002). Specimens of all tree species recorded were collected and herbarium specimens were prepared following (Jain and Rao1977) and identification was done following taxonomic literature and herbarium specimens of regional and national herbaria (ASSAM and ARUN). Important community characteristic of the selected sites like frequency, density, dominance, abundance, basal cover, Importance Value Index (IVI) were calculated using standard methods (Phillips 1959, Misra 1968). The Abundance – Frequency (AF^{-1}) ratio was calculated and used to interpret the distribution pattern of the species (Whitford 1949). Several indices were calculated to measure the species diversity (Shannon and Weiner 1949, Simpson 1949), species evenness (Pielou 1966); species richness (Margalef 1958) and similarity between the two forests (Sorensen 1957). The above ground biomass (AGB) of tree species was estimated by following the allometric equation of Chave et al 2005 i.e. AGB (Kg) = ρ x exp $(- 1.499 + 2.148 \ln (D) + 0.207 (\ln (D))^2 – 0.0281 (\ln (D)^3)$, where, D is diameter and ρ is the wood specific gravity of tree species. Wood specific gravity of tree species had been taken from world agroforestry database (Chave et al 2009). Where ever the wood density of tree species was unavailable the standard average value of 0.62 gm cm^3 was used (IPCC 2003). Wood specific gravity is an important prediction of AGB (Baker et al 2004). The belowground biomass (BGB) of tree species was calculated by multiplying AGB taking 0.26 as the root shoot ratio (Zanne et al 2010). By summing the AGB and BGB, the total biomass (TB) was calculated. The total carbon stock (TCS) of each tree was calculated by multiplying the total biomass of the species by a conversion factor of 0.5 which represents that the carbon content is assumed as 50% of the total biomass (IPCC 2003).

RESULTS AND DISCUSSION

Phytosociology of the different tree species in PF and SF: A total of 33 species of trees belonging to 26 genera and 17 families were recorded from the study sites. 26 species, 21 genera and 15 families were recorded from PF while 27 species, 20 genera and 13 families were recorded from SF (Table 1). The findings of both PF and SF were comparatively less than that of temperate mixed Rhododendron forest of Arunachal Pradesh (72 species) (Bharali et al 2011); Talle Wildlife Sanctuary, Arunachal Pradesh (63 species) (Yam and Tripathi, 2016) and temperate forest of Sangla Valley, Himachal Pradesh (320 species) (Sharma et al 2014). Total tree density of PF was 395.75 stem ha^{-1} with *Castanopsis indica* accounted for the highest density (43.25 ha^{-1}) followed by *Quercus lamellosa* and *Phoebe lanceolata* while, total tree density of SF was 425 stem ha^{-1} with *Myrica esculenta* accounted for the highest density (36.67 ha^{-1}) followed by *Alnus nepalensis* and *Quercus semiserrata* (Table 1 and 2). Total tree density was comparable to that of Talle Wildlife Sanctuary, Arunachal Pradesh (Yam and Tripathi, 2016) and temperate forest of Sangla Valley, Himachal Pradesh (Sharma et al 2014) but less than that of temperate mixed

Table 1. Community characteristics of the study sites (PF and SF)

Parameter	PF	SF
No. of species	26	27
No. of genera	21	20
No. of family	15	13
Shannon Weiner index	3.10	3.21
Simpson dominance index	0.05	0.04
Margalef's richness index	4.57	4.33
Pielou's evenness index	0.95	0.97
Sorensen similarity index	79%	
Density (Stems ha^{-1})	395.75	425
Basal area (m^2 ha^{-1})	34.90	56.34

Table 2. Phytosociological attributes of the different tree species in PF and SF

Botanical name	PF						SF					
	F* (%)	D (ha)	TBC $m^2 ha^{-1}$	A	A/F	IVI	F (%)	D (ha)	TBC $m^2 ha^{-1}$	A	A/F	IVI
Acer acuminatum Wall. ex D.Don	20.00	6.75	0.32	1.33	0.07	5.87	20.00	8.33	0.61	1.67	0.08	5.56
Acer pectinatum Wall. ex G.Nicholson	-	-	-	-	-	-	20.00	5.00	0.74	1.00	0.05	5.01
Acer sp.	13.33	6.75	0.33	2.00	0.15	4.82	-	-	-	-	-	-
Alnus nepalensis D.Don	33.33	23.25	1.34	2.80	0.08	15.18	33.33	31.67	1.12	3.80	0.11	13.64
Balakata baccata(Roxb.) Esser	-	-	-	-	-	-	33.33	18.33	3.35	2.20	0.07	14.47
Beilschmiedia roxburghiana Nees	-	-	-	-	-	-	40.00	16.67	1.53	1.67	0.04	11.68
Castanopsis indica(Roxb. ex Lindl.) A.DC.	53.33	43.25	3.65	3.25	0.06	30.13	33.33	20.00	2.85	2.40	0.07	13.96
Castanopsis tribuloides(Sm.) A.DC.	26.67	16.75	1.58	2.50	0.09	13.08	26.67	20.00	6.80	3.00	0.11	20.14
Cinnamomum glaucescens (Nees) Hand.-Mazz.	33.33	15.00	1.62	1.80	0.05	13.87	33.33	16.67	1.08	2.00	0.06	10.04
Citrus hystrix DC.	6.67	1.75	0.06	1.00	0.15	1.67	-	-	-	-	-	-
Dodecadenia grandiflora Nees	20.00	18.25	1.06	3.67	0.18	10.94	13.33	5.00	0.82	1.50	0.11	4.32
Engelhardia spicata(Lindl. ex Wall.) Koord. & Valeton.	-	-	-	-	-	-	33.33	21.67	2.99	2.60	0.08	14.61
Eurya acuminata DC.	20.00	15.00	0.81	3.00	0.15	9.39	26.67	18.33	1.15	2.75	0.10	9.72
Exbucklandia populnea(R.Br. ex Griff.) R.W.Br.	20.00	11.75	0.81	2.33	0.12	8.52	33.33	13.33	2.80	1.60	0.05	12.31
Illicium griffithii Hook.f. & Thomson	26.67	10.00	0.76	1.50	0.06	9.06	26.67	11.67	1.75	1.75	0.07	9.21
Juglans regia L.	33.33	23.25	1.83	2.80	0.08	16.59	-	-	-	-	-	-
Lindera megaphylla Hemsl.	13.33	11.75	0.41	3.50	0.26	6.30	33.33	16.67	0.62	2.00	0.06	9.23
Listea sp.	20.00	6.75	0.55	1.33	0.07	6.52	20.00	10.00	0.91	2.00	0.10	6.48
Maesa indica(Roxb.) A. DC.	20.00	15.00	0.89	3.00	0.15	9.61	-	-	-	-	-	-
Magnolia champaca(L.) Baill. ex Pierre	20.00	16.75	5.43	3.33	0.17	23.05	33.33	21.67	4.33	2.60	0.08	16.99
Magnolia globosa Hook.f. & Thomson	26.67	16.75	1.32	2.50	0.09	12.35	26.67	13.33	2.83	2.00	0.08	11.52
Magnolia hodgsonii (Hook.f. & Thomson) H.Keng	26.67	21.75	1.87	3.25	0.12	15.18	26.67	11.67	0.86	1.75	0.07	7.63
Myrica esculenta Buch.-Ham. ex D. Don	13.33	5.00	0.58	1.50	0.11	5.11	46.67	36.67	2.56	3.14	0.07	19.05
Persea odoratissima(Nees) Kosterm.	20.00	6.75	0.50	1.33	0.07	6.38	33.33	15.00	1.87	1.80	0.05	11.05
Persea sp.	13.33	5.00	0.18	1.50	0.11	3.97	20.00	5.00	0.31	1.00	0.05	4.25
Phoebe lanceolata (Nees) Nees	26.67	30.00	2.78	4.50	0.17	19.90	20.00	13.33	2.82	2.67	0.13	10.66
Quercus lamellosa Sm.	40.00	31.75	3.14	3.17	0.08	23.53	26.67	11.67	3.20	1.75	0.07	11.79
Quercus semiserrata Roxb.	-	-	-	-	-	-	40.00	26.67	4.58	2.67	0.07	19.44
Salix tetrasperma Roxb.	20.00	13.25	0.90	2.67	0.13	9.20	20.00	6.67	0.60	1.33	0.07	5.15
Saurauria nepaalensis DC.	20.00	6.75	0.51	1.33	0.07	6.40	33.33	11.67	1.49	1.40	0.04	9.58
Schima wallichii Choisy	26.67	16.75	1.68	2.50	0.09	13.39	-	-	-	-	-	-
Toona sp.	-	-	-	-	-	-	40.00	18.33	1.77	1.83	0.05	12.49
Total		395.75	34.90			300.00		425.00	56.34			300.00

*F = Frequency, D = Density, TBC = Total basal cover, A = Abundance, A/F = Abundance: Frequency ratio, IVI = Importance Value Index

Rhododendron forest of Arunachal Pradesh (963 stem ha^{-1}) (Bharali et al 2011). The total basal cover of trees in PF was 34.90 m^2 ha^{-1}, with the maximum basal cover occupied by *Magnolia champaca* (5.43 m^2 ha^{-1}) followed by *Castanopsis indica* and *Quercus lamellosa* while, the total basal cover of trees was 56.34 m^2 ha^{-1}, with the maximum basal cover occupied by *Castanopsis tribuloides* (6.80 m^2 ha^{-1}) followed by *Quercus semiserrata* and *Magnolia champaca* (Table 1 and 2). The total basal cover of both the forest were comparable to that of Talle Wildlife Sanctuary, Arunachal Pradesh (43.02 m^2 ha^{-1}) (Yam and Tripathi, 2016) and temperate forest of Sangla Valley, Himachal Pradesh (8.70-42.42 m^2 ha^{-1}) (Sharma et al 2014) but less than that of temperate mixed Rhododendron forest of Arunachal Pradesh (74.6 m^2 ha^{-1}) (Bharaliet al 2011).Variation in tree density and basal area of different forest stand may be the result of species composition, age structure, successional stage of the forest and degree of disturbance (Swamy et al 2000). The highest IVI in PF was in *Castanopsis indica* (30.13) followed by *Quercus lamellosa* (23.53) and *Magnolia champaca* while, the highest IVI in SF was observed in *Castanopsis tribuloides* (20.14) followed by *Quercus semiserrata* and *Myrica esculenta* (Table 2). Higher IVI of a species indicated its good power of regeneration and wider ecological amplitude (Singh et al 1991). From the values of IVI of various tree species, it indicated that *Castanopsis indica* and *Castanopsis tribuloides* were the most dominant tree species in PF and SF respectively. The Shannon Weiner's Index of PF and SF were 3.10 and 3.21 respectively (Table 1) which were more than that of temperate mixed Rhododendron forest of Arunachal Pradesh (2.59) (Bharali et al 2011) and temperate forest of Sangla Valley, Himachal Pradesh (1.28) (Sharma et al 2014) but less than that of Talle Wildlife Sanctuary, Arunachal Pradesh (3.99-4.06) (Yam and Tripathi 2016). The Simpson's index value of PF and SF were 0.05 and 0.04 respectively (Table 1) which was within the range of different Indian forests between 0.03 and 0.92 (Deb and Sundriyal 2011). Margalef's richness index of PF and SF were 4.57 and 4.33 rspectively (Table 1) which were within the range between 4.54 and 23.41 for Indian forests (Sathish et al 2013). The Pielou's species evenness index of PF and SF were 0.95 and 0.97 respectively (Table 1) which was quite high. The higher evenness index value reveals more consistency in species distribution. Sorensen's similarity index of the study sites was quite high (79%) (Table1) as the two selected study sites were in the same altitude, topography and climatic zone. Both PF and SF did not follow Raunkiaer's frequency law (A>B>C>=<D<E). Calculated frequency class in PF was A>B>C and in SF was A<B>C. As per the Raunkiaer's law of frequency (Raunkiaer 1934) both the study sites represented heterogeneous vegetation. Understanding the pattern of distribution of organisms is a key aspect in conservation and management (Mao et al 2009). In PF, 96.15% of the tree species showed contiguous and 3.85% showed random distribution pattern while in SF, 77.78% of the tree species showed contiguous and 22.22% showed random distribution pattern (Table 2). This was generally due to uneven distribution of nutrients or other resources in the environment, resulting in the dominance of a contiguous distribution pattern.

Biomass and total C stock of the different tree species in PF and SF: Total AGB, total BGB and total TB of PF were 2068.32, 537.76 and 2606.08 Mg ha^{-1} respectively while SF were 3669.72, 954.13 and 4623.84 Mg ha^{-1} respectively (Table 3). Total AGB, total BGB and total TB of both the forests were comparatively higher than that of temperate forest of China (Zhu et al 2010); Garhwal Himalaya, India (Sharma et al 2010), temperate forest of Kedarnath Wildlife Sanctuary, Uttarakhand (Bhat et al 2013) and temperate forests of Kashmir Himalaya of India (Dar and Sundarapandian 2015). In both the forests, total AGB represented 79.36 % of the total biomass and total BGB 20.63% of the total biomass which were comparable to the finding of Indian forests (79 % and 21 %) (Chhabra et al 2002); Garhwal Himalaya, India (80.8.and 19.2) (Gairola et al 2011) and temperate forests of Kashmir Himalaya of India (80.1 % and 19.9 %) (Dar and Sundarapandian 2015). Most of the tree species present in both the forests had higher average diameter of girth in SF than in the PF. Average diameter of *Castanopsis tribuloides* in PF was 69.40 cm while in SF it was 131.67 cm, *Quercus lamellose* 71.05 cm and 118.27 cm, *Magnolia globasa* 63.50 and 104.00 cm respectively (Table 3). Only few tree species such as *Alnus nepalensis, Cinnamomum glaucescens, Magnolia champaca, Myrica esculenta* had lower average diameter of girth in SF than in PF (Fig. 1). The same pattern followed in TB and TCS. Higher average diameter of girth of most tree species in SF than in the PF could be due to avoiding of cutting certain big tree species during forest clearing for *Jhum* so as not to invoke the spirits of the forest, moreover, the locals knew the significance of trees to immediate ecosystem and sustainability (Bhagawati et al 2015). The highest TB and TCS in PF was in *Magnolia champaca* (449.75 Mg ha^{-1} and 224.87 Mg C ha^{-1}) followed by *Quercus lamellosa* and *Castanopsis indica* while the highest TB and TCS in SF was observed in *Castanopsis tribuloides* (625.94 Mg ha^{-1} and 312.97 Mg C ha^{-1}) followed by *Quercus semiserrata* and *Quercus lamellosa* (Table 3). The result of higher TB and TCS in *Magnolia champaca, Quercus* sp. and *Castanopsis* sp. could be due to higher girth size and higher

Table 3. Biomass and total C stock of the different tree species in PF and SF

Botanical name	Wood density g/cm^3	Primary forest Mg ha^{-1}				Secondary forest Mg ha^{-1}			
		AGB	BGB	TB	TCS	AGB	BGB	TB	TCS
Acer acuminatum Wall. ex D.Don	0.54	15.65	4.07	19.72	9.86	32.25	8.38	40.63	20.32
Acer pectinatum Wall. ex G.Nicholson	0.54	-	-	-	-	44.52	11.58	56.10	28.05
Acer sp.	0.54	16.44	4.27	20.72	10.36	-	-	-	-
Alnusne palensis D. Don	0.42	52.13	13.56	65.69	32.85	38.83	10.10	48.93	24.46
Balakata baccata (Roxb.) Esser	0.62	-	-	-	-	240.21	62.45	302.67	151.33
Beilschmiedia roxburghiana Nees	0.58	-	-	-	-	91.28	23.73	115.01	57.51
Castanopsis indica(Roxb. ex Lindl.) A.DC.	0.59	217.48	56.54	274.02	137.01	186.86	48.58	235.44	117.72
Castanopsis tribuloides (Sm.) A.DC.	0.59	96.61	25.12	121.73	60.87	496.77	129.16	625.94	312.97
Cinnamomum glaucescens(Nees) Hand.-Mazz.	0.49	84.00	21.84	105.84	52.92	50.69	13.18	63.87	31.93
Citrus hystrix DC.	0.69	3.44	0.89	4.33	2.17	-	-	-	-
Dodecadenia grandiflora Nees	0.62	60.96	15.85	76.82	38.41	58.18	15.13	73.31	36.65
Engelhardia spicata (Lindl. ex Wall.) Koord. and Valeton.	0.47	-	-	-	-	155.50	40.43	195.93	97.97
Eurya acuminata DC.	0.56	41.82	10.87	52.69	26.34	61.41	15.97	77.38	38.69
Exbucklandia populnea (R.Br. ex Griff.) R.W.Br.	0.67	52.67	13.69	66.36	33.18	221.03	57.47	278.50	139.25
Illicium griffithii Hook. f. and Thomson	0.57	43.05	11.19	54.24	27.12	111.90	29.09	141.00	70.50
Juglans regia L.	0.52	94.45	24.56	119.01	59.51	-	-	-	-
Lindera megaphylla Hemsl.	0.51	17.36	4.51	21.87	10.93	26.74	6.95	33.69	16.85
Listea sp.	0.49	27.38	7.12	34.50	17.25	45.62	11.86	57.49	28.74
Maesa indica (Roxb.) A. DC.	0.67	55.95	14.55	70.49	35.25	-	-	-	-
Magnolia champaca (L.) Baill. ex Pierre	0.53	356.94	92.81	449.75	224.87	268.39	69.78	338.18	169.09
Magnolia globosa Hook.f. and Thomson	0.50	66.15	17.20	83.34	41.67	166.75	43.35	210.10	105.05
Magnolia hodgsonii (Hook.f. and Thomson) H.Keng	0.50	95.06	24.71	119.77	59.89	42.28	10.99	53.27	26.64
Myrica esculenta Buch.-Ham. ex D. Don	0.61	38.15	9.92	48.07	24.04	151.45	39.38	190.82	95.41
Persea odoratissima (Nees) Kosterm.	0.59	29.40	7.64	37.04	18.52	119.92	31.18	151.10	75.55
Persea sp.	0.52	8.01	2.08	10.09	5.04	15.35	3.99	19.34	9.67
Phoebe lanceolata(Nees) Nees	0.68	194.43	50.55	244.99	122.49	225.55	58.64	284.20	142.10
Quercus lamellosa Sm.	0.71	233.10	60.60	293.70	146.85	276.00	71.76	347.76	173.88
Quercus semiserrata Roxb.	0.71	-	-	-	-	372.16	96.76	468.93	234.46
Salix tetrasperma Roxb.	0.38	32.59	8.47	41.07	20.53	23.17	6.03	29.20	14.60
Saurauria nepaalensis DC.	0.43	21.85	5.68	27.53	13.76	69.80	18.15	87.95	43.98
Schima wallichii Choisy	0.64	113.27	29.45	142.72	71.36	-	-	-	-
Toona sp.	0.42	-	-	-	-	77.08	20.04	97.12	48.56
Total		2068.32	537.76	2606.08	1303.04	3669.72	954.13	4623.84	2311.92

*AGB = Above ground biomass, BGB = Below ground biomass, TB = Total biomass, TCS = Total Carbon stock

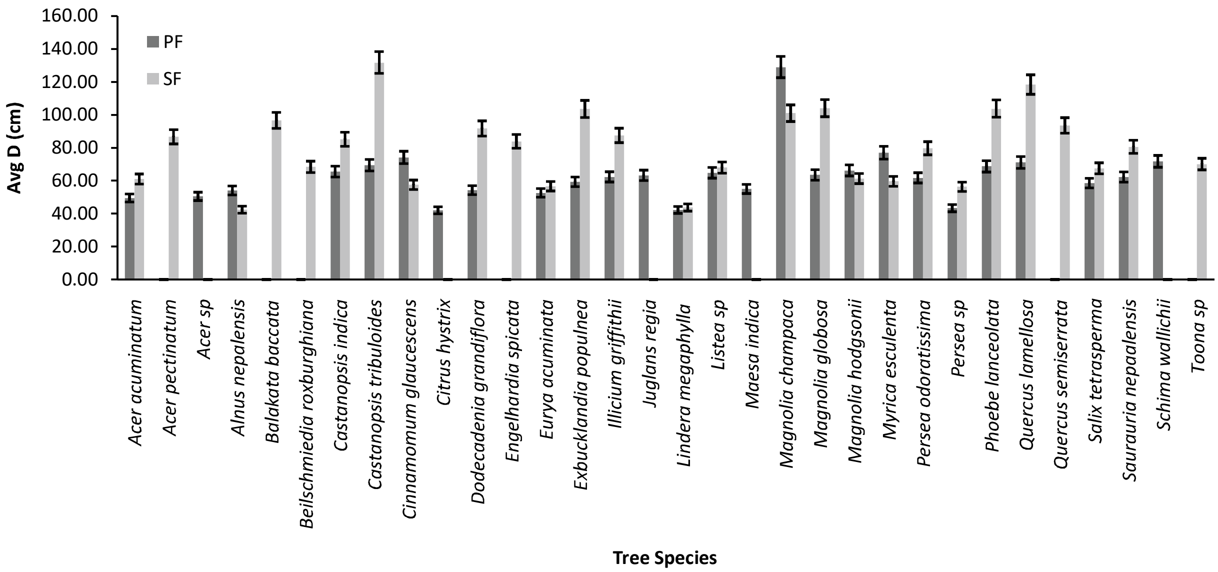

Fig. 1. Average diameter at girth (cm) of different tree species in PF and SF

wood density of these tree species. Wood specific gravity is an important prediction of AGB (Baker et al 2004). Total TCS of PF and SF were 1303.04 and 2311.92 Mg C ha^{-1}(Table 3) respectively which were comparatively more than that of Garhwal Himalaya, India (Sharma et al 2010); temperate forests of China (Zhu et al 2010); (Zhang and Wang 2010) and temperate forests of Kashmir Himalaya of India (Dar and Sundarapandian, 2015) which could be due to high density of many tree species with higher girth size and higher wood density. Tree species composition is an important criterion for carbon storage in regions of the same climate range (Chen et al 2011).

CONCLUSION

The higher biomass and higher C stocks with good species richness, higher density and basal area in Secondary Forest than Primary Forest. This could be attributed to management history, climate as well as biotic and abiotic factors of the area. Disturbance (forest clearing for *Jhum*) in SF could have attributed more opportunities for other species to thrived in the study area along with the creation of ecological niches and microhabitats, hence leading to more species diversity. Nevertheless, forest clearing during *Jhum* may not be considered as deforestation but forest modification allowing forest regrowth during sufficient long fellow that the involvement of the local communities along with their indigenous knowledge can lead to the development of effective and robust strategies in a very cost-effective, participatory and sustainable way to conserve biodiversity, to increase long term C sequestration in plants and to mitigate climate change.

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Floristic Diversity in Dahra Region Northwest of Chlef (Western Algeria)

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Abstract: The study was undertaken in the Dahra region northwest of Chlef West Algeria in 2019 to invent natural vegetation and characterized it in syntaxomic, biological, morphological and chorological terms .by Zuricho Montpelierine method .The method include all the plant species encountered and make the list of species on a square of 100 m^2 (minimum area). The floristic inventory indicated more than 138 taxa, divided into 54 families belongs to the Mediterranean biogeographic type with a percentage of 38.7%. There is a therophytization marked by a general invasion of annual species (39%).

Keywords: Diversity, Vegetation, Dahra, Chlef West Algeria

Mediterranean forests constitute a fragile natural environment that is deeply disturbed by multiple uses. The aggressions to which they have been subjected, however, varied considerably in frequency and intensity over the ages according to human demography, which has determined phases of progression or regression in their surface area. In Algeria, the forest is particularly important because it is an essential element of the ecological and socio-economic balance of rural regions in particular and of the country in general. The forest and pre-forest ecosystems of the study area are currently undergoing major changes. One of the main questions raised is to understand how and to what extent plant biodiversity contributes to the stability of the ecosystem and its functions. The efforts made to study the flora are very important in order to know the main biological traits of the plants and their biogeographical distribution (Hedidi et al 2019). The knowledge, classification, characterization and conservation of different taxa is a global scientific priority for biodiversity assessment and management (Belhacini 2015).

The study is based on the phytoecological, biological, morphological and biogeographical aspects of the plant cover with a vegetation inventory carried out in the station, based on stratified sampling.

MATERIAL AND METHODS

Geographical location: The study area is located in the extreme north-west, 70 km from the central headquarters of the wilaya Chlef, bordered to the west by the commune of Ouled Boughaleme (wilaya of Mostaganem), to the east by the commune of Taougrite , in the north by the Mediterranean Sea and the commune of Marsa and to the south the commune of Sidi M'hammed Ben Ali or Renou (Wilaya of Relizane). It is located on a large part of the Dahra mountains, contains natural properties that are the same characteristics of the high plains like Algiers and Oran (36, 2574 -0.8508). The wilaya of Chlef have a Mediterranean climate, relatively cold in winter and hot in summer where the dry period extends over 6 to 8 months. The coldest month is January and the driest July when temperatures exceed 45°C.

Methodological approach: Within the Dahra region, surveys were done in a subjective way, taking care to respect the criterion of structural, floristic and ecological homogeneity. For our case the floristic surveys were carried out in plots of 100 m², containing almost all the species present. The botanical determination of species is done directly in the field, when the recognition of a species is not possible in the field, a sample is kept in a herbarium and identification was done using several references (Quezel and Santa 1962 -1963, Dobignard, and Chatelain 2010-2013, Sterry 2006).

RESULTS AND DISCUSSION

Systematic composition: The Dahra forest, the flora represented by 138 plant species, grouped into 54 families and 115 genera. The distribution of families in the study area is heterogeneous, the best represented families on the generic and specific level are: Asteraceae (19 species),

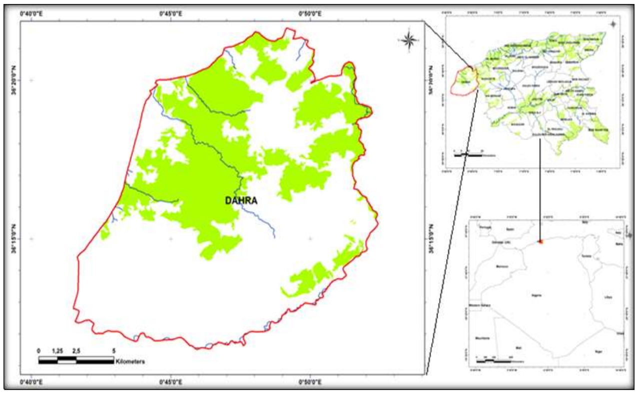

Fig. 1. Geographical location of the study area

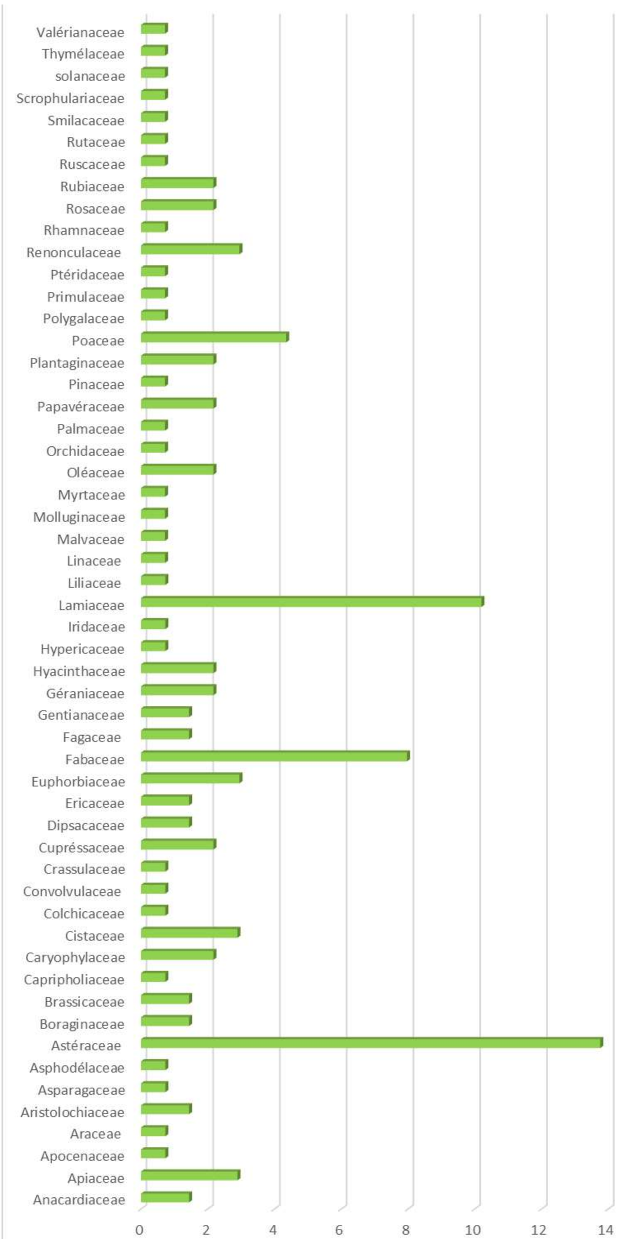

Fig. 2. Family composition in the study area

Lamiaceae (14 species), Fabaceae (11 species) and Poaceae (06).

Biological characteristics: The biological distribution established shows a predominance of therophytes (39%), which is strictly linked to seasonal rainfall. These ephemerals seem to be influenced by the northern or southern exposure and by the more intense grazing. The latter determines a more modest increase in the southern slopes than in the northern slopes (Belhacini et al 2017). In the case of Chamaephytes 20%, this distribution is in line with Ghalem and Hassani (2020), Chamaephytes to be better adapted to low temperatures and aridity ,their proportion increases as soon as there is degradation of forest environments because this biological type seems to be better adapted than phanerophytes to summer drought . The hemicryptophytes is 18%. Ghezlaoui and Benabadji (2017) observed that the abundance of hemicrytophytes in the Maghreb countries is to the abundance of organic matter and soil moisture. Geophytes (12%), are certainly less diversified in degraded environments due to monospecific tendency (overgrazing,

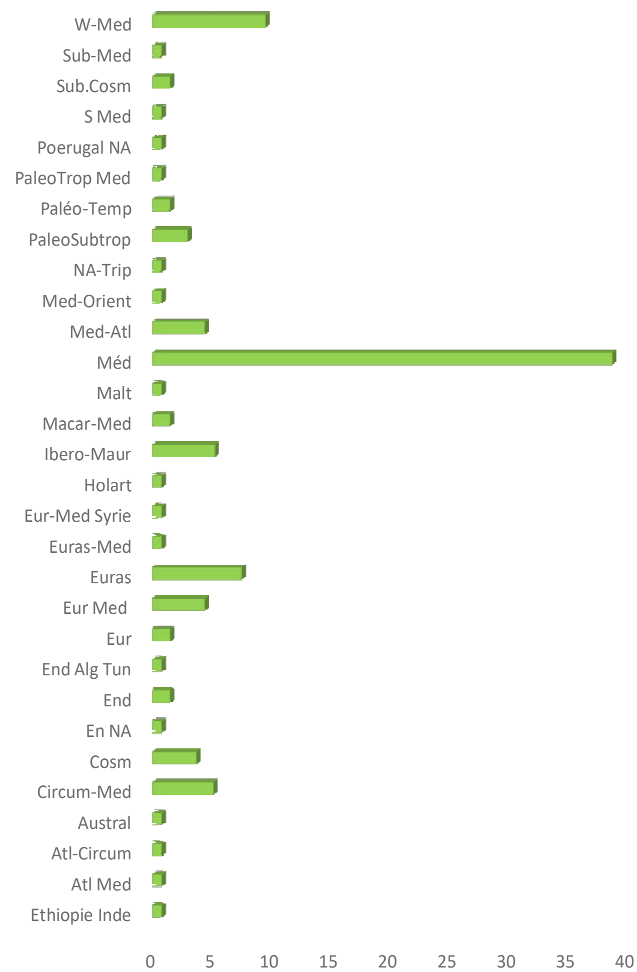

Fig. 3. Biogeography types in the study area

repeated fires). The phanerophytes with 11% of this biological type are represented essentially by *Quercus ilex, Q. coccifera, Arbutus unedo,* which reflect the changes in the state of the environment under the action of ecological and especially anthropozoic factors. The vegetation of the study area follows the following pattern: TH > CH > HE > GE > PH.

Morphological characterizations: From a morphological point of view, the plant formations in the study area are marked by heterogeneity between woody and herbaceous species, and between perennials and annuals. In the study area, herbaceous plants, either annuals or perennials, largely dominate with 72%, and woody perennials coming in second place with 28%. This result is similar to that of most research carried out on Algerian flora and vegetation.

Biogeographical characteristics: Among the species present in the Dahra region, several have a Mediterranean range with a percentage of 38.7%. This result is in agreement with the whole flora of Algeria by other researchers (Chenchouni 2012, Belhacini and Bouazza 2015) .

The West-Mediterranean is with 13 species (9.5%) and the Eurasian with 10 species (7.44%) followed by the Ibero-Maur and Circum-Mediterranean elements (07) European-Mediterranean and Med-Atl (06), Cosm (05), PaleoSubtrop (04) , Endemic EurMacar-MedPalaeo-TempSub and Cosm (02) and rest represents a low participation with only one species .

CONCLUSION

The forest of Dahra, part of the extreme west in Chlef, was chosen as a model for a contribution to the study of plant diversity and constitutes a natural environment disturbed by multiple uses which has determined phases of regression of their surface. The flora of the study area comprises 54 families, 115 genera and 138 plant species. The vegetation dynamics in the study area is considered rather favourable to therophytes and champhytes, where the Dahra region is marked by a high percentage of therophytes (39%), which are the most dominant. There is heterogeneity between woody and herbaceous species and between perennials and annuals.

The distribution of species shows a dominance of Mediterranean type species in the study area with a percentage of 38.7%, followed by the western Mediterranean type with a percentage of 9.5% and the Eurasian element in third place with 7.44%. The impact of man on the environment is becoming more and more intense, and this has led to the disruption, sometimes irreversible, of ecological balances. The causes are obvious: overgrazing, cultivation, urbanization and eradication of woody plants, so the use or even overexploitation has largely contributed to the degradation of the vegetation cover in the study area. The emergency measures aimed at protecting and conserving this heritage will enable the irreversible degradation of these formations and thus ensure their sustainability.

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Remote Sensing and Geographic Information System Applications for Precision Farming and Natural Resource Management

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Abstract: In all types of agriculture practises, RS and GIS are frequently utilised to explain events, anticipate consequences, and plan tactics. The user can examine, evaluate, and comprehend multiple geographically referenced data using such a system. When the two are combined, the user has vast geographic knowledge about any region. Modern geospatial tools such as Remote Sensing (RS), Geographic Information System (GIS), and Global Positioning System (GPS) have provided extremely powerful methods for surveying, identifying, classifying, mapping, monitoring, characterization, and tracking changes in the composition, extent, and distribution of a variety of earth resources, both renewable and non-renewable, living and nonliving in nature. The potential of advanced satellite systems for sustainable agriculture development is investigated, as well as the fusion of GIS and remote sensing knowledge for precision farming, natural resource management, and land management. The capability of RS and GIS for monitoring and managing natural resources at multi-temporal, multi-spectral, and multi-spatial resolution was examined. Remote sensing is quite useful for assessing rates and trends, but GIS is particularly useful for evaluating the causes and implications. However, combining such spatial technologies with other analytical methodologies is frequently useful in order to generate better knowledge about potential implications and improve our understanding of natural resource management. Natural resource managers can better comprehend and interact with remote sensing scientists to create and implement remote sensing science to achieve productive monitoring by utilising such advanced technologies.

Keywords: Remote sensing, Geographic Information System, Global Positioning system, Multi-spatial resolution, Natural Resource Management (NRM)

The world's population continues to rise, with a projected population of 10.0 billion by 2050. In this sense, cost-effective food production is a critical goal, and remote sensing and geographic information systems, which are used to evaluate and visualise agricultural surroundings, have shown to be extremely valuable to the farming community as well as industry. It plays an important role in agriculture around the world, assisting farmers in boosting production, lowering costs, and better managing their property. Geographic information systems (GIS) have been widely used and regarded as a useful and strong tool for detecting changes in land cover and land use (Marshet et al 2019).The remote sensing technique collects geographical data scientifically for large areas at a low cost, and as a result, it has become the standard method for collecting natural and agricultural data surveys in recent decades. The ambiguity of spatial data of agricultural parameters, which is required for crop modelling, is resolved to some extent by remote sensing (Kumari 2020). To estimate agricultural yield locally and internationally, a variety of RS and GIS methodologies were integrated. Using RS and GIS data, studies were conducted to estimate canopy density, biomass, canopy characteristics, and soil parameters, which were then combined with several crop models. Using Geographic Information Systems (GIS) and Remote Sensing (RS) techniques, it is possible to store and interpret complex geo-referenced and themed layers acquired from numerous sources on a computer. This will deliver precise information to decision makers in a short amount of time and at a cheaper cost (Kumari 2020). These methods reduce the use of water, pesticides, and herbicides, maintain soil fertility, and aid in the efficient use of manpower, so increasing productivity and improving quality (Talaviya et al 2020). New technologies that are not only cost-effective but also in line with the country's natural climatic regime; technologies relevant to rain-fed areas specifically; continued genetic improvements for better seeds and yields; data improvements for better research, better results, and sustainable planning; bridging the gap between knowledge and practise; and judicious land use resource surveys, efficient management, and judicious land use resource surveys, efficient management, and judicious land use resource surveys, efficient management, and judicious land use resource.

Sustainable agricultural production is dependent on the wise use of natural resources (soil, water, livestock, plant genetics, fisheries, forest, climate, rainfall, and topography) in accordance with current socioeconomic infrastructure. Technology has a critical role in developing countries' rapid economic growth and social transformation.

GIS and Remote Sensing Application in Various Sector

Horticulture crops assessment: India is the world's second-largest fruit and vegetable grower. Inventory of fruits, vegetables, plantation crops, crop health, disease mapping, yield modelling and year-to-year changes, site suitability, and post-harvest research are all done with Indian satellite sensors such as AWiFS, LISS-III, and IV. Although remote sensing data has been used to measure yield and production for crops such as potato, mango, citrus, and banana, accuracy is still a challenge for other crops due to scattered and tiny fields, mixed cropping, many seasons, and short duration. The utilisation of satellite data and GIS tools, on the other hand, has shown considerable potential for horticulture development, particularly in terms of infrastructure and horticultural extension. The investigations are mostly based on high resolution or hyper spectral remote sensors and time series analysis for crop inventory and production projections.

Table 1. Evolution and advancement in remote sensing sensors

Phases	Time series	Remarks
Airborne remote sensing	During the First and Second World Wars	The use of photographs for surveying, mapping, reconnaissance and military surveillance
Rudimentary spaceborne satellite remote sensing	In the late 1950s	The launch of Sputnik 1 by Russia in 1957 and Explorer 1 by US in 1958
Spy satellite remote sensing	During the Cold War (1947–1991)	Remote sensing for military use spilled over into mapping and environment applications
Meteorological satellite sensor remote sensing	1960˜	The launch of the first meteorological satellite (TIROS-1) by the US in 1960. Since then, data in digital formats and the use of computer hardware and software
Landsat	1972˜	Landsat 1, 2, and 3 carrying a multispectral scanner; Landsat 4 and 5 carried a Thematic Mapper sensor; Landsat 7 carries an Enhanced Thematic Mapper; Landsat 8 carries the Operational Land Imager. Landsat satellites have high resolution and global coverage. Applications were initially local and have become global since then
European Space Agency's first Earth observing satellite program	1991˜	The European Space Agency launched the first satellite ERS-1 in 1991, which carried a variety of earth observation instruments: a radar altimeter, ATSR-1, SAR, wind scatter meter, and microwave radiometer. A successor, ERS-2, was launched in 1995
Earth observing system (EOS)	Since the launch of the Terra satellite in 1999	Terra/Aqua satellites carrying sensors, such as MODIS and taking measurements of pollution in the troposphere (MOPITT). Global coverage, frequent repeat coverage, a high level of processing, easy and mostly free access to data
New millennium	Around the same time as EOS	Next generation of satellites and sensors, such as Earth Observing-1, acquiring the first spaceborne hyperspectral data
Private industry/commercial satellite systems	2000˜	1. Very high-resolution data, such as IKONOS and Quick bird satellites 2. A revolutionary means of data acquisition: daily coverage of any spot on earth at a high resolution, such as Rapid eye 3. Google streaming technology allows rapid data access to very high-resolution images 4. The launch of GeoEye-1 in 2008 for very high-resolution imagery (0.41 m)
Microsatellite era and satellite constellations	2008˜	1. Small satellites and satellite constellation (Rapid Eye and Terra Bella, formerly Skybox): Rapid Eye was launched in August, 2008, with five EOS. These are the first commercial satellites to include the Red-Edge band, which is sensitive to changes in chlorophyll content. On March 8, 2016, Skybox imaging was renamed to Terra Bella. Satellites provided the ability to capture the first-ever commercial high-resolution video of Earth from a satellite and the ability to capture high-resolution colour and near-infrared imagery 2. For the first time, Russia carried out a single mission to launch 37 satellites in June of 2014 3. ESA launched the first satellite of the Sentinel constellation in April of 2014. 4. SpaceX reusable rocket capacity since December of 2015 5. Current satellites in high revisiting period, large coverage, and high spatial resolution, up to 31 cm

Hyper spectral sensors, in particular, allow us to detect the energy reflected from the sun in multiple channels (typically more than 200). It is possible to generate the spectral signature of the targets of interest with great precision and then characterise them radio metrically in this way. It is critical to use the Indian Remote Sensing Satellite (IRS)-ID Linear Imaging Self-Scanning (LISS)-III sensor to estimate the productivity of fruit and vegetable crops cultivated. The optimal method is to use a Supervised Maximum Likelihood Classifier (MLC) plus a visual interpretation of the texture from a PAN (panchromatic) sensor.

For hyper spectral, a portable hyper spectral camera was demonstrated, as well as an object-oriented software framework with models that identified crop, soil, and weed; the study case was sugar beet and green citrus (Talaviya et al 2020). Site-specific crop management (SSCM) is a type of precision agriculture that is commonly used in row crops, although it is rarely used in fruit and nut production. High-resolution satellites, hyper spectral imaging, LIDARS, UAVs, and other technologies; as well as GIS spatial modelling for fruit orchards (Talaviya et al 2020). However, sensors and platforms with higher resolutions, free-access collection imagery (i.e. Sentinel-ESA and Landsat-NASA), aircraft-mounted sensors, UAVs, the power of computational processing, fusion data, the mayor accesses to digital big data, and historical yield information all point to a bright future for GRS in horticulture.Due to the distributed and small field sizes, as well as the comparably short period of vegetable crops and mixed cropping in India, satellite RS technology for horticulture crops has some obstacles. Improved observations from hyperspectral, thermal infrared sensors, and advanced radars or LIDARs on-board forthcoming satellites have a significant potential for application in this industry. Estimating yields, particularly for orchard crops, was difficult.

Crop inventory: Crop discrimination is based on the differential spectral response of distinct crops in a multi-dimensional feature space generated by different spectral bands, time domain, or both, and is influenced by sensor features and pattern recognition techniques. Visual or digital interpretation approaches are used to do crop discrimination/mapping utilising space data. Standard FCC (False Color Composite) created using green, red, and near-IR wavelengths assigned blue, green, and red colours is used in most visual approaches. Over a research site in Imperial Valley, California, it was established that a colour composite formed by the best three bands (TM bands 3, 4 & 5) provided superior discrimination than normal FCC. Digital approaches are recommended for crop discrimination because they apply to each pixel and employ the entire dynamic range of data. When single-date data does not allow for effective crop differentiation, a multi-temporal technique is applied (Kumari 2020). The approach in this case consists of three stages: (a) pre-processing, (b) data compression, and (c) image categorization. Multispectral and multi-temporal data, as well as supervised and unsupervised classification approaches, are employed for crop identification and classification. In supervised classification, training sets are given to categorise pixels of a specific class, and then the image's Information classes (i.e., crop type) are identified. "Training signatures" are what they're called. Unsupervised classification, on the other hand, is a technique that analyses a large number of unknown pixels and separates them into groups based on spectral groupings found in the image data. Analyst-specified training data is not required for unsupervised classification. The so-called "regression estimator," which has been recommended, is one of the practical approaches of using remote sensing in agricultural statistics. The procedure entails pre-processing satellite data to remove radiometric and geometric inaccuracies, as well as classification of the data using supervised methods that include classifier training using sample segments. The area frame sampling and image processing results are statistically connected and used to create an enhanced area estimate per crop in each stratum in this method (Singh 2017).

Assessment of crop condition: The condition of cereal crop seedlings, as well as the status and trend of their growth, can be determined via remote sensing. It also aids in the gathering of crop production data. When large-scale commissariat shortages or surpluses occur, obtaining crop condition information early in the crop growth cycle is even more crucial than obtaining actual production after harvest. Obtaining crop condition as soon as feasible has a significant impact on decisions regarding commissariat price, circulation, and storage. In western industrialised countries, particularly the United States, remote sensing technology is being used to monitor crop conditions. The "Large Area Crop Inventory Experiment (LACIE)" programme was carried out by the United States Department of Agriculture (USDA), the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the United States Department of Commerce (USDC) from 1974 to 1977. Wheat is the principal monitoring crop in the programme, with the United States, Former Russia, and Canada as the monitoring areas. The "redirected from Agriculture and Resources Inventory Surveys through Aerospace (AgRISTARS)" initiative, which ran from 1980 to 1986, brought these departments back together. In 1986, a global scale operational crop monitoring system was built as a result of that effort. The system not only assessed crop conditions and predicted production for a variety of crops (including wheat, rice, maize, soybean, and cotton) in the United States, but it also kept track of the world's major food producers, including Former Russia, Canada, Mexico, Argentina, Brazil, China, India, and Australia. The system's operation generates significant economic benefits for the United States. Following that, under the "Monitoring Agriculture with Remote Sensing (MARS)" programme, the European Union's Joint Research Centre (JRC) developed its own crop production estimation method. The system's monitoring results were used in the European Union's common agricultural policy, such as agricultural subsidies and the verification of farmers' declarations. During that time, scientists in the field all over the world focused on crop monitoring methods using NOAA/AVHRR, and significant progress was made.

High-resolution meteorological satellites can collect data on terrestrial processes on a daily basis, allowing for continuous and dynamic crop monitoring. The NDVI profile of crops is created by collating NDVI values along time lines and can indicate the shift in crop NDVI from planting, seedling, tassel, maturation, and harvesting. Varied crops have different NDVI profiles, and even the same crop growing in different conditions has different NDVI profiles. By evaluating the characteristics of the crop's time series NDVI profile, the crop's status and growth trends can be determined. Crop Growing Models allow for the dynamic monitoring of the crop growing process by simulating the crop growing process. The basic concept of a crop growing model is to use a mathematical formula to represent the crop growing process. The interception of solar energy for vegetation canopy and photosynthesis, which produces dry biomass, is the driving force behind all crop growing models. SUCROS (Simple and Universal Crop Growth Simulator), (Modules of all Annual Crop Simulator), CERES (Crop Environment Resource Synthesis), and P-1/2/3 are some of the most prominent crop growing models. Some of these models concentrate on the commonality of all crops, while others concentrate on the specialisation of various crops. Researchers in the field have been working hard in recent years to build new models such as ORYZA, SERES-RICE, and SIMRIW, among others. Crop-growing models can correctly portray the crop-growing process and monitor crop health. The advancement of remote sensing technology, as well as the usage of remote sensing data, has enabled the application of crop-growing models on a broad scale. However, the use of these models necessitates a large number of agro-parameters, and the model must be calibrated using local field data before being used in multiple locations. The lack of local agro-parameters and observable field data, as well as its complexity, limit the use of these models to some extent.

Identification of weeds and its management: Weeds are undesired plants that compete for water, nutrients, light, space, and carbon dioxide, reducing crop yields. Weeds must be controlled to satisfy future food supply demands. Drones, artificial intelligence, and numerous sensors, such as hyper spectral, multi-spectral, and RGB (red-green-blue), all work together to assure a superior outcome in weed management. It is a multidisciplinary science that encompasses spectroscopy, optics, computer science, photography, satellite launch, electronics, communication, and a variety of other disciplines. Future concerns like as food security, sustainability, supply and demand, climate change, and herbicide resistance may be addressed through machine learning-based technology. The integrated weed management (IWM) method, which combines numerous treatments, is a step toward addressing difficulties associated with traditional tactics, such as herbicide resistance (MacLaren et al 2020, Hu et al 2020). In early-season agronomic settings, where crop and weed seedlings have identical spectral signatures, UAV photography aids in better categorising findings (Castro et al 2018). By detecting weeds early in the season as a first and critical stage, precision farming systems can efficiently control weed problems while minimising operating expenses and environmental damage (Chlingaryan et al 2018, Torres et al 2015). Chlingaryanet al (2018) identified multi-spectral remote sensing as a technique for analysing multi-temporal crop diseases employing three high resolutions of remote sensing pictures to undertake a spatio-temporal analysis of the impaction dynamic. The applicability of multi-spectral remote sensing data for disease identification in late occurrences and at high infection rates was demonstrated in this work, showing the suitability of these methods for disease detection in late occurrences and at high infection rates. Establishment of airborne multispectral techniques for analysing tree health problems in a citrus orchard, which can be combined with variable rate technology (VRT) for mandatory pesticide application and environmental modelling for pollutant reduction assessment (Mink et al 2020). Multi-spectral photography was used to detect anomalies, and a spectral linear unmixing-based approach with site-specific agriculture was used to evaluate stress severity and detect past infection, according to the study. The data obtained through airborne multispectral imaging evaluation is more detailed and complete than data obtained visually in field experiments (Mink et al 2020). Image segmentation between crop and weed in a soybean field for weed detection using hyperspectral remote sensing revealed a high degree of accuracy (99.9%) for soil and plant differentiation (Mink et al 2020). This research used a hyperspectral camera with a spectral wavelength range of 360 to 1010 nm and a spectral resolution of 10 nm (ImSpector V10: Specim Ltd., Oulu, Finland). Hyperspectral imaging with wavelet analysis was used to classify plants for weed identification. The authors investigated three alternative plant classification approaches, including Euclidean distance, discriminant analysis, and wavelet coefficient, using hyper spectral pictures with 240 wavebands for spectral information. The wavelet coefficient is more useful for weed detection, and the validation result suggests that the created classification technique will be useful in the future (Li et al, 2021).

The ability of HSI to detect unique spectral signatures of a wide range of weed species, including grasses, broadleaves, annuals, and perennials. In comparison to averaged spectrum data, models constructed with Sp spectral data can deliver superior outcomes for weed classification. When generated with Sp data, MLP is a more robust and reliable method than standard classification systems. The application of HSI in plant identification will be greatly enhanced by this unique approach based on Sp. This is particularly useful in the grazing field, where it is used in mixed swards of a few plant species (Li et al, 2021).

Crop water stress monitoring: The phenological stage of a crop is often referred to when monitoring it. The plant's "internal clock" is defined by a sequence of events that allows us to follow its evolution from emergence to senescence, through various levels of "greenness" that characterise the condition of vegetation and the accumulation of biomass in distinct organs. These stages vary greatly in space, depending on the practise management and climatic interactions. The use of radiometric indices such as the normalised vegetation index (NDVI), the normalised difference water index (NDWI), the global vegetation index (GVI), or the enhanced vegetation index EVI has piqued the interest of many researchers. The NDVI has a number of benefits: it is a stable and trustworthy indicator, and the spectral bands used to calculate it are available on all optical satellites. As a result, it is frequently utilised in science, and its straightforward formulation makes it accessible to non-expert remote sensing users. NDVI maps created from observations made by the FORMOSAT-2 satellite every three days over a small 4 km x 4 km agricultural sector north of Mexico in the Yaqui Valley (27.263°N, 109.892°W). Because of the excellent spatial resolution of the photos, each field can be identified on these maps (8 m). Winter wheat is the most common. Its growth is restricted to the initial stages in November and December (the blue colour represents low NDVI values). The growth of the leaves begins in January–February, increasing the percentage of green colour recorded by the satellite in each pixel of the photos, with the growth peak represented in red (the highest NDVI values) (Seifried 2017).

During the Rabi season, the most common crops grown in the study region are wheat and sugarcane. This study used Landsat data from the 2009-10 and 2013-14 Rabi seasons. Crop discrimination was done using a rule-based classification technique because the study was limited to wheat. Wheat was properly identified from other classes using a rule-based classifier, with individual accuracy of 85 percent and total accuracy of 90 percent (Seifried 2017). Ws LSWI, Ws VWSI, and Ws WSI are three satellite-based water stress indices that were developed separately from optical and thermal datasets. Using multitemporal landsat data, the SEBS model was also utilised to calculate daily ET. Water stress predictions for 2009-10 were compared to ET based on flux towers. The LUE model was used to examine the impact of water stress on productivity. Productivity was calculated using the water scalar, temperature scalar, and maximum light use efficiency. In the LUE model, the two most essential inputs were APAR and LUE. The LUE model was used to analyse the influence of water stress on wheat productivity using the water scalars Ws LSWI and Ws VWSI. Final productivity was validated with yield estimated by crop cutting experiment (CCE) for 2013-14 and crop statistics (BES) for 2009-10. Estimated FAPAR was developed using ground readings taken during field visits and showing a logarithmic relation between FAPAR and NDVI, which was validated and used for productivity calculation (2013-14).The influence of water stress on wheat productivity using two different water scalars, namely Ws LSWI and Ws VWSI. Ws LSWI indices demonstrated to be more accurate in assessing water stress and demonstrating its impact on productivity. Non-imaging chlorophyll fluorescence research has produced some promising results, but it can only provide point data measurements with restricted information on a tiny leaf region sensed rather than the entire leaf or canopy area, which is what advanced chlorophyll imaging wants to solve. The multi-pixel feature of larger-scale fluorescence sensing with imaging provides additional fluorescence fingerprints, allowing for full screening of all points of leaf. This benefit accounts for minor changes in fluorescence emission pattern due to a variety of plant internal variables that would be missed by non-imaging approaches, reducing measurement errors (Buschmann et al 2019).

Thermography, unlike fluorescence imaging, can show stomatal movement without the use of a light source (Vadivambal et al 2018). The thermal signal under investigation is a change in temperature collected in the form of reflected or emitted radiation from the scanned plant. Thermal intensity is determined by the ambient temperature, with infrared radiation intensifying as the temperature rises. The opening and closing of stomata for gas exchange or cooling are common responses to changes in leaf temperature. The cooling process stimulates stomatal opening, which results in a lower temperature and heat loss to the atmosphere. However, nutritional availability in the soil and water flow within the plant determine transpiration and, eventually, stomatal control. Water or nutrient shortage affects the movement of dissolved nutrients and water from the soil to the roots, and then to the entire plant, where nutrient uptake is hindered by greater nutrient concentrations in the soil (Li et al 2017). As a result, the stomata close in order to prevent further moisture loss, and the temperature of the leaf surface rises. This explains why some studies conclude that nutrient deficiency has an impact on stomatal regulation and can lead to an increase in plant temperature. On thermal imaging, a magnesium-deficient bean plant displayed a greater leaf temperature under controlled conditions (Chaerle et al 2017). Under fertilized barley (Hordeum vulgare L.) had a higher temperature than well-fertilized barley (Hordeum vulgare L.) with nitrogen as the reference nutrient (Tilling et al 2016).

Precision farming (PF): Precision agriculture (PA) is an integrated information and agricultural management system that uses a variety of technology instruments such as GPS, GIS, and remote sensing. Precision farming (PF) is intended to boost overall agricultural production efficiency while minimising the negative effects of chemical use on the environment. Precision farming aims to collect and evaluate data about the variability of soil and crop conditions in order to maximise crop input efficiency in tiny areas of the farm field. To achieve this efficiency aim, the field's variability must be controlled. A growing number of scientists, engineers, and large-scale crop growers are using remote sensing technology as part of precision farming (Liaghat et al 2018). In the mid-to-late 1980s, PA research began in the United States, Canada, Australia, and Western Europe. Despite a significant amount of study, only a small percentage of farmers have used any sort of PA technology. PA has primarily been implemented by modifying current field gear with controllers and GPS to enable spatially varied uses. The most common application of PA is still fertiliser application on a site-by-site basis. Most PA trials focused on VRT fertiliser and herbicide applications, several types of PA technologies have been tested around the world (Naiqian et al 2015). A base map or base data layer must be referenced in every GIS database. The database should ideally be linked to a large-scale, highly accurate base map. When attempting to explore the true spatial relationships between features digitised from a small scale map and features whose coordinates were taken with GPS, there may be issues if the base map is smaller scale (quad scale or smaller).This can be a significant issue if a grower decides to use a GIS data layer that was created using small scale base maps as a reference point for any new data generated. Developing an accurate base data layer based on geodetic control and photogrammetric mapping is the best strategy to avoid such mismatch (Hendrickson et al 2020). Another facet of GIS support for precision agriculture is the engineering component, which involves translating research findings into operational systems that can be used on farms. GIS can help with this engineering effort by offering a good platform for storing base data, simple modelling, presenting results, developing a user interface, and controlling farm navigation when used in conjunction with GPS. A decision support system for operationalizing precision farming at the farm level can be constructed using GIS. Crop yield monitors are devices that measure crop yields and are fitted on harvesting machinery. The yield data from the monitor, as well as positional data from the GPS device, are captured and saved at regular intervals of time or distance. They also keep track of distance and bushels every load, as well as the number of loads and fields. Yield maps can be created with the use of GIS software. In recent years, several technologies for quantitatively assessing spatial correlations within and between layers of environmental data have been developed. These tools can be used to determine whether a given variable has a spatial pattern or structure, or if it can be related to other (s), and so explain and/or predict a crop's productive and quality behaviour. Without a doubt, simply visualising data has significant ramifications for our ability to comprehend or visualise possible relationships between, say, environmental variables and yield. However, we can't tell if the connections are meaningful or if they're veiled by other types of inaccuracy or stochasticity. As a result, statistical analysis plays a critical role here, allowing us to quantify and numerically characterise the spatial relationships that exist in the field.

Precision farming necessitates knowledge of the average features of tiny, homogeneous management zones. Soil tests for nutrient availability, yield monitors for crop yield, soil samples for organic matter content, information in soil maps, or ground conductivity metres for soil moisture can all provide these average properties. In most cases, the fields are manually sampled along a regular grid, and the sample results are interpolated using geostatistical techniques. Soil, water, and crop variability geostatistical modelling necessitates the collection of a large number of samples at close intervals over the agricultural area. These kinds of samplings are both expensive and time-consuming. The benefits of using remote sensing technologies to acquire geographically and temporally varied information for precision farming have been demonstrated by a number of researchers. Satellite-based sensors or CIR video digital cameras on board small aircraft can be used to collect remote sensing imagery for PF. Aerial, satellite, and spacecraft observations of the surfaces and atmospheres of the planets in our solar system are included in the science of remote sensing, with the Earth being the most frequently studied. RS is mainly limited to methods for detecting and measuring electromagnetic energy, such as visible and non-visible radiation that interacts with surfaces and the atmosphere. Planners observed RS and GIS technologies to be extremely useful in planning for the efficient use of natural resources at the national, state, and district levels. Due to considerable advancements made in space-borne RS satellites in terms of spatial, temporal, spectral, and radiometric resolutions, application of these technologies in the management of natural resources is quickly growing. Many researchers have debated the benefits of remote sensing technology. Remote sensing imagery can be used for mapping soil parameters, crop species classification, crop water stress detection, weed and crop disease monitoring, and crop yield mapping. The number and width of spectral bands captured by the sensor (multi versus hyperspectral); and spatial (high, medium, and low), temporal (hourly, daily, and weekly), and radiometric (8-, 12-, and 16-bit) resolutions at which sensors collect data are all factors that influence the use of remote sensing in PA.

Through the use of on-board GPS and the Inertial Measurement Unit (IMU) technology, pattern recognition technology, and digital elevation models, efforts have been made in recent years to automate the ortho-rectification process. Although considerable progress has been achieved in automating the ortho-rectification process, it has only been applied to photos captured by UAVs. Images from satellites or piloted planes have not had the same level of success. High overlap (approximately 80% frontal overlap and 60% side overlap) between images acquired by UAVs, as well as GPS on board UAVs that provides detailed metadata describing the camera in terms of position (latitude and longitude) and parameters, have aided the automation of ortho-rectification processes for UAVs images (sensor size, pixel resolution and focal length).

Crop yield and production forecasting: Models that integrate climate, soils, and other environmental variables as response functions to characterise development, photosynthesis, evapotranspiration, and yield for a specific crop are among the traditional techniques of predicting agricultural yields during the growing season. These models are poor predictors when geographical variability in soils, stressors, or management techniques are present (Jensen et al 2016), despite the fact solid physiological and physical ideas. Because of its synoptic coverage and capacity to 'see' in various spectral wavelengths, remote sensing of crop canopies has been suggested as a potentially beneficial tool for agricultural monitoring (Moran et al 2017). Plant development, stress, and yield capacity are all expressed in the spectrum reflectance from crop canopies, which may be evaluated using spectral vegetation indices (Javid et al 2020, Rehman et al 2018). The Normalized Difference Vegetation Index (NDVI) is a vegetation indices (VI) that is a sum, difference, or ratio of two or more spectral wavelengths. They have a strong relationship with photosynthetic activity in non-wilted plant foliage and are excellent predictors of canopy biomass, vigour, and stress. One of the most extensively used indices is vegetation monitoring using the red and near-infrared SPOT VGT channels. Green biomass and the leaf area index are closely correlated with the Normalized Difference Vegetation Index (NDVI). Despite the spatial resolution of 1 km at nadir, several scientific articles have shown the use of SPOT VGT data in monitoring vegetation conditions in near real-time. Crop output is estimated by taking into account crop area estimates and crop yield estimations, which are generally subjective, expensive, and prone to huge errors, resulting in poor crop assessment (Reynolds et al, 2020). Furthermore, the obtained data may become available too late for decision-makers or planners in the country to take necessary action. Remote sensing, on the other hand, can aid in the macroscopical, periodic, and cost-effective acquisition of surface information, and has numerous advantages in agricultural monitoring, with recent success (Narasimhan et al 2018, Dadhwal et al 2018, Bastiaanssen et al 2017, Prasad et al 2016). The Normalized Difference Vegetation Index (NDVI) is a critical indicator of vegetative growth conditions and the degree of vegetative cover in this study (Banair et al 2015). It's worth noting that if a region is covered by vegetation, the NDVI value of that area is positive, and it rises in tandem with the amount of vegetation (Zhao et al 2018). In the last two decades, a few studies have attempted to estimate rice yield using high-resolution remote sensing data (Quick bird; 0.65 m, Worldview; 0.31 m, and IKONOS; NIR 3.2 m, PAN 0.82 m) (Nuarsa et al, 2015), but their technique has run into issues with swath width and expensive prices (Seifried et al 2017). Similarly, due to the temporal resolution of Landsat data, it has been difficult to capture cloud-free images, making it impossible to obtain phenology information throughout the important crop time. MODIS constellations employed to retrieve agricultural crop information, owing to their bigger regional size, smaller dataset, and faster revisiting time (Whitcraft et al 2015). Furthermore, the dynamics of MODIS-derived NDVI products are reflective of crop growth and biomass changes that are directly related to agricultural yield, and they have a direct relationship with LAI, biomass, and plant cover. Several studies have suggested the use of MODIS-derived NDVI data for agricultural yield estimation prediction, crop production, and monitoring (Mahboob et al 2016, Faisal et al 2019).

Rice-SRS (simulation remote sensing) model (Jingfenget al, 2018) was created to approximate rice yield in China using remote sensing data as input. The model receives three types of normalised difference vegetation index (NDVI) inputs: (AVHRR LAC) NDVI, (AVHRR LAC) NDVI, and (AVHRR LAC) NDVI. (AVHRR GAC) NDVI superior extremely high resolution radiometer global area coverage and radiometric measurements NDVI advanced very high promise radiometer limited area coverage To achieve the goal, the leaf area index (LAI) is calculated separately for each input. With AVHRR GAC input, the proposed model produces good results with lower average error. In Haryana, India, Advanced Wide Field Sensor (AWiFS) photos were combined with Monteith's model to assess wheat yield (Patel et al 2016). To estimate wheat yield, a remotely sensed approximation of photo unnaturally active radiation (fAPAR) and every day temperature were used as inputs. The main disadvantage of this model is that as the heterogeneity of field crops increases, the model's accuracy declines. Rice yield is predicted using the Support Vector Regression (SVR) approach. There are three steps in the suggested model (Jaikla et al 2018). To begin, SVR is used to calculate the nitrogen weight of the soil. Second, SVR is used to compute the weight of the rice stem. Third, SVR is used to compute the weight of rice grains.The model's performance is measured in terms of mean absolute error (MAE) and mean absolute percentage error (MAPE), which are compared to their commercial model and reveal that the proposed model's MAPE is higher than the commercial model's but still within acceptable limits, i.e. 5%. To estimate the winter wheat yield in North China, the RS-P-YEC (Remote Sensing – Photosynthesis – Yield Estimation for Crop) model was created (Peijuan et al 2019). To collect the data, the model used remote sensing and meteorological data. The yield of the winter wheat crop was predicted using the harvest index and net primary productivity. The findings of model are compared to meteorological station observations, which provide an R2 of 0.817. At each crop growth stage, a relationship between leaf area index (LAI) and yield is formed (Ren et al 2019). The research area is in North China. To remove the influence of clouds and simulate daily crop LAI to obtain an average for each crop stage, the Savitzky-Golay filter (S-G filter) and Gaussian model are utilised. To predict wheat yield, a link between NDVI computed from remote sensing imagery and LAI is constructed. The biggest disadvantage is that the report does not discuss crop growth stage indicators. (Li et al 2018) discusses various crop growth monitoring indicators used to monitor wheat crop at various stages via remote sensing. Due to the presence of non-vegetation percentage and soil background, NDVI have limitations in vegetation monitoring. The importance of new vegetation indices such as the soil-adjusted vegetation index (SAVI), modified soil-adjusted vegetation index (MSAVI), enhanced vegetation index (EVI), and perpendicular vegetation index (PVI) in achieving accuracy in wheat crop yield prediction is discussed. SAVI with L=0.1 outperforms in heading stage even when crop cover is high, according to the correlation coefficient derived for all variables and LAI. Using Landsat 8 time series pictures, advanced machine learning techniques such as boosted regression tree, random forest regression, support vector regression, and Gaussian process were utilised to estimate silage maize yield (Aghighi et al 2018). To complete the work, the NDVI standards of all fodder maize fields were collected and merged into a two-dimensional dataset for each year. The results suggest that machine learning techniques outperform traditional regression methods because they have the ability to work with high-dimensional composite distribution data.

Water resource management: In the conservation and usage of the country's water resources, remote sensing and GIS play a critical role. Related initiatives and cutting-edge remote sensing techniques must be blended with traditional groundwater measurement and management approaches to provide optimal planning and operation of water resources that will last into the future. Soil moisture patterns in arid settings are a direct indicator of the presence of water. Soil moisture patterns indicate the presence of water in arid environments. Irrigation water distribution or locations with a shallow water table are reflected in moist top soils. Because in-situ sensors make it very hard to obtain soil moisture information at broad spatial scales, soil moisture is rarely included in models. Because it is nearly hard to obtain soil moisture information at wide spatial scales with in-situ sensors, soil moisture is rarely considered in management decisions. Satellites with passive microwave sensors, such as AMSR-E, SMOS, and Feng Yung, give free global scale estimations of daily surface soil moisture. These sensors provide constant estimates of soil moisture that are unaffected by weather conditions. That's also why a new evapotranspiration (ET) method based on soil moisture readings is being used. The brightness temperature collected by satellites is used to predict surface soil moisture using inversion techniques. Because the technique is not error-free, the satellite soil moisture had to be validated before it could be used to estimate other hydrological processes. Classic validation procedures are not technically possible due to the lack of in situ soil moisture measurements in large river basins. As a result, additional validation methods were required in order to increase trust in the use of satellite soil moisture products. To explain soil moisture behaviour, researchers looked at how vegetation reacts to soil moisture and how soil moisture reacts to rainfall. In the land use classes "bare soil," "rainfed," and "very sparse vegetation," there were strong connections between AMSR-E surface soil moisture and TRMM rainfall. In land use classes, AMSR-E surface soil moisture has a strong association with TRMM rainfall occurrences. Furthermore, rather than NDVI and TRMM cumulative rainfall (rs=0.70), there is a substantial link between TRMM accumulated rainfall and the AMSR-E mean soil moisture (Spearman's rank correlation coefficient rs=0.74). In contrast to NDVI and TRMM rainfall (rs=0.70), NDVI and Mean soil moisture have a good connection (rs=0.85) (Muhammad et al, 2017).Groundwater hydrology applications of Geographic information system (GIS) and remote sensing (RS) technology have gotten only a cursory examination. Water management requires a thorough understanding of geographical space and related spatial information such as water sources, watersheds, terrain surfaces, land use, land cover, rainfall, temperature, humidity, soil condition and composition, geology, atmospheric conditions, human activities, environmental data, and so on.The issues, importance, and long-term management of groundwater and freshwater are also described using geographic information system (GIS) and remote sensing (RS) technology (Rani et al, 2018). With careful consideration of source materials and database creation, the integration of geographic information systems and remote sensing techniques has permitted analyses of aquatic vegetation growth, salt marsh quality, and floodplain disturbances throughout time.

CONCLUSIONS

Remote sensing and geographic information systems (GIS) have shown to be useful tools for generating spatial information about natural resources. Soils have been greatly degraded as a result of the planned and indiscriminate exploitation of land. A reliable inventory of soils and other resources is needed, and it must be obtained quickly. Remote sensing data has shown to be an effective technique for mapping soil and other resources. The development of a new generation of high spatial resolution cameras with improved spectral coverage, revisit capabilities, and stereo viewing has opened up new possibilities in a variety of applications. GIS technology is causing rapid changes in natural resource spatial analysis and management. New methods for data gathering, storage, processing, analysis, and modelling are being developed using GIS in conjunction with remote sensing, GPS, and computer technology. Even at small farm holdings, remote sensing is quite effective in analysing various abiotic and biotic stresses in various crops, as well as in recognising and managing various crop concerns. It is necessary to establish a database on diverse crops at the state or district level using remote sensing and GIS techniques in order to effectively use information on crops for policy choices. The implantation of nano-chips in plant and seed tissue, which may be used in near-real time to monitor agriculture, is a novel and non-traditional remote sensing application. Clearly, these and other novel methodologies will emphasise the importance of remote sensing in agricultural science analysis in the future.

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Dynamics of Land-use/Land Cover Changes in Upper Jhelum Catchment of Kashmir Himalayas, India

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Abstract: The increasing population pressures and anthropogenic changes have more frequently led to the alterations in the hydrological regimes across the world .These stressors have drastically affected the feedback systems both at watershed level and the compounding impacts being felt across the bio-physical environments. The present study attempts to analyse the impacts of land use/land cover changes on the hydrological patterns of Upper Jhelum catchment of river Jhelum. A 13-year period of study has been analysed from 1992 to 2015, with the aid of geo-statistical and geospatial approaches.The major decrease was recorded in agricultural and dense forest categories. . The findings further register a decreasing trend in the dense forests with other areas of natural land cover including water-bodies, scrubs and glaciers manifesting overall decrease. The accuracy assessment for the year 1992 revealed that the image has an overall accuracy of 95% while as for the year 2015 it is 97%. These aberrations in the natural bio-physical systems being largely accelerated by stressors ranging from natural to human induced ones have a cumulative bearing on the overall environmental and social balance. This demands a thorough and action-oriented policy re-evaluation being carried in Kashmir Himalayas for the ecological and sustainable development of the region. The human-environment interface studies need to be prioritised with the much added emphasis on adaptation and the well-balanced planning for the long term bio-environment security.

Keywords: Land-use/Land cover, Stressors, Bio-physical environment, Hydrological regimes, Bio-environment security

Land use and Land cover (LULC)is often used to describe the land surfaces and the anthropogenic activities that alter the land surface dynamics. Changes in climate have recently impacted on the agricultural production, and more observed impact assessment showing increase in the climate induced droughts across the world (IPCC, 2022) which are further accentuated by land use changes .This led to the warning semantics being paralleled from United Nations Office from 'code red', 'atlas of human suffering' to 'climate disruption' illustrating the accelerated vicissitudes in the natural environment around us. Often, used interchangeably, the terms connote to slightly different meanings. Land cover is the naturally existing, physical coverage of the land such as forest, water, etc. The anthropogenic application or use of the land determines its land use type, e.g. built-up, agriculture, etc. Land use/ land cover analysis is definitive for various research purposes, including urbanization, land degradation, change detection, etc. (Chaitanya et al 2018, Shahid et al 2021). The identification of the spatio-temporal change in the state of a feature using a multi-date dataset, more popularly remotely sensed datasets is referred to as Land use Land Cover (LULC) change detection. LULC change monitoring is an important aspect of understanding the mechanism and modeling of environmental change, its management and implications. Changes in the landuse and land cover pattern are one of the most important determinants of changes in the geo-environmental interactions. These are in fact the most obvious component of man induced changes in the land system. Understanding Land use change is of key importance while studying environmental interactions and responses. Land use and land cover has undergone a significant change in the past century, mainly due to the pressure exerted by the expanding population. The most important approach towards studying and quantifying the pattern of land use change is by the application of geo-spatial techniques which involves mapping of the LULC and quantifying the spatio-temporal variations thereof.

Earlier studies have focused on mapping and quantifying landuse land cover changes (Shalaby and Tateishi 2007, Tian et al 2014, Azmat et al 2016, Alam et al 2020). Many studies have been conducted in various areas of the Kashmir valley pertinent to land use land cover changes. The studies have ranged from being conducted on a district (Lone and Mayer 2019, Meer and Mishra 2020), watershed (Rafiq et al 2018, Saini et al 2019, Ganaie et al 2020), a town/city (Amin et al 2012; Alam et al 2020) scale. Irrespective of the scale of these studies, almost all the studies in the region have identified that the built-up/Urban, horticulture and pastures have increased while as the agriculture, snow/glacier and forest are the major land use categories to register significant decline. The major drivers that have been identified for such pattern of Land use Land cover changes are climatic, economic as well as demographic - in terms of population growth (Ahmed et al 2021). This work maps out the dynamics in land use land cover changes in the upper Jhelum catchment by employing the geospatial methods which infer the changing land use characteristics in the area and subsequently quantifies the magnitude of the changes that have been witnessed in this active bio-physical 'space' of Kashmir Himalayas. This study acts as the guidepost for further research on land use typology dynamics vis-à-vis the frontiers of watershed scale thereby adding to the scope of the present work vastly given the socio-political ecologies Kashmir is endowed with geographically and geomorphologically.

MATERIAL AND METHODS

Study area: The Upper Jhelum catchment forms the Southern terminus of the Kashmir Valley. The basin is bounded by the Pir-Panjal range from South and Southwest and the Greater Himalayas from the East and Southeast. The geographic extent of the study area is 33º- 35ºN and 74º - 76ºE.This is the source region of the River Jhelum which is one of the major tributaries of the Indus River. River Jhelum rises in the Pir-Panjal range from a spring in Verinag which flows along north-western direction, downstream. Initially the river is formed by flows of the spring water from Verinag. The flows of Jhelum are reinforced by its twenty four right and left bank tributaries. In the Upper Jhelum catchment the left bank tributaries are: Sandran, Vishow and Rambiara and the right bank tributaries are: Brengi, Lidder and Arapal (Fig. 1).

Data collection: Satellite images of two dates (in 1992 and 2015) were downloaded from the United States Geological (USGS) Earth Explorer (https://earthexplorer.usgs.gov/). Images with low cloud cover were selected. The images of September/October months were downloaded given the fact that the study area has maximum foliage in the respective months, which makes the classification of the vegetative cover easier. Further the images were pre-processed and classified into thematic layers of LULC in a geospatial environment using latest GIS softwares: Erdas-Hexagon, ArcGIS,. using the supervised classification method (Fig. 2) which refers to a form of image classification where the user trains the software based on samples of spectral signatures of the LULC categories, using the pixel categorization process by specifying the computer algorithm of the statistical parameters, viz. mean vector and variance-covariance matrix of various thematic classes present in the scene. In order to achieve this objective, representative sample site of known thematic classes, known as 'training sets' are to be computed in the above parameters. They are required for compiling the discriminant function or the interpretation key which describes the spectral attributes for each thematic class of interest. Any known pixel in the data sets is then compared numerically to each category in the interpretation key and is assigned to a specific class (Swain and Davis, 1978,; Lillesand and Kiefer, 1987). With respect to the training signatures, the software assigns the rest of the image to the various LULC categories, based on the values closest to the values of the training sets (a maximum likelihood algorithm).The LULC categories classified for this study was a modified NRSC classification scheme and included the following classes: agriculture, barren, built-up, pastures, marshes, sparse-forest, dense-forest, water-bodies, scrubs, horticulture/plantation, river-bed, glacier /snow. Furthermore, a complete accuracy assessment (producer's accuracy, user's accuracy, over-all accuracy and Kappa coefficient) was performed on both the images generated during the present study to assess the reliability of the classifications.

RESULTS AND DISCUSSION

Conforming to the standard two date analysis, the landuse Land-cover (LULC) mapping was carried out for the years of 1992 and 2015 using Landsat-5 (ETM) and Landsat-8 (OLI) respectively. Following is the description of various LULC categories and the change registered therein.

Agriculture: Agricultural land is the land area utilized for cropping and food and fodder production. In Upper Jhelum catchment agriculture class includes land under various agricultural crops (i.e. paddy, maize, saffron, etc.) as well as agricultural lands under fallow. In the satellite images the agricultural area is light red or pinkish color, and represented by regular to irregular shapes, normally seamless. A fallow is identified with its associative property with agriculture. The texture of the agricultural class is more or less smooth. The acreage of land under agricultural class was about 100074 ha (19.5% of the total land area). It decreased by 50% to an area of 49645 ha in 2015, more than halving from its values in 1992. The area occupied by the agriculture class in 2015 was thus 9.7% of the total area (Table 1, Fig. 5).

Barren: The 79316 ha of land was under the barren category in the year 1992, which amounted to about 15.4% of the total area. In 2015 the area under the barren category was 86934 ha, therefore increasing by 11% in two decades. In 2015, the total area under the barren category was 16.9% of the total area (Table 1, Fig. 6). Barren land comprises land of limited ability to support flora or fauna and one- third of the area can sustain vegetation. It is normally an area of thin soil cover and a significant exposure in bed-rock, scarps or rock formations without vegetation. The land area devoid of major vegetation and other rocky surfaces were included in this class. In the satellite image, Barren areas are represented with dark grayish color, with a stony texture and often associated with high altitude areas, proximate to snow

Marshes: Areas with moderate to severe waterlogging (such that lentic water bodies appear over ground) with typical wetland vegetation are called marshes. Marshes appear with a reddish brown color and have a smooth texture and a smaller extent. The wetlands, bogs and marsh lands were categorized under this class. Marshes occupied an area of about 686 ha (0.1% of the total area) in 1992. In 2015, area under the marshes classes was 847 ha which amounts to

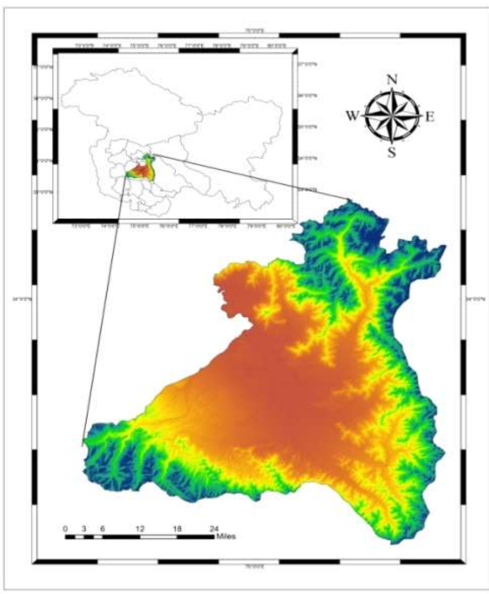

Fig. 1. Study area

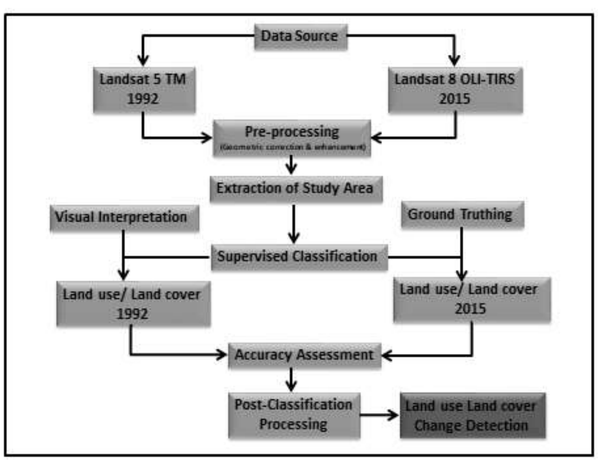

Fig. 2. Methodology- Land use land cover classification

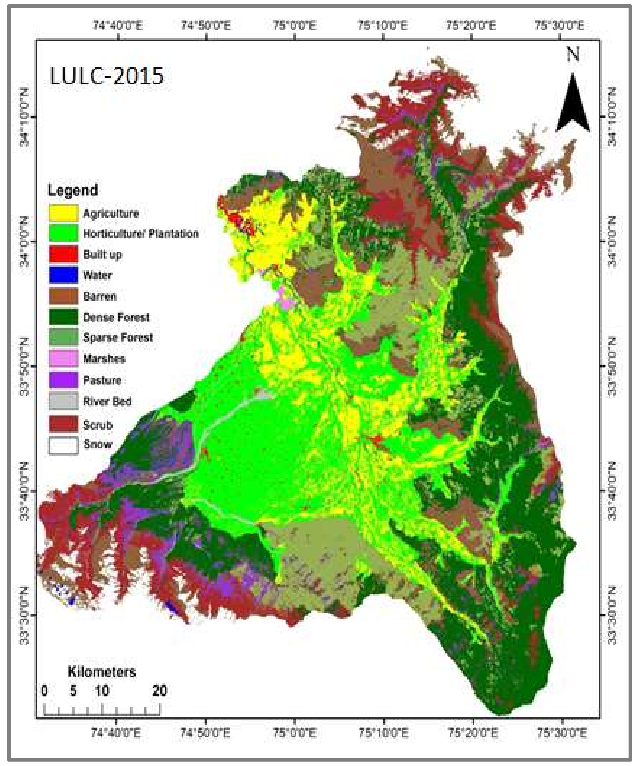

Fig. 3. Land use / Land Cover pattern of 1992 in the Upper Jhelum Catchment

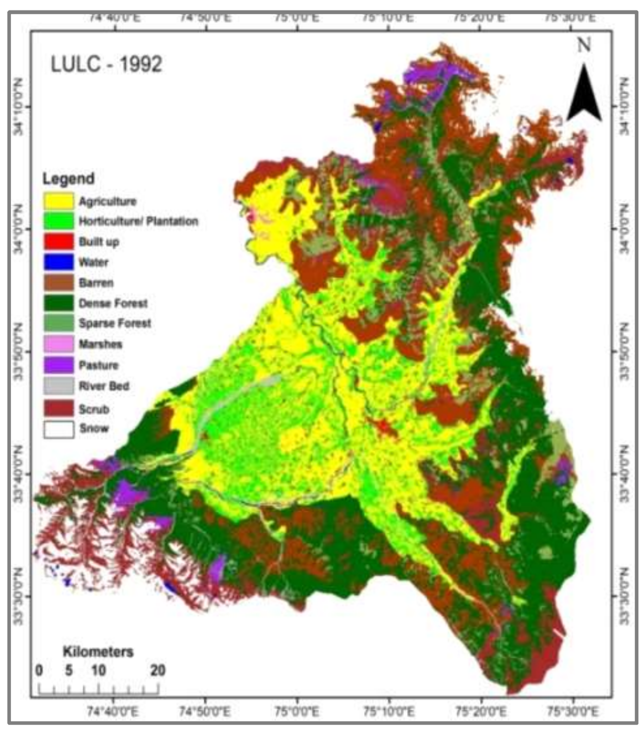

Fig. 4. Land use / Land Cover pattern of 2015 in the Upper Jhelum Catchment

about 0.2%. The area under the marshes registered an increase of 34.9% from 1992 to 2015 (Table 1, Fig. 7)

Pasture: Pastures are rangelands and are defined as land where the predominant vegetation is grasses, shrubs and the kind. These pastoral lands include grasslands and pastures. Pastures in the image show a slightly brighter light magenta with smooth texture and have proximity with forest areas. In 1992, the pastures were about 1.8% of the total land area which means an area of 9027 ha. This increased by 66.2% in 2015, where the area under the Pasture class was 13078 ha (2.5% of the total area) (Table 1 Fig. 8).

Sparse forest: The sparse forest category means the forest class with a low density canopy (less than 10% crown closure). These are forests where normally trees have been removed for any developmental purpose. These are represented by deep reddish tone but visibly differentiable color than the dense forests. In 1992 the sparse forests covered about 9.3% of the total land area, occupying an area of 47597 ha. In the year 2015, the sparse forest category showed an 89% increase. The sparse forest class in the year 2015, occupied an area of 90149 ha (17.5% of the total area) (Table 1, Fig. 9).

Built-up: Built-up comprises areas of intensive structure. Built up includes all infrastructure; residential areas, buildings and roads. This category consists of cities, villages, institutional, commercial or industrial structures. Built-up looks cyan or bluish gray in a false color composite satellite image and is often clustered. The area under built-up was 5191 ha in 1992 which is about 1.06 % of the total area of the land. Built-up area increased by 71% in 2015, to an area of 8834 ha (1.82% of the total area (Table 1). The change in the built-up land use class is depicted in Figure 10.

Riverbed: The area fringing the rivers and streams, particularly in a stony texture is the riverbed. The river-bed has a grayish white tone and is often associated with the rivers. LULC analysis shows that the area under the riverbed class has been decreasing over the years. While the area covered by the riverbeds was 10604 ha (2.17% of the total area) in 1992, it registered a decline of 29.5% and was reduced to an area of 7469 ha (1.53% of the total area) in the year 2015.The change in the riverbed class can be seen in Figure 11.

Horticulture/Plantation: The horticultural class includes orchards, vineyards, horticultural plantations, floricultural nurseries, willow thickets, social forestry and groves. These areas are mostly found associated with agricultural areas. These areas have a reddish tone but have somewhat granular texture which implies the tree crowns.In 1992 the area occupied by horticulture and plantations was 47242 ha (8.68% of the total area). The area under this class almost doubled in 2015 to 96498 ha (18.44% of the total area) with a 104% increase in two decades. The increase in the Horticulture/Plantation land use class is depicted in Figure 12.

Water-Bodies: In the study area glacial lakes, rivulets, streams are found. Clear waters which completely absorb the near infrared band are represented by a jet black surface on the satellite image. Water loaded with sediments has a bluish tone. The water bodies in the study area have considerably shrunk. This class includes lakes, rivers and other water bodies. 2692 ha (0.55% of the total land area) of the land area in the Upper Jhelum catchment was occupied by water bodies in the year 1992. The area halved to 1381 ha in 2015

Table 1. Area under different landuse in 1992 and 2015

LULC Class	LULC 1992 (Area in ha)	Percentage of the total area	LULC 2015 (Area in ha)	Percentage of the total area	Difference (Area in ha)	Percent Change
Agriculture	100074	19.5	49645	9.7	-50429	-50
Barren	79316	15.4	86934	16.9	7617	10
Marshes	686	0.1	847	0.2	161	23
Pastures	9027	1.8	13078	2.5	4050	45
Sparse Forest	47597	9.3	90149	17.5	42552	89
Built Up	5191	1.0	8834	1.7	3642	70
Riverbed	10604	2.1	7469	1.5	-3135	-30
Horticulture	47242	9.2	96498	18.8	49255	104
Water-bodies	2692	0.5	1381	0.3	-1311	-49
Scrub	52978	10.3	35402	6.9	-17576	-33
Dense Forest	127041	24.7	96372	18.8	-30669	-24
Glaciers	31336	6.1	27178	5.3	-4158	-13
Total	513785		513785			

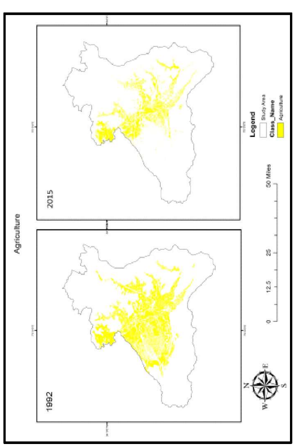

Fig. 5. Change map for agriculture landuse class

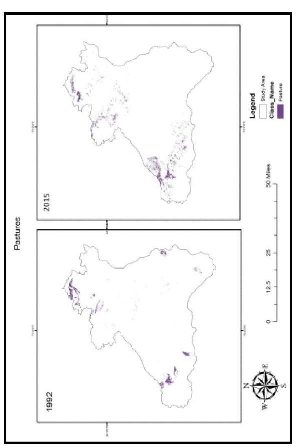

Fig. 8. Change map for Pastures landuse class

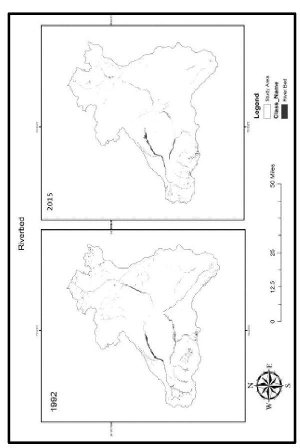

Fig. 11. Change map for the River-bed landuse class

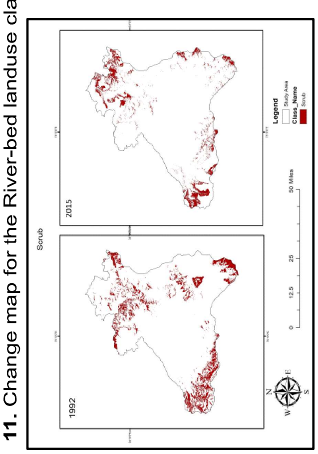

Fig. 14: Change map for Scrub Landuse Class

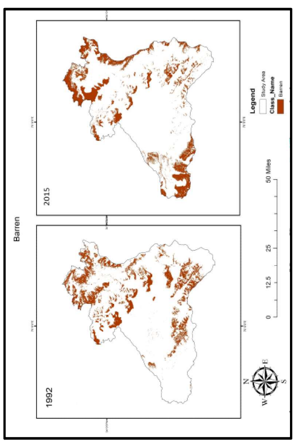

Fig. 6. Change map for Barren landuse class

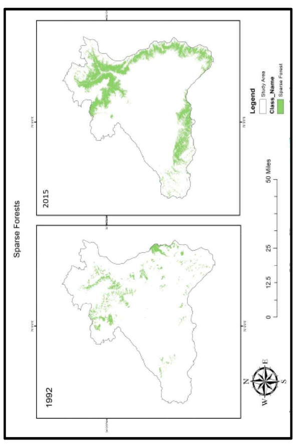

Fig. 9. Change map for the Sparse forest landuse class

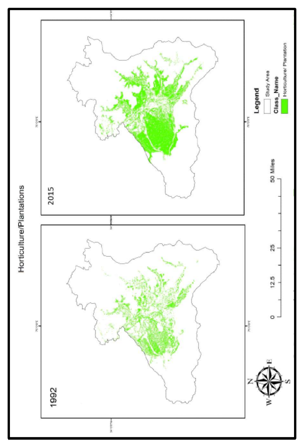

Fig. 12. Change map for the Horticulture/Plantation landuse class

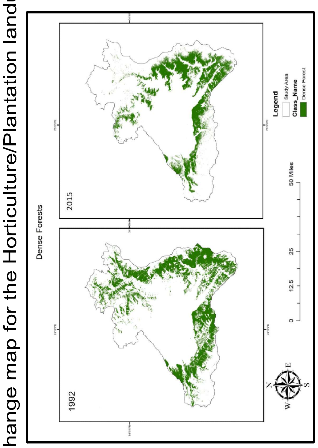

Fig. 15. Change map for Dense Forest Landuse Class

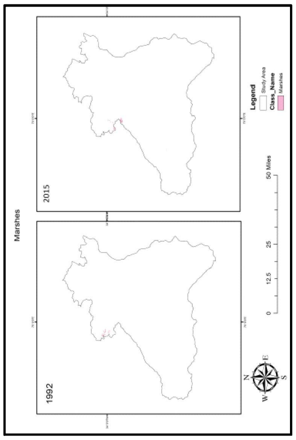

Fig. 7. Change map for the Marshes landuse class

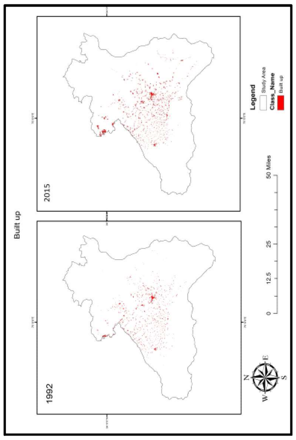

Fig. 10. Change map for Built-up landuse class

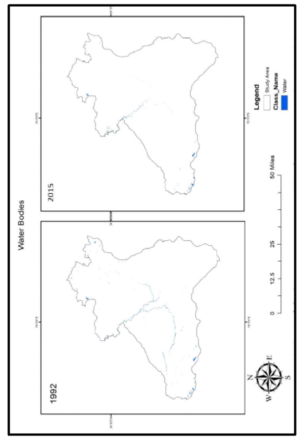

Fig. 13. Change map for Water Bodies landuse class

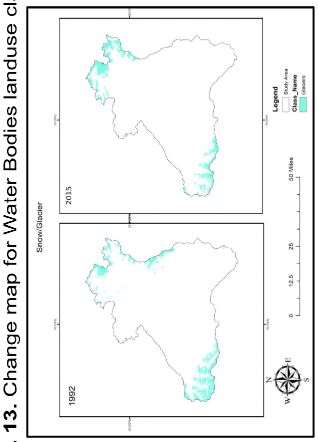

Fig. 16. Change map for Snow/Glacier Landuse Class

decreasing by 48.6%. The change in the water bodies is depicted in Figure 13.

Scrubs: Scrub lands or wastelands are under-utilized, semi-degraded or degraded land, or land devoid of moisture and thus carries lesser vegetation. Scrub lands appear in an orange to brownish or greenish tinge with a contagious spatial extent. The area occupied by the scrub lands in the year 1992 was 52978 ha (10.3 % of the total area), which reduced to 35402 ha (6.9% of the total area) by a percent decrease of -33% in the two decades. The change in the Scrub land use class is seen in Figure14.

Dense-forest: Dense forest is the category of landuse which includes dense canopy forest cover, with extensive crown coverage (more than 10% crown closure). The study area has a cover of dense forests of Pine and Deodar. Dense forest have a deep reddish tone on a satellite imagery and in the study area, are more or less identified along the sparse forests, well below the tree-line.the Upper Jhelum catchment the dense forests formed the largest LULC class in 1992 (24.7% of the total area) having an area of 127041 ha. However, in 2015 the area has reduced to an area of 96372ha decreasing by -24.14%. The area under dense forest continues to be the largest landuse category in UJC, although has reduced to 18.8% of the total area. The change in the Dense Forests land use class is depicted in Figure 15.

Snow/Glaciers: This class includes Glaciers, snow fields and snow. Snow or glaciers have a white or a light grayish color. Alike most of the Himalayan glaciers, the glacial areas in the study region are debris covered, which reduces the accuracy of demarcating these glaciers. Restricted to the highlands of the study area, this class occupied an area of 31336 ha in 1992 (6.42% of the total area, Table 1.). This area reduced to 27178 ha (5.3% of the total area) in 2015, decreasing by -10.8%. The change in the Snow/Glaciers and use class is depicted in Figure 16.

Accuracy assessment: For verifying the authenticity of the thematic classification in this study accuracy assessment was carried out. This reference data is compared with reference pixels which are selected for which the reference data is acquired. A matrix is generated which simply compares the agreement between classified and reference points. The error matrix determines the percentages of accuracy based upon User's accuracy, Producer's accuracy and the Kappa Coefficient.

The accuracy assessment for the year 1992 revealed that the image has an overall accuracy of 95%. The producer accuracy for various classes ranges from 91% - 100%. The Kappa Coefficient for the classification is 0.94 (Table 2). The accuracy assessment for the year 2015 revealed that the image has an overall accuracy of 97%. The producer accuracy for various classes ranges from 90.4% - 100%. The Kappa Coefficient for the classification is 0.96 (Table 3).

Table 2. Error matrix and accuracy assessment (1992)

CLASS	A	H/P	WB	DF	SF	Ba	Ma	Sc	Pa	BU	S/G	RB	Row total	User's accuracy
(A)	20	0	0	0	0	0	0	0	0	0	0	0	20	100%
(H/P)	1	19	0	0	0	0	0	0	0	0	0	0	20	95%
(WB)	0	0	20	0	0	0	0	0	0	0	0	0	20	100%
(DF)	0	0	0	20	0	0	0	0	0	0	0	0	20	100%
(SF)	0	0	0	2	18	0	0	0	0	0	0	0	20	90%
(Ba)	1	0	0	0	0	19	0	0	0	0	0	0	20	95%
(Ma)	0	2	0	0	0	0	18	0	0	0	0	0	20	90%
(Sc)	0	0	0	0	1	0	0	18	1	0	0	0	20	90%
(Pa)	0	0	0	0	0	0	0	1	19	0	0	0	20	95%
(BU)	1	0	0	0	0	0	0	0	0	19	0	0	20	95%
(S/G)	0	0	0	0	0	0	0	0	0	0	20	0	20	100%
(RB)	0	0	0	0	0	0	0	0	0	0	0	20	20	100%
Column Total	23	21	20	22	19	19	18	19	20	19	20	20	240	
Producer's accuracy	8%	90.4%	100%	91%	94.7%	100%	100%	94.7%	95%	100%	100%	100%		

Sum of diagonal=230; Total=240; Overall accuracy = 95%; Kappa coefficient (K)= 0.94
A=Agriculture, H/P=Horticulture and Plantation, WB=Water-bodies, DF=Dense Forest, SF=Sparse Forest, Ba=Barren, Ma=Marshes, Sc=Scrubs, Pa=Pastures, BU=Built-up, S/G= Snow and Glacier, RB=River-bed

Table 3. Error matrix and accuracy assessment (2015)

CLASS	A	H/P	WB	DF	SF	Ba	Ma	Sc	Pa	BU	S/G	RB	Row total	User's accuracy
(A)	20	0	0	0	0	0	0	0	0	0	0	0	20	100%
(H/P)	0	20	0	0	0	0	0	0	0	0	0	0	20	100%
(WB)	0	0	19	0	0	0	0	0	0	0	0	1	20	95%
(DF)	0	0	0	18	2	0	0	0	0	0	0	0	20	90%
(SF)	0	0	0	0	20	0	0	0	0	0	0	0	20	100%
(Ba)	0	0	0	0	0	19	0	1	0	0	0	0	20	95%
(Ma)	0	0	0	0	0	0	20	0	0	0	0	0	20	100%
(Sc)	0	0	0	0	0	0	0	19	1	0	0	0	20	95%
(Pa)	0	0	0	0	0	2	0	0	18	0	0	0	20	90%
(BU)	0	0	0	0	0	0	0	0	0	20	0	0	20	100%
(S/G)	0	0	0	0	0	0	0	0	0	0	20	0	20	100%
(RB)	0	0	0	0	0	0	0	0	0	0	0	20	20	100%
Column Total	20	20	19	18	22	21	20	20	19	20	20	21	240	
Producer's Accuracy	100%	100%	100%	100%	91%	90.4%	100%	95%	94.7%	100%	100%	95.2%		

Sum of diagonal=233; Total=240; Overall accuracy = 97%; Kappa coefficient (K)= 0.96
See Table 2 details

CONCLUSION

It can be inferred from the above analysis of LULC that considerable changes have occurred in various land use categories. Major declines have been registered in the areas occupied by agricultural and dense forest categories. Most of the agricultural land has been converted to horticultural category, for the obvious economic gains that the latter provides. The findings indicate that whilst the dense forests have decreased and that the sparse forests have increased in area, can basically be attributed to the removal of tree cover from the dense forests, as a result of which the crown coverage of such forests is visibly reduced. With removal of the vegetal cover, the area under barren categories has also seen an increase. Other areas of natural land cover, such as water-bodies, scrubs, glaciers have overall decreased. Our study is in line with other LULC studies carried out in the region. The implications of such changes are rather straight-forward that the changes are not sustainable. The implications of such changes are rather straight-forward and can have long term effect on the human-environment feedback system in the region. Moreover, it becomes a pre-requisite for the action driven research and policy invigoration in the region devoid of which the perils of food security issues and entropy in the natural systems would have disastrous repercussions in the region. Furthermore, there needs to be citizen driven awareness with whole-of-society response and political commitment in realizing the sustainable and holistic development in the region.

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Probiotic Manipulation of the Gut Ecosystem and its Impact on Body Condition Score in the Asian Elephant

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Abstract: A study was carried out to evaluate the effect of dietary manipulation of the gut ecosystem by supplementing probiotics on body condition score (BCS) in 18 captive female Asian elephants of 30-62 years age for a period of two months. The elephants were randomly divided into three groups, with six each. The control group, in which the elephants received basal feed without any probiotic supplements, whereas the elephants of the group 2, and the group 3 were, fed a similar basal feed along with oral powdered probiotics, i.e.*Lactobacillus acidophilus* and *Saccharomyces cerevisiae* @ 1 gm 1×10^9 cfu/gm for every 50 kg BW/day each, respectively. An overall visual evaluation based BCS on a 5-point scale was taken once at the end of the study.The statistical analysis of the data did not reveal any significant effect of the treatments. The overall mean BCS was 3.78 and showed a tendency toward fat condition. Total 77.78 and 22.22% elephants had BCS-4 and BCS-3, respectively. No elephants had BCS-1, 2, and 5. In conclusion, supplementation of probiotics did not affect the body condition score and exhibited a good maintenance of the nutritional status.

Keywords: Asian elephant, Body condition score, Probiotic manipulation**,** Gut ecosystem

The Asian elephant (*Elephas maximus*) is the continent's largest terrestrial, intelligent, social and long-ranging endangered migratory animal. The species has been listed in the IUCN Red List of Threatened Species due to decline in population size by approximately 50 per cent over three generations (Choudhury et al 2008, CMS COP13 2020). Based on the recommendation of the Elephant Task Force, India has declared Indian Elephant as "National Heritage Animal" (Rangarajan et al 2010). It provides the highest degree of legal protection under Schedule I of Wildlife (Protection) Act, 1972. For the conservation of the elephant species globally, the Association of Zoo and Aquariums Elephant Taxon Advisory Group/ Species Survival Plan Management Committee have endorsed research to better understand causes of poor health, nutritional and welfare issues of elephants (Keele and Ediger 2011). For these issues, obesity might be the prime suspected reason (Clubb et al 2008). The condition of an animal is primarily a reflection of fat reserves which in turn are generally assumed to determine an individual's nutritional and habitat status (Ramesh et al 2011). Body condition scoring is a reasonable alternative to direct measurement of chemical composition. It provides an index of the energy stored as fat and muscle and is a quick reliable means of identifying extremes in manage mental and nutritional welfare approaches used for the animals. Assessment of body condition score (BCS) is individual based that does not require a high technical skill and comparatively inexpensive as well as meaningful when applied to a large wild population like elephants (Fernando et al 2009). This is one of the important tools in the elephant management, whether in captivity or in the wild (Wijeyamohan et al 2014).

The gastrointestinal tract harbours a complex community of microbiota, and it plays a pivotal role in health and wellbeing of animals. Any manipulation in diet can rapidly change the microbial community in the gut, as the gut ecosystem strongly contributes to animal physiology (Bruni et al 2020). Various strategies have been developed to maintain gut ecosystem with the growing concerns about using antibiotics and other growth stimulants (Chharang et al 2021). Probiotics could be a potential strategy to successfully exhibit the effect of the microbes on gut function, and it is considered to be important in treatment of obesity along with significant reductions in body mass index, body weight and fat mass (John et al 2018) as well as better nutrients utilization resulted in improved health performance and nutritional status (Anee et al 2021). Thus, an attempt was made to evaluate the effect of dietary manipulation of the gut ecosystem by supplementing probiotics on body condition score (BCS) in Asian elephants.

MATERIAL AND METHODS

Ethical statement: The study was carried out with the prior permission of the Additional Principal Chief Conservator of

Forest and Chief Wildlife Warden, Government of Rajasthan, Jaipur (India). The study protocol was duly approved by the Institute Animal Ethics Committee (PGIVER/IAEC/I9-05) and performed in accordance with relevant guidelines and regulations for care and management (MoEF and CC 2008).

Study area: The present study was undertaken during the monsoon season at Elephant Village, Jaipur (India), which is located at latitude 26° 59'47" N, longitude 75° 52'35" E and altitude of 431 meters above the sea level.

Study animals: Eighteen healthy, captive adult female Asian elephants of 30 to 62 years age and alike BW (3495 ± 133.34 kg) were selected and stall-fed a consistent feed of green pearl millet forage commonly known as bajra as basal feed throughout the research period of 60 days. An adaptation period of 10 days was observed prior to start of experimental feeding trial. Thereafter, the selected elephants were divided into three similar groups of six elephants each in such a way that each group had almost similar average body weight.

Table 1. Experimental feeds offered to Asian elephants in different groups

Experimental groups	Experimental feed
T_1	Green pearl millet forage as basal feed (without probiotic)
T_2	Green pearl millet forage + *Lactobacillus acidophilus* @ 1 gm 1 × 10^9 CFU/ 50 kg body weight per day
T_3	Green pearl millet forage + *Saccharomyces cerevisiae* @ 1 gm 1 × 10^9 CFU/ 50 kg body weight per day

Feeding of experimental probiotics: The elephants were then placed on three dietary experimental feeds for 50 days of experimental feeding trial (Table 1). All the elephants were housed in a hygienic and well ventilated individual enclosure, with a separate feeding arrangement.

Data collection: Body condition score (BCS) is an index of an animal's health. The BCS of all elephants were assessed by using a method described by Baarlen and Gerritsen (2012), Morfeld et al (2014) and Pokharel et al (2017). An overall score on a 5-point scale, with 1 representing the lowest and 5 representing the highest body fat level was used (Table 2, Fig.1) (Pokharel et al 2017). The BCS-3 was considered ideal for the animal. The BCS assessment in this study was based on visual evaluation and scoring of subcutaneous fat stores of the body parts, including bony structures such as pelvic girdles, pectoral girdles, skull, ribs, backbone, and any depressions as shown in Figure 2 (Wijeyamohan et al 2014). The BCS was taken once at the end of the experiment, in the morning before the elephants received their first meal.

Table 2. BCS index used for the experimental Asian elephants

BCS	Head	Ribs	Backbone	Shoulder	Hind quarter
1. Very thin	Entire head looks hollowed and highly sculpted, bones were easily visible, hollow behind the ears, division between head and body easily visible	Very prominent and easily visible	Prominent from tailhead to shoulders, deep depression alongside backbone in lumbar region	Emaciated, shoulder blades clearly visible. No muscular fat visible	Pelvis clearly visible, deep depression in front and behind pelvis. Prominent tailhead
2. Thin	Head had sculpted appearance, bones were easily visible, hollowed behind the ears and under the eyes	Prominent and appeared to be covered by a thin fat layer	Clearly visible from tailhead to mid-back, depression alongside backbone in lumbar region	Shoulder blades visible. A slender body	Pelvis clearly visible, a gradual sunken area in front and flattened area behind pelvis, flat tailhead
3. Moderate	Bones on the head were clearly visible, but no hollowed areas	Not visible	Visible from tailhead to mid-back, sloping alongside backbone in lumbar region	Shoulder blades visible during movement	Pelvis visible as a ridge, entire pelvis may not be visible, slight sunken or flattened area in front and/or behind pelvis, moderate fat around tailhead
4. Fat	Rounded head, little sculpting evident, division between head and body not easily visible	Not visible	Visible as a ridge from tailhead to mid-back, no apparent depression and fat began to accumulate alongside backbone in lumbar region	Not visible, fat deposits evident	Pelvis not visible, fat around tailhead, hips rounded
5. Obese	Rounded head, bones hardly visible, division between head and body not easily visible	Not visible	Difficult to differentiate, may be visible from tailhead to pelvic bone region and appeared to be covered with thin fat layer, area in lumbar region filled in	Not visible, fat deposits extremely evident	Pelvis not visible,excessive fat around tailhead, hips, and pelvic bones very rounded, rotund

Statistical analysis: The experimental data were subjected to statistical analysis (SPSS version 24).

RESULTS AND DISCUSSION

All the elephants were healthy throughout the study, and no side effects of probiotics supplementation in both the groups were recorded. No change in feed consumption was recorded. A summary for the effect of dietary supplementation of probiotics *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* on body condition score is presented in Table 3. The overall mean was 3.78. The BCS results revealed that 14 out of 18 elephants (77.78%) and 4 out of 18 (22.22%) had BCS-4 and BCS-3, respectively. No elephants had BCS-1, 2, and 5. The statistical analysis of the data did not reveal any significant effect of the treatments.No difference in BCS between control and probiotic groups for the whole study period was recorded.

There were no statistical differences (regarding the body condition score (BCS) in the Asian elephants of different groups. The overall BCS recorded to be higher side and the trend of BW and BCS revealed that all the elephants were in good condition but showed a tendency toward fat condition. The possible reason for the higher body condition score might be linked to overfeeding of large quantity of readily available energy feedstuffs and lesser energy expenditure due to the captive nature of elephants throughout the year. All the elephants in the treatment groups maintained their BCS score throughout the trial compared to the control group. The results exhibited good maintenance of the nutritional status in elephants that were prone to overweight, meaning that even in healthy elephants with no gastrointestinal disorder the addition of these supplements to the diet helps to maintain the optimal balance of their intestinal microbiota.

Overfeeding and obesity are common problems mentioned in the literature on zoo animal nutrition in herbivores (Ange et al 2001, Hatt and Clauss 2006). It has long been a concern that zoo elephants are 'obese' (Clubb et al 2008). Based on BCS measures, a survey confirmed that, over 65 and 56% of adult Asian elephants are obese in North American and European zoos, respectively (Morfeld et al 2016, Schiffmann et al 2018). Elephants under captivity appear to have higher BCSs (Schiffmann et al 2018) and greater body mass compared with wild elephants (Schiffmann et al 2019). Being the intestinal microbiota involved in the regulation of fat storage, the feeding of probiotics could have positive metabolic effects in the prevention and treatment of fat and obese conditions in animals (Miyoshi et al 2014, John et al 2018).

In agreement with the result of present study, Lehloenya et al (2008), Al Ibrahim et al (2010) in dairy cows, Rossi et al

Table 3. Mean values of BCS in different groups

Groups	Name of elephant	Reg. No.	Age (yrs)	Body Wt. (kg)	BCS	Mean BCS
T_1	Jaimala	11	41	3018	4	3.83 ± 0.17
	Rajrani	20	56	3000	3	
	Phoolwanti	116	30	3594	4	
	Jhomati	53	48	3900	4	
	Chameli	123	44	3324	4	
	Jaytara	92	45	4116	4	
T_2	Laxmi	125	47	3000	3	3.67 ± 0.21
	Laxmi	130	52	2964	4	
	Anno	93	48	3234	4	
	Tami	109	35	3702	3	
	Gomati	81	33	3864	4	
	Shobha	96	40	4080	4	
T_3	Bhogwati	30	49	2658	4	3.83 ± 0.17
	Champa	105	33	3180	4	
	Rangoli	43	44	3900	4	
	Majani	55	50	3684	3	
	Champakali	52	50	3936	4	
	Chanchal	9	62	4620	4	

BCS-4 =77.78%; BCS-3 = 22.22%; BCS-1=Nil; BCS-2=Nil; BCS-5=Nil, overall BCS=3.78 ± 0.10
P-value=0.761

(2020) in dogs and Sri Lekha et al (2021) in Murrah buffalo calves, showed non-significant effects of probiotics on body condition score. Contrary to results of this study, Bruni et al (2020) and Marelli et al (2020) showed significantly lower and higher BCS in probiotics supplemented dogs, respectively.

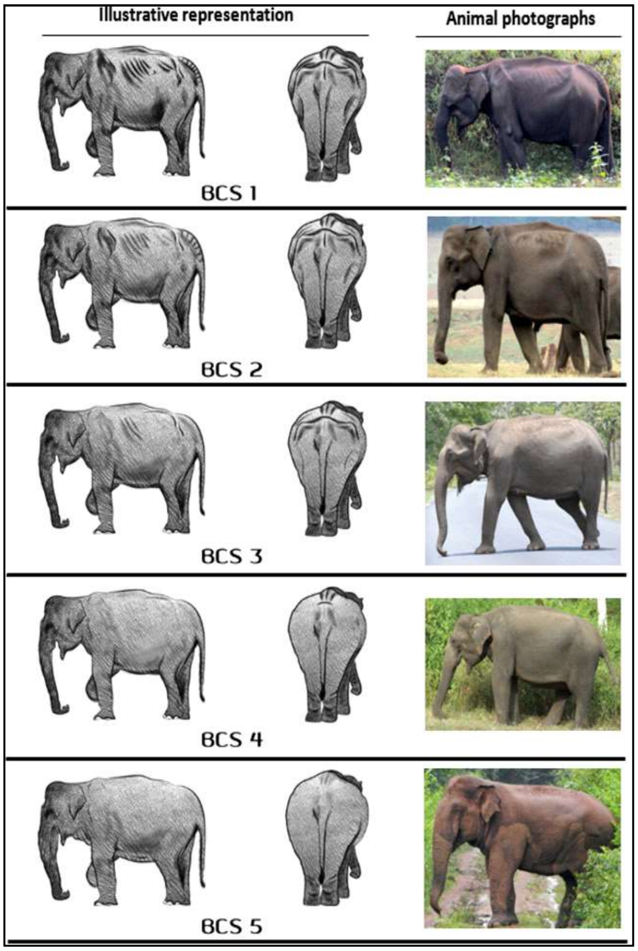

Fig. 1. Representative schematic and photographic illustrations of elephant showing body conditions with assigned BCS values, ranging from 1 to 5

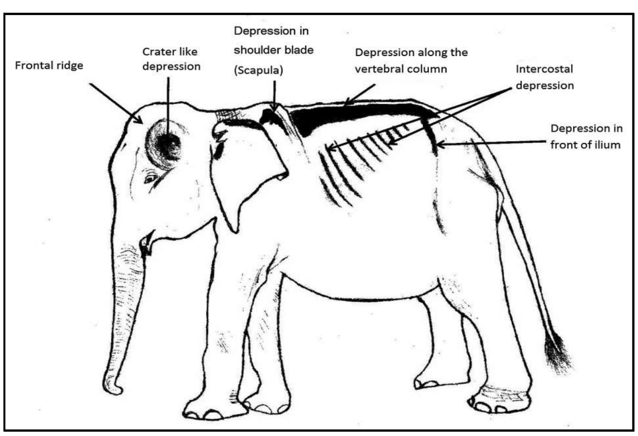

Fig. 2. Sketch of emaciated elephant showing all the depressions, bones, and spines

CONCLUSION

Dietary supplementation of probiotics *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* did not affect the body condition score and exhibited a good maintenance of the nutritional status. Probiotics were supplemented at the recommended dosage, but perhaps it was not enough to make a difference in healthy elephants. Further studies are needed to increase the dose rate and test the long term probiotic effects on BCS in healthy elephants.

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Birds in Agricultural Fields of Ayodhya District, Uttar Pradesh

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***Abstract*:** Birds play a crucial role in functioning of the agro-ecosystems. It is important to understand the bird diversity of agricultural fields to develop a baseline for continuous monitoring of ecosystem changes in future. This study was carried out by plotting fixed radius point counts in the agricultural fields across Ayodhya district, Uttar Pradesh to determine the diversity and distribution of birds in agro-ecosystems of the study area. A total of 128 bird species belonging to 49 families and 15 orders were recorded from the study area. Passeriformes (71) had the maximum number of bird species. The highest number of species recorded were Omnivores (35%). Out of the 128 bird species recorded, six species were in the threatened category of IUCN Red List (2021) which highlights the conservation value of agricultural landscapes in Uttar Pradesh.

Keywords: Avian, Agro-ecosystems, Threatened, Conservation, Foraging guild, Feeding guild

Birds are an important constituent of the agro-ecosystems. Role of birds as seed dispensers, pollinators, scavengers and predators of insects, help in ecosystem functioning. They are known to be the best indicators of environmental changes (Kushwaha et al 2015). The agro-ecosystems in turn provide these birds with food in the form of grains, seeds, vegetables, grasses, weeds, insects, invertebrates and rodents (Asokan et al 2009). The insectivorous and carnivorous birds help in keeping the population of insect pests and rodents under control. Thus, benefitting the farmers by providing natural crop protection. Uttar Pradesh has 16.81 million ha of land under agriculture i.e. 70% (Anonymous 2021a) which makes it one of the most intensively cultivated state among other Indian states. But studies related to bird distribution in agricultural lands in Uttar Pradesh is limited. There are a few studies done by Sundar (2006, 2009), Sundar and Subramanya (2010), Sundar and Kittur (2012, 2013) on bird composition. But there are no studies done on bird diversity on agro-ecosystems in Ayodhya district of Uttar Pradesh. A checklist of birds distributed in agricultural habitat is needed so that a reliable baseline can be developed for monitoring changes in biodiversity and environment. So, there is an urgent need to document the bird diversity found in agro-ecosystems of Ayodhya district.

MATERIAL AND METHODS

Study site: This study was conducted in the Ayodhya district of Uttar Pradesh which consists of five tehsils (Fig. 1). This district lies between 26.7730 ^{0}N and 82.1458 ^{0}E and situated 93 m above MSL (Anonymous 2021b). The climate of the district is tropical monsoon. The average temperature varies from 32 ^{0}C in summers to 16 ^{0}C in winters and the average annual rainfall is 1067 mm (Anonymous 2021b). There are three distinct seasons – summer (March to June), rainy (July to October) and winter (November to February). The study area includes reserve forests, remnant vegetation patches, rivers, temple ponds, wetlands, gardens, paddy fields and human habitations.

Methodology: The study was carried out from September 2020 to August 2021 with an aim to prepare a checklist of birds present in agricultural fields of Ayodhya district, Uttar Pradesh. Fixed radius, point counts (Bibby et al 2000) were placed at fixed sites distributed across the agricultural fields throughout the district. Surveys were conducted during 06:00 am to 09:00 am during summers and after disappearance of fog during winter mornings. At every point count species were recorded for 10 minutes. A pair of field binoculars (Nikon 7x35) was used to record species. The opportunistic sightings of birds during other time of day were also included. Photographs were taken wherever possible to aid in identification. Grimmett et al (2011) was used for bird identification. For every species observed, the data sheet was filled in to record the date, time, GPS location (Garmin GPS), species name, number of individuals, feeding habit and habitat. Every species recorded was assigned the taxonomic position, common and scientific names by referring to Praveen et al (2020). The assessment of threat status of the recorded bird species was based on IUCN Red List (2021).

RESULTS AND DISCUSSION

A total of 128 bird species belonging to 49 families and 15 orders were recorded from the study area (Table 1). Similar studies in different paddy fields have reported 97 species in Maharashtra (Abdar 2014) and 144 species in West Bengal (Hossain and Aditya 2016). Passeriformes (71) had the maximum number of species, followed by Pelecaniformes (10) (Fig. 2). The order of Bucerotiformes, Falconiformes and Strigiformes (1 each) had the lowest number of species (Fig. 2). The order of Passeriformes (28) had the maximum number of families, followed by Coraciiformes. The family Accipitridae and Muscicapidae (9 each) had the highest number of species, followed by Ardeidae and Columbidae (7 each) (Fig. 3). In India, Passeriformes are known to be the most dominant order (Praveen et al 2016) and Muscicapidae is known to be the most diverse family (Manakadan and Pittie 2001). Out of 128 bird species recorded, 100 bird species (78%) were resident, 24 bird species (19) were winter visitors and only 4 bird species (3%) were summer visitors. Studies conducted by Hossain and Aditya (2016) in West Bengal have reported similar results. According to the feeding guilds, the 128 bird species recorded were classified into six foraging guilds. The maximum number of species were Omnivores (35%), followed by insectivores (30%) (Fig. 4). This result is not in accordance with the study conducted by Narayana et al (2019), where insectivores were dominant foraging guild in agro-ecosystems. According to the IUCN Red List (2021), out of the 128 bird species recorded, one species (0.78%) was 'Endangered', two species (1.56%) were 'Vulnerable', three species (2.34%) were 'Near Threatened' and the rest 122 species (95.31%) were of 'Least Concern' (Table 1). This work thus, highlights the conservation value of agricultural landscapes in Uttar Pradesh.

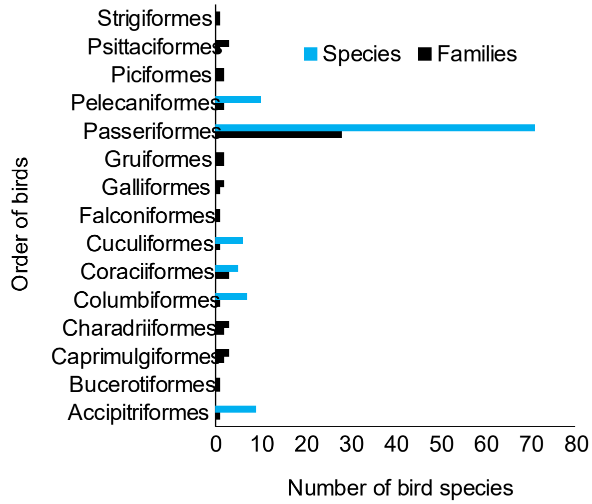

Fig. 2. Order wise bird community composition in agricultural fields of study area

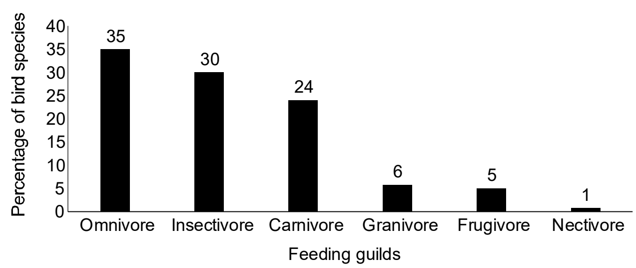

Fig. 4. Foraging guild-based classification of bird species in agricultural fields of study area

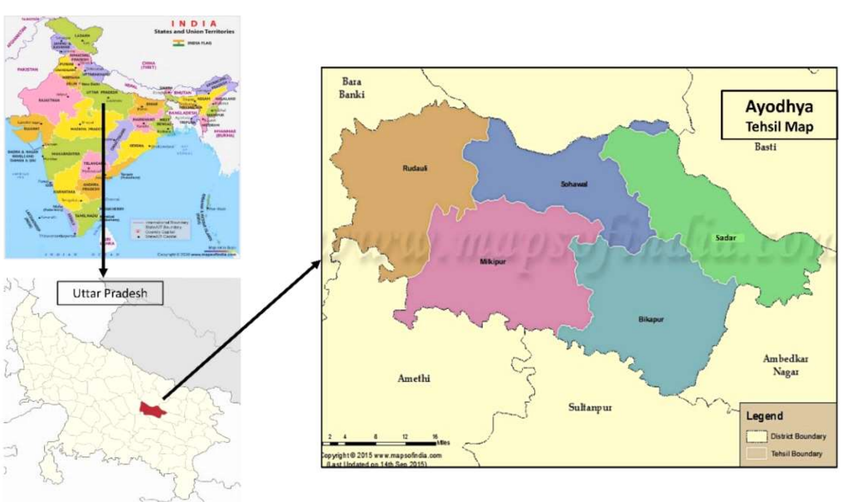

Fig. 1. Location map of study area

Table 1. Checklist of birds recorded in agricultural fields of study area

Order/Family/Common name	Scientific name	Residential status	Feeding status	IUCN status
Accipitriformes Accipitridae (9)				
Black Kite	*Milvus migrans* (Boddaert 1783)	R	C	LC
Black-winged Kite	*Elanus caeruleus* (Desfontaines 1789)	R	C	LC
Crested Serpent Eagle	*Spilornis cheela* (Latham 1790)	R	C	LC
Egyptian Vulture	*Neophron percnopterus* (Linnaeus 1758)	R	C	EN
Indian Spotted Eagle	*Clanga hastata* (Lesson 1831)	R	C	VU
Shikra	*Accipiter badius* (Gmelin 1788)	R	C	LC
Short-toed Snake Eagle	*Circaetus gallicus* (Gmelin 1788)	R	C	LC
Western Marsh-harrier	*Circus aeruginosus* (Linnaeus 1758)	WV	C	LC
White-eyed Buzzard	*Butastur teesa* (Franklin 1831)	R	C	LC
Bucerotiformes Bucerotidae (1)				
Indian Grey Hornbill	*Ocyceros birostris* (Scopoli 1786)	R	O	LC
Caprimulgiformes Apodidae (2)				
Asian Palm Swift	*Cypsiurus balasiensis* (Gray 1829)	R	I	LC
Indian House Swift	*Apus affinis* (Gray 1830)	R	I	LC
Upupidae (1)				
Common Hoopoe	*Upupa epops* (Linnaeus 1758)	R	O	LC
Charadriiformes Charadriidae (2)				
Red-wattled Lapwing	*Vanellus indicus* (Boddaert 1783)	R	O	LC
Yellow-wattled Lapwing	*Vanellus malabaricus* (Boddaert 1783)	R	C	LC
Glareolidae (1)				
Small Pratincole	*Glareola lactea* (Temminck 1820)	R	I	LC
Columbiformes Columbidae (7)				
Eurasian Collared Dove	*Streptopelia decaocto* (Frivaldszky 1838)	R	G	LC
Laughing Dove	*Streptopelia senegalensis* (Linnaeus 1766)	R	G	LC
Oriental Turtle Dove	*Streptopelia orientalis* (Latham 1790)	WV	G	LC
Red Collared Dove	*Streptopelia tranquebarica* (Hermann 1804)	R	G	LC
Rock Pigeon	*Columba livia* (Gmelin 1789)	R	G	LC
Spotted Dove	*Streptopelia chinensis* (Scopoli 1786)	R	G	LC
Yellow-footed Green Pigeon	*Treron phoenicopterus* (Latham 1790)	R	F	LC
Coraciiformes Alcedinidae (2)				
Common Kingfisher	*Alcedo atthis* (Linnaeus 1758)	R	C	LC
White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus 1758)	R	C	LC
Coraciidae (1)				
Indian Roller	*Coracias benghalensis* (Linnaeus 1758)	R	C	LC
Meropidae (2)				
Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus 1767)	SV	I	LC
Green Bee-eater	*Merops orientalis* (Latham 1801)	R	I	LC
Cuculiformes Cuculidae (6)				
Asian Koel	*Eudynamys scolopaceus* (Linnaeus 1758)	R	O	LC
Common Hawk Cuckoo	*Hierococcyx varius* (Vahl 1797)	R	O	LC
Greater Coucal	*Centropus sinensis* (Stephens 1815)	R	O	LC

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Table 1. Checklist of birds recorded in agricultural fields of study area

Order/Family/Common name	Scientific name	Residential status	Feeding status	IUCN status
Indian Cuckoo	*Cuculus micropterus* (Gould 1838)	SV	O	LC
Pied Cuckoo	*Clamator jacobinus* (Boddaert 1783)	SV	O	LC
Sirkeer Malkoha	*Taccocua leschenaultii* (Lesson 1830)	R	O	LC
Falconiformes Falconidae (1)				
Common Kestrel	*Falco tinnunculus* (Linnaeus 1758)	WV	C	LC
Galliformes Phasianidae (2)				
Grey Francolin	*Francolinus pondicerianus* (Gmelin 1789)	R	O	LC
Indian Peafowl	*Pavo cristatus* (Linnaeus 1758)	R	O	LC
Gruiformes Gruidae (1)				
Sarus Crane	*Antigone antigone* (Linnaeus 1758)	R	O	VU
Rallidae (1)				
White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant 1769)	R	O	LC
Passeriformes Acrocephalidae (2)				
Blyth's Reed Warbler	*Acrocephalus dumetorum* (Blyth 1849)	WV	O	LC
Booted Warbler	*Iduna caligata* (Lichtenstein 1823)	WV	I	LC
Aegithinidae (1)				
Common Iora	*Aegithina tiphia* (Linnaeus 1758)	R	O	LC
Alaudidae (4)				
Ashy-crowned Sparrow-Lark	*Eremopterix griseus* (Scopoli 1786)	R	O	LC
Bengal Bushlark	*Mirafra assamica* (Horsfield 1840)	R	O	LC
Crested Lark	*Galerida cristata* (Linnaeus 1758)	R	O	LC
Sand Lark	*Alaudala raytal* (Blyth 1845)	R	O	LC
Campephagidae (3)				
Indian Cuckooshrike	*Coracina macei* (Lesson 1831)	R	I	LC
Long-tailed Minivet	*Pericrocotus ethologus* (Bangs & Phillips 1914)	WV	I	LC
Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus 1766)	R	I	LC
Cisticolidae (4)				
Ashy Prinia	*Prinia socialis* (Sykes 1832)	R	I	LC
Common Tailorbird	*Orthotomus sutorius* (Pennant 1769)	R	I	LC
Plain Prinia	*Prinia inornata* (Sykes 1832)	R	I	LC
Zitting Cisticola	*Cisticola juncidis* (Rafinesque 1810)	R	I	LC
Corvidae (3)				
House Crow	*Corvus splendens* (Vieillot 1817)	R	O	LC
Large-billed Crow	*Corvus macrorhynchos* (Wagler 1827)	R	O	LC
Rufous Treepie	*Dendrocitta vagabunda* (Latham 1790)	R	O	LC
Dicaeidae (1)				
Thick-billed Flowerpecker	*Dicaeum agile* (Tickell 1833)	R	O	LC
Dicruridae (1)				
Black Drongo	*Dicrurus macrocercus* (Vieillot 1817)	R	C	LC
Estrildidae (3)				
Indian Silverbill	*Euodice malabarica* (Linnaeus 1758)	R	G	LC
Red Munia	*Amandava amandava* (Linnaeus 1758)	R	O	LC
Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus 1758)	R	O	LC

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Table 1. Checklist of birds recorded in agricultural fields of study area

Order/Family/Common name	Scientific name	Residential status	Feeding status	IUCN status
Hirundinidae (4)				
Barn Swallow	*Hirundo rustica* (Linnaeus 1758)	WV	I	LC
Red-rumped Swallow	*Cecropis daurica* (Laxmann 1769)	R	I	LC
Streak-throated Swallow	*Petrochelidon fluvicola* (Vlyth 1855)	R	I	LC
Wire-tailed Swallow	*Hirundo smithii* (Leach 1818)	R	I	LC
Laniidae (3)				
Bay-backed Shrike	*Lanius vittatus* (Valenciennes 1826)	R	C	LC
Brown Shrike	*Lanius cristatus* (Linnaeus 1758)	WV	C	LC
Long-tailed Shrike	*Lanius schach* (Linnaeus 1758)	R	C	LC
Leiothrichidae (3)				
Common Babbler	*Argya caudata* (Dumont 1823)	R	O	LC
Jungle Babbler	*Argya striata* (Dumont 1823)	R	O	LC
Striated Babbler	*Turdoides earlei* (Blyth 1844)	R	O	LC
Monarchidae (1)				
Indian Paradise-flycatcher	*Terpsiphone paradisi* (Linnaeus 1758)	SV	I	LC
Motacillidae (5)				
Citrine Wagtail	*Motacilla citreola* (Pallas 1776)	WV	I	LC
Grey Wagtail	*Motacilla cinerea* (Tunstall 1771)	WV	I	LC
Paddyfield Pipit	*Anthus rufulus* (Vieillot 1818)	R	C	LC
White Wagtail	*Motacilla alba* (Linnaeus 1758)	WV	I	LC
White-browed Wagtail	*Motacilla maderaspatensis* (Gmelin 1789)	R	I	LC
Muscicapidae (9)				
Black Redstart	*Phoenicurus ochruros* (Gmelin 1774)	WV	I	LC
Bluethroat	*Luscinia svecica* (Linnaeus 1758)	WV	I	LC
Brown Rockchat	*Oenanthe fusca* (Blyth 1851)	R	I	LC
Indian Robin	*Copsychus fulicatus* (Linnaeus 1766)	R	C	LC
Oriental Magpie Robin	*Copsychus saularis* (Linnaeus 1758)	R	C	LC
Pied Bushchat	*Saxicola caprata* (Linnaeus 1766)	R	I	LC
Siberian Stonechat	*Saxicola maurus* (Pallas 1773)	WV	I	LC
Taiga Flycatcher	*Ficedula albicilla* (Pallas 1811)	WV	I	LC
Tickell's Blue Flycatcher	*Cyornis tickelliae* (Blyth 1843)	R	I	LC
Nectariniidae (1)				
Purple Sunbird	*Cinnyris asiaticus* (Latham 1790)	R	N	LC
Oriolidae (2)				
Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus 1758)	R	O	LC
Indian Golden Oriole	*Oriolus kundoo* (Sykes 1832)	R	O	LC
Paridae (1)				
Cinereous Tit	*Parus cinereus* (Vieillot 1758)	R	I	LC
Passeridae (1)				
House Sparrow	*Passer domesticus* (Linnaeus 1758)	R	O	LC
Phylloscopidae (4)				
Blyth's Leaf Warbler	*Seicercus reguloides* (Blyth 1842)	WV	I	LC
Common Chiffchaff	*Phylloscopus collybita* (Vieillot 1817)	WV	I	LC
Greenish Leaf Warbler	*Seicercus trochiloides* (Sundevall 1837)	WV	I	LC
Hume's Leaf-warbler	*Abrornis humei* (Brooks 1878)	WV	I	LC

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Table 1. Checklist of birds recorded in agricultural fields of study area

Order/Family/Common name	Scientific name	Residential status	Feeding status	IUCN status
Ploceidae (2)				
Baya Weaver	*Ploceus philippinus* (Linnaeus 1766)	R	O	LC
Black-breasted Weaver	*Ploceus benghalensis* (Linnaeus 1758)	R	O	LC
Pycnonotidae (2)				
Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus 1766)	R	O	LC
Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus 1758)	R	O	LC
Sittidae (1)				
Chestnut-bellied Nuthatch	*Sitta castanea* (Lesson 1830)	R	O	LC
Stenostiridae (1)				
Grey-headed Canary Flycatcher	*Culicicapa ceylonensis* (Swainson 1820)	WV	I	LC
Sturnidae (6)				
Asian Pied Starling	*Gracupica contra* (Linnaeus 1758)	R	O	LC
Bank Myna	*Acridotheres ginginianus* (Latham 1790)	R	O	LC
Brahminy Starling	*Sturnia pagodarum* (Gmelin 1789)	R	O	LC
Common Myna	*Acridotheres tristis* (Linnaeus 1766)	R	O	LC
Common Starling	*Sturnus vulgaris* (Linnaeus 1758)	WV	O	LC
Jungle Myna	*Acridotheres fuscus* (Wagler 1827)	R	O	LC
Turdidae (1)				
Black-throated Thrush	*Turdus atrogularis* (Jarocki 1819)	WV	G	LC
Vangidae (1)				
Common Woodshrike	*Tephrodornis pondicerianus* (Gmelin 1789)	R	I	LC
Zosteropidae (1)				
Indian White-eye	*Zosterops palpebrosus* (Temminck 1824)	R	I	LC
Pelecaniformes Ardeidae (7)				
Black-crowned Night-heron	*Nycticorax nycticorax* (Linnaeus 1758)	R	O	LC
Cattle Egret	*Bubulcus ibis* (Linnaeus 1758)	R	C	LC
Grey Heron	*Ardea cinerea* (Linnaeus 1758)	WV	C	LC
Indian Pond-heron	*Ardeola grayii* (Sykes 1832)	R	C	LC
Intermediate Egret	*Ardea intermedia* (Wagler 1827)	R	C	LC
Little Egret	*Egretta garzetta* (Linnaeus 1766)	R	C	LC
Purple Heron	*Ardea purpurea* (Linnaeus 1766)	R	C	LC
Ciconiidae (3)				
Asian Openbill	*Anastomus oscitans* (Boddaert 1783)	R	C	LC
Painted Stork	*Mycteria leucocephala* (Pennant 1769)	WV	C	NT
Woolly-neck Stork	*Ciconia episcopus* (Boddaert 1783)	R	C	NT
Piciformes				
Picidae (2)				
Black-rumped Flameback	*Dinopium benghalense* (Linnaeus 1758)	R	O	LC
Brown-capped Pygmy Woodpecker	*Dendrocopos moluccensis* (Gmelin 1788)	R	I	LC
Piciformes Ramphastidae (2)				
Brown-headed Barbet	*Psilopogon zeylanicus* (Gmelin 1788)	R	F	LC
Coppersmith Barbet	*Psilopogon haemacephalus* (Muller 1776)	R	F	LC
Psittaciformes Psittaculidae (3)				
Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus 1766)	R	F	NT
Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus 1766)	R	F	LC
Rose-ringed Parakeet	*Psittacula krameri* (Scopoli 1769)	R	F	LC
Strigiformes Strigidae (1)				
Spotted Owlet	*Athene brama* (Temminck 1821)	R	C	LC

IUCN: International Union for Conservation of Nature and Natural Resources; R: Resident, WV: Winter Visitor, SV: Summer Visitor; C: Carnivorous; O: Omnivorous; I: Insectivorous; F: Frugivorous; G: Granivorous; N: Nectarivore; LC: Least Concern; EN: Endangered; VU: Vulnerable; NT: Near Threatened

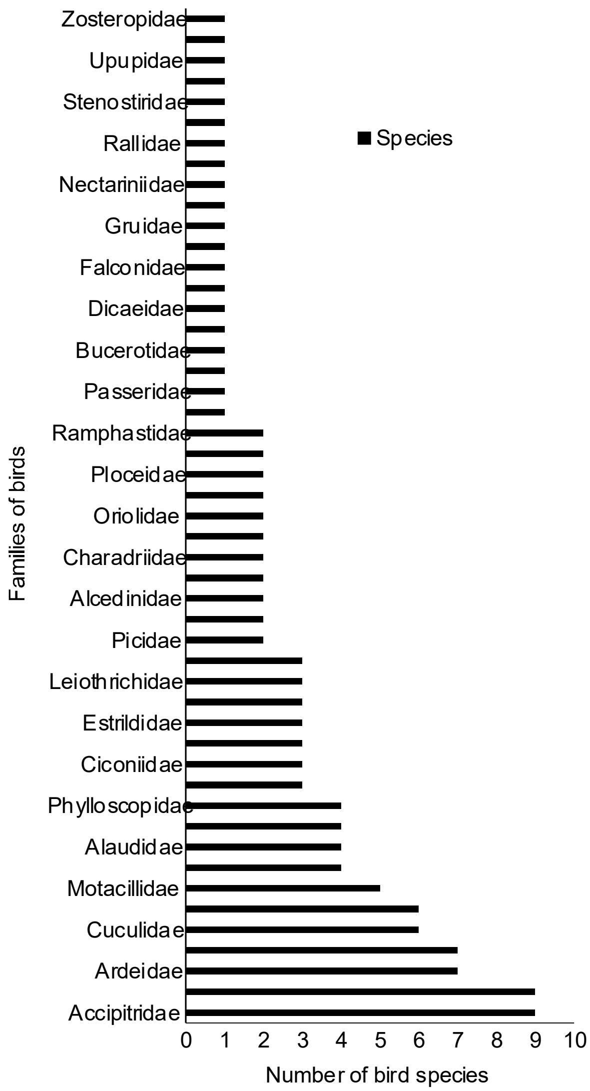

Fig. 3. Family wise bird community composition in agricultural fields of study area

CONCLUSION

This study provides the baseline information on bird species associated with the agricultural fields in the Ayodhya district of Uttar Pradesh. The results obtained from this research highlights that the agricultural landscapes support highly threatened species and therefore plays an important role in conservation of bird species outside protected areas. The results obtained from this research can be taken up by the policy makers and local environmental NGO's for further strengthening conservation measures in Uttar Pradesh.

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Digital Mapping of Soil Physicochemical Properties of Ramban District of Jammu and Kashmir using Geographic Information System

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Abstract: A study was carried out to assess and generate the prediction maps of the physicochemical properties of the soils in the Ramban district. The Ramban district of Jammu and Kashmir covers an area of 113787 ha and falls in the temperate zone of the state. It is an upland valley in the north-east corner of Jammu region. Soil samples were collected from the entire Ramban district in a stratified random manner. The digitization process and generation of maps was carried out with ArcGIS 10.0. Sandy loam was the dominant textural class in the district. Soil pH varied widely across the Ramban district ranging from as low as 5.70 to as high as 7.90. The electrical conductivity (EC) ranged from 0.16 to 6.90 dS m^{-1}.Organic carbon (OC) was found to be in a range from 0.11 to 1.95%.The calcium carbonate content ranged from traces to 2.20%. Cation exchange capacity (CEC) had values ranging from 4.34 to 42.04 cmol p^{+}/kg. Almost all recorded physicochemical properties of Ramban district soils were conducive for crop growth, although the major area of the district was either devoid of cultivation or difficult to cultivate because the region is having undulating topography.

Keywords: Mapping, Soil, Physicochemical properties, Geographic information system

Soil is a dynamic natural body which develops as a result of pedogenic natural processes during and after weathering of rocks(Wagh 2014). It consists of mineral and organic constituents, processing definite chemical, physical, mineralogical and biological properties having a variable depth over the surface of the earth and providing a medium for plant growth (Osman 2012). Soil is a heterogeneous, diverse and dynamic system and its properties change in time and space continuously. Heterogeneity may occur at a large scale (region) or at small scale (community), even in the same type of soil or in the same community (Hussain et al 2021). Soil which is a natural resource has variability inherent to how the soil formation factors interact within the landscape. However, variability can occur also as a result of cultivation, land use and erosion (Wani 2016, Singh et al 2021).Soil properties vary spatially from a field to a larger regional scale and it is affected by soil forming factors which can be termed as intensive factors and extrinsic factors such as soil management practices, fertility status and crop rotation (Gull et al 2020). Variability is an inherent soil condition, and its origin is influenced by both natural conditions (Various factors and pedogenic processes) and induced conditions through the use and management of them (Gull et al 2020, Sun et al 2003). Those soil properties that are most altered by soil management will be those with the greatest variability (Chhagan et al 2019, Jan et al 2020, Ovalles 1992). Sustainable crop production requires a good understanding of the fertility status of the soil in order to impose appropriate nutrient management strategies (Khadka et al 2018, Singh et al 2021). Fertility management based on soil tests is an effective strategy for enhancing productivity in agricultural soils with considerable geographical variability due to the combined effects of physical, chemical, and biological processes .The key markers of soil fertility include soil physical properties (Texture, structure), pH, organic matter, macro- and micronutrients, among many others (Brady et al 2008). These parameters can correctly determine plant growth and development. Understanding the current state of soil fertility is critical for developing effective soil management techniques and devising crop cultivation plans in the proposed area. Global Positioning Systems (GPS) and Geographic Information Systems (GIS) are also excellent tools for assessing soil spatial variability. The current study aims to improve soil resource management, agricultural production, and serve as a guideline for future research in the field. The main objective of this research was to determine various soil physico-chemical properties of district Ramban, to develop their maps and to delineate problem soil of district Ramban for future planning and management.

MATERIAL AND METHODS

Study area: Ramban district is in Jammu Division of Jammu and Kashmir UT of India (Fig. 1) and is located in the lap of Pir Panjal Range of the mighty Himalayas between at 33° 14' N and 75° 17'E longitudes with an average elevation of 1,156 metres from sea level. The temperature in case of District Ramban rises as high as 42°C in the low-lying areas, located in between steep mountains on the banks of river Chenab and drops to sub-zero in the high altitude areas. However, the average annual temperature is 21.1 °C. The climate of Ramban varies momentously due to its uneven topography. Ramban experiences a subtropical climate. Ramban district come under the climate type- Interior Mediterranean, mild winter, dry and hot summer. The average annual rainfall in the district is 1209 mm. The rainfall varies from place to place in the district due to topographic variation. The major crops grown in the district are maize and paddy, whereas the majority of the area is rainfed (90%) which is under cultivation.

Collection and analysis of soil samples: A total of 114 surface soil samples were taken randomly across whole district. Soil samples were taken on basis of stratified random sampling. Location coordinates of sampling sites The collected soil samples were air- dried, ground with wooden pestle and mortar and sieved through 2-mm sieve, labelled, stored and analysed for pH (1:2.5 soil: water suspension), EC (1:2 soil: water supernatant), organic carbon (OC) (Walkley & Black, 1934), $CaCO_3$ and Cation exchange capacity (CEC) by (Piper 1966). Soil texture was determined by the International pipette method. The USDA textural triangle was used for determining textural classes (Parkin 1993).

Mapping and interpolation: Mapping of spatial distribution of soil properties require spatial interpolation methods. In the present study, interpolation technique inverse distance weighting (IDW) was employed and soil maps of each property were generated using ArcMap 10.0. These interpolation techniques have been commonly used in mapping of soil properties (Caridad Cancela, 2002; Nayak et al 2006; Schloeder et al 2001).

RESULTS AND DISCUSSION

Soil texture: Ramban soils were classified into ten different categories depending upon the varying content of sand, silt, and clay. Clay loam texture was dominant (25.44%) in the district followed by clay, silty clay, silt loam, and silt clay loam soils represented sufficient samples (21.05, 17.54, 11.40 and 7.02%), respectively in the district (Fig. 2). Sand percentage in soil varied widely across district from as low as2.96% to as high as 86.96% (Table 1). The coefficient of variation (CV)

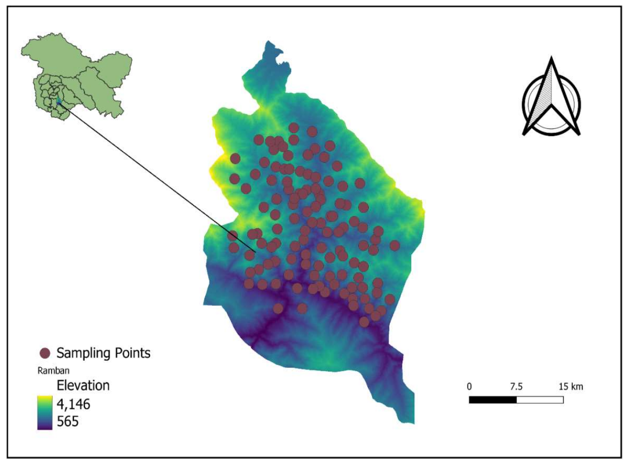

Fig. 1. Study area map and sampling points

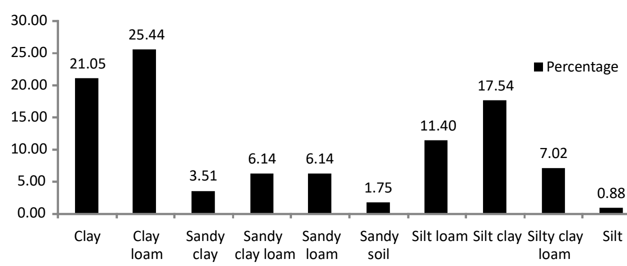

Fig. 2. Percentage distribution of different textural groups

Table 1. Descriptive statistics of sand, silt, clay, pH (1:2.5), electrical conductivity, calcium carbonate, organic carbon and cation exchange capacity of soils of Ramban District

Name of parameter	Minimum	Maximum	Range	Mean	Coefficient of variation (%)	Standard Error	Skewness	Kurtosis
Sand (%)	2.96	86.96	2.9-86.96	31.10	58.78	1.71	0.55	-0.08
Silt (%)	4.00	90.00	4.00-90.00	33.59	47.69	1.50	0.67	0.29
Clay (%)	7.04	67.04	7.04-67.04	35.30	36.47	1.20	-0.27	-0.21
pH	5.70	7.90	5.70-7.90	6.98	6.10	0.03	-0.67	0.42
EC (dS m^{-1})	0.16	6.90	0.16-6.90	1.01	113.71	0.10	3.20	11.71
OC (%)	0.11	1.95	0.11-1.95	0.86	49.24	0.04	0.33	-0.61
$CaCO_3$ (%)	----	2.20	0 -2.20	0.29	146.73	0.04	1.91	4.12
CEC (Cmol p+/kg)	4.34	42.04	4.34-42.04	19.73	40.66	0.75	0.33	-0.19

was 58.78%, skewness and kurtosis was 0.55and -0.08respectively. Based on skewness distribution was approximately asymmetric (>0.5) and negative kurtosis indicates that the distribution has lighter tail and flatter peak than normal distribution (Fig. 3a). Silt and clay also varied widely across district from as low as 4.00 and 7.04% to as high as 90.00 and 67.04% with CV of 47.69 and 36.47% (Table 1), respectively. Skewness and kurtosis were 0.67, -0.27 and 0.29, -0.21, respectively (Fig. 3b,c).Sand content insoils of Ramban district mainly varied between 20 to 40%. However, on south-western side sand content was between 40 to 60% (Fig. 2a). In case of silt majority area of district Ramban had silt content between 30 to 40%followed by area containing 20 to 30% (Fig. 2b).In clay majority of area in Ramban district had 20 to 30% clay followed by the area on eastern side having 40 to 50% clay content in soils, although scattered patches of less than 20 % clay were also noticed (Fig. 2c).Differentiation in the textural composition of soils is caused by pedogenic and geological processes (Schoonover & Crim, 2015). Soil organic matter and nutrient contents, pore size, water availability, and leaching losses of nutrients are controlled by the soil texture (Plante et al 2006; Scott et al 1996).

Soil pH: Soil pH is the key factor influencing soil organic matter, nutrient availability and their dynamics (Rasmussen et al 2018). The10.52% of the samples were in acidic range having pH less than 6.5, soil pH ranging from 6.5-7.5 constitute 85.08% and basic soils having greater than 7.5 constitute only 5.26% of the total soil samples (Table 2). Acidic soils can be attributed to hilly terrain, which leads to leaching of salts and making soils acidic. Soil pH in theRamban district varied across district from 5.70 to 7.90 with mean of 6.98 (Table 1). Frequency distribution curve of data was negatively skewed (-0.67) and kurtosis (0.42) (Fig. 3d). Suitable soils for most of the crops are in pH range of 6.5-8.7 (Havlin et al 2004). Coefficient of variation of data was recorded 6.10%. CV of pH is in consonance with the findings of Aishah et al (2010). Soils present in majority area of district Ramban was neutral to basic. Very small patches of the district on south-western side were acidic in reaction (Fig. 2d). The wide variation in soil pH was mainly observed due to variation in topography, slope and use of amendments at varying rates (Jiao et al 2016, Jatav et al 2007, Seibert et al 2007).

Electrical conductivity: EC of the soils ofRamban varied widely as low as 0.16to as high as 6.90 dS m^{-1} (Table 1). Frequency distribution curve of EC was positively skewed (3.20) (Fig. 5a). Soils with an EC<0.8 with mean value in that group 0.45 dS m^{-1} represented 62.28% of the total samples, other category where EC>0.8 with mean of 1.93 dS m^{-1}represented 37.71% of the total samples, respectively (Table 2). EC was mostly under safe limits except some patches where EC was more than critical value (Fig. 4a). Dissolved salts cause an ionic imbalance, which prevents nutrients from being absorbed. The fundamental effect of

Table 2. Critical ranges and distribution of pH (1:2.5), electrical conductivity, calcium carbonate organic carbon and cation exchange capacity of soils of Ramban district

Categories range	Mean	Percentage out of total Samples
pH		
Normal (6.5-7.5)	7.08	85.08
Acidic (< 6.5)	6.16	10.52
Basic (> 7.5)	7.63	5.26
EC		
Normal (< 0.8)	0.45	62.28
Saline (> 0.8)	1.93	37.71
$CaCO_3$		
0.0–1.00	0.22	93.85
1.01–5.00	1.54	6.14
Organic carbon		
Low < 0.40	0.22	11.40
Medium 0.40–0.75	0.55	30.70
High > 0.75	1.16	57.89
CEC		
Low < 20	13.82	55.26
High > 40	40.32	0.87

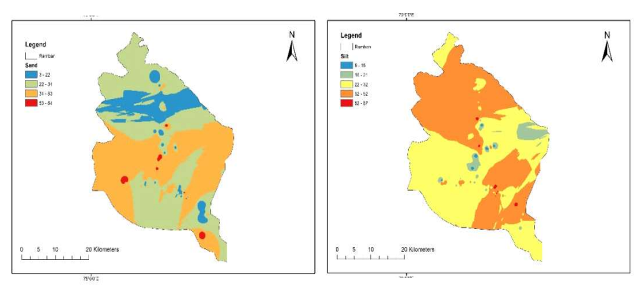

Fig. 3. Thematic maps of sand (a) silt (b), clay (c) and pH (d) of Ramban soils

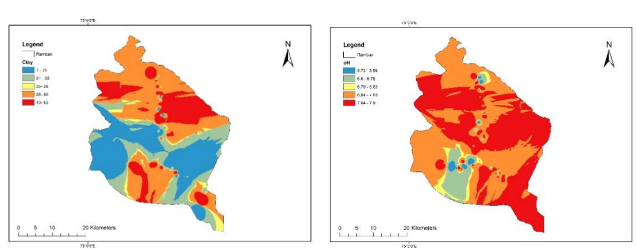

Fig. 4. Thematic maps of sand (a) silt (b), clay (c) and pH (d) of Ramban soils

high EC is the plant's inability to compete with ions in soil solution (Bajwa and Choudhary 2014). The high percentage of land in low EC could be attributable to salt leaching from intensive irrigated agriculture and the expansion of submerged paddy cultivation.

Calcium carbonate: Calcium carbonate is mainly derived from rock minerals. However, certain environmental conditions like more evaporation and less rainfall leads to its accumulation in soils. $CaCO_3$ content of soils ranged from traces to 2.20% (Table 1). Frequency distribution curve of $CaCO_3$ was positively skewed (1.91) (Fig. 5b). The first category (0.0-1.00% $CaCO_3$) had an average of 0.22% and the second category (1.01-5.0% $CaCO_3$) with 1.54% constituting 93.85 and 6.14% of the total samples taken, respectively (Table 2). The study area was non-saline, with lowest mean value observed in forests and highest in wastelands, which could be owing to $CaCO_3$ and salt accumulation in wastelands and a higher amount of decaying litter in the forest (Kiflu & Beyene, 2013). Shamsi et al (2010) revealed that high $CaCO_3$ is mainly in agricultural lands than in natural systems. Tillage action removes surface horizons with less calcium carbonate due to erosion, causing outcropping of the bottom horizons with more calcium carbonate, resulting in high $CaCO_3$ in agricultural land use. Vafaeizadeh et al (2016) observed that agricultural soils have more $CaCO_3$ than pasture and forest lands, which is compatible with the findings of our study. The Ramban Plateau lies in higher Himalayas which is coupled with an assemblage of silty material at the top (10-12m. thick) underlain by silt and angular fragments of mainly quartzites and schists (80m thick) mixed in varied proportions (Sharma et al 2012).

Organic carbon: Soil organic carbon is considered as vital and essential for maintaining soil productivity and health and also helps in the improvement of soil quality parameters (Funderburg, 2020).Organic carbon in soil varied from as low as 0.11% to high as 1.95% (Table 1). Frequency distribution curve of OC was slightly skewed (0.33) (Fig. 5c). In Ramban district southern side of district has more OC than northern side. OC content was higher mostly in forest areas (Fig. 4c). Many factors such as topography, land-use, field management and vegetation may influence the spatial variability of OC (Francaviglia et al 2017, Parras-Alcántara et al 2015, Sahoo et al 2019). Nine textural classes were reported in district (Fig. 1) with varying topography as Ramban District consists of hills and valleys. Out of total samples taken 11.40% were low, 30.70% were medium, and 57.89% were in high range (Table 1). The 57.89% of total samples were high in range comprising mainly of forest area. A likely explanation was that in the forest soils, lower temperatures at higher altitudes limited carbon decomposition, which resulted in increased carbon accumulation (Nath et al 2018). The higher SOC may be

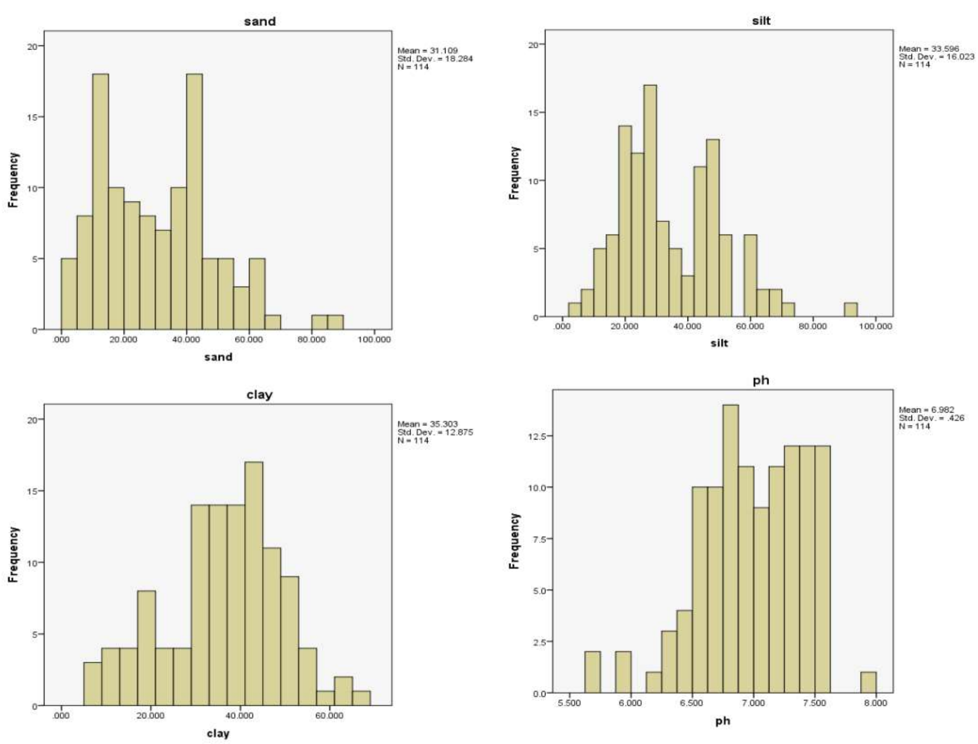

Fig. 5. Frequency distribution of sand (a), silt (b), clay(c) and pH (d) of Ramban soils

attributed due to high above and below ground biomass which increases soil OC by organic tissues, litter and secreting root exudates rich in binding agents increasing physical stability and microbial activity (Kukal et al 2008, Smith 2008, Wang et al 2014). Land use is a major factor influencing SOC storage because it affects the amount and quality of litter added, decomposition rate and processes of organic matter stabilization in soils.

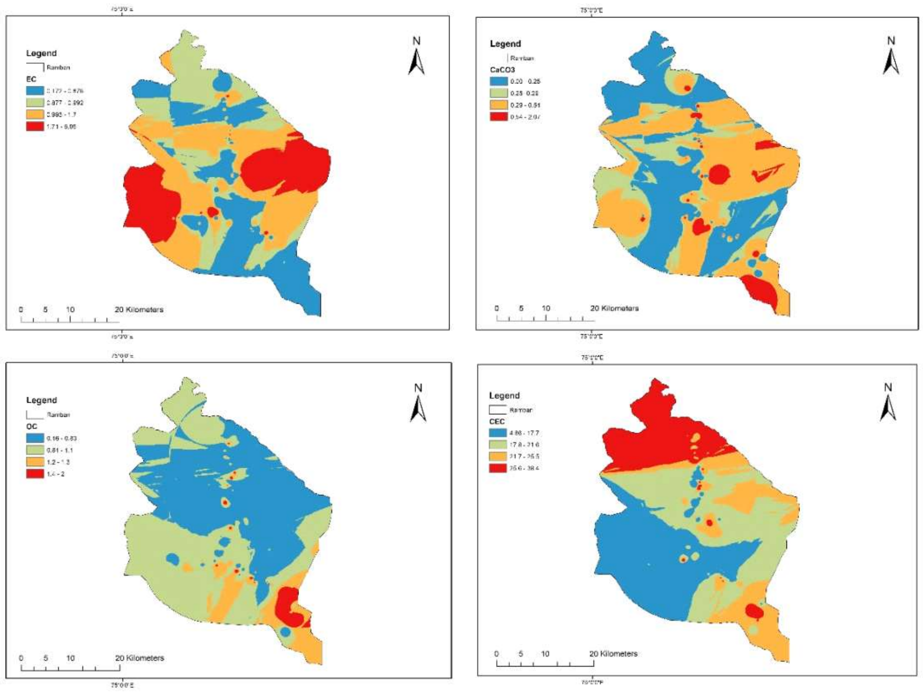

Fig. 6. Thematic maps of EC (a), $CaCO_3$ (b), OC (c) and CEC (d) of Ramban soils

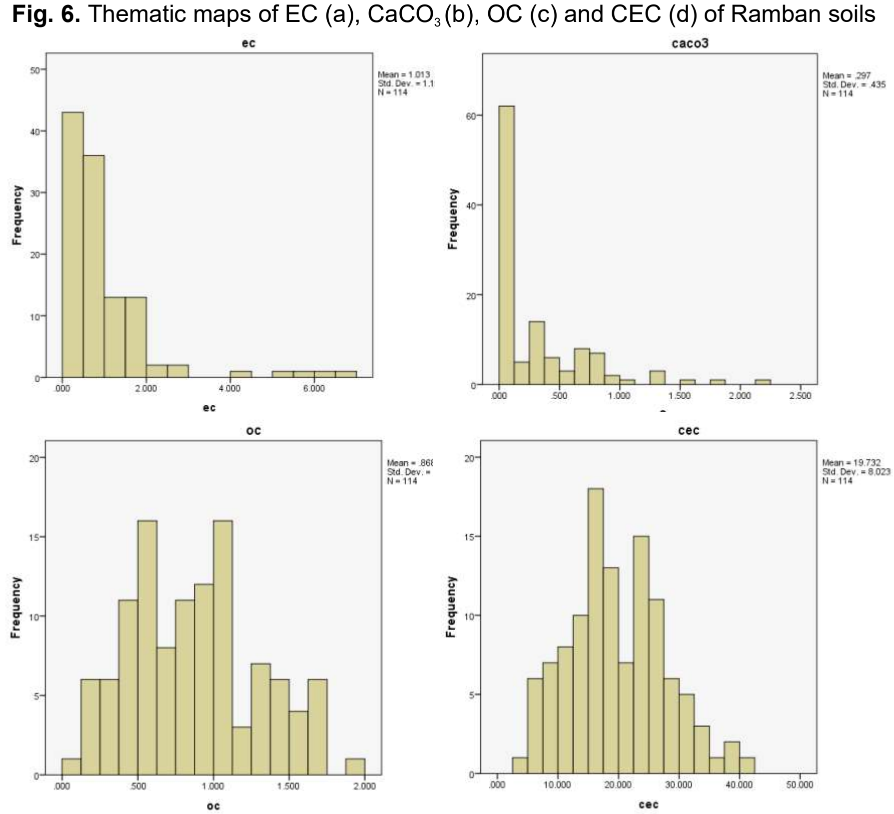

Fig. 7. Frequency distribution of EC (a), $CaCO_3$ (b), OC (c) and CEC (d) of Ramban soils

Cation exchange capacity: The CEC values ranged from 4.34 to 42.04 cmol p^+/kg. Different soil types, texture, land-use types, humus, clay and soil fertility management all contribute to this wide range of results (Selassie et al 2015, Huang et al 2016, Lazaratou et al 2020) (Table 2). Frequency distribution curve of CEC was slightly skewed (0.33) (Fig. 5d). The CEC was less than 20 cmol p^+/kg with mean value of 13.82 and in the other category >40 cmol p^+/kg with mean value of 40.32 cmol p^+/kg (Table 2) (Fig. 4c). CEC is an important indexing parameter for evaluating soil fertility and buffering capacity since it shows soil nutrient conservation and buffering capability (Bagherzadeh and Gholizadeh 2018, Muntiani 2021). Panagopoulos et al (2006) found that the kriging method performed better than IDW, while others showed that kriging was no better than alternative methods (Sekulic et al 2020, Fuhg et al 2021).

CONCLUSION

Majority of the soils in district were neutral in reaction, followed by acidic and alkaline soils. Due to lower temperatures at higher altitudes, it reduced carbon loss, where majority of the samples had a high OC concentration, resulting in increased carbon storage. The study area had mainly moderate CEC as recorded in majority of samples, followed by high CEC. Almost all of the physicochemical properties of Ramban district soils were favourable for crop cultivation, despite the fact that a large portion of the district was either barren or difficult to cultivate due to the study area's sloppy topography, which made cultivation difficult. We can plan resource allocation and distribution in the region with the help of the maps generated, where policymakers and state agencies will be able to draft appropriate development plans with the use of these maps.

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Screening of Rhizobacteria Isolated from Rice (*Oryza sativa* L.) and Chickpea (*Cicer arietinum* L.) from the Paddy Fields Near Mumbai and Exploring Their Potential

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Abstract: Rhizosphere provides all the necessary nutrients to plants by direct and indirect means. Plant Growth Promoting Rhizobacteria (PGPR) residing in rhizosphere are able to synthesize various metabolic compounds beneficial to plants and carry out different biological processes including Nitrogen fixation and Phosphate solubilization, etc. Current study focuses on gibberellic acid (GA_3) production and Phosphate solubilization. Gibberellic acid is one of the phytohormones responsible for the growth of the plants. Phosphate solubilization property of PGPR aid in the conversion of insoluble Phosphate into more soluble form and make it available to plants. 45 different soil samples were collected from the rhizosphere of rice and chickpea plant each. 319 isolates were obtained from the soil and were screened for Phosphate solubilization and production of gibberellic acid. Solubilization indices (SI) of the isolates were calculated and 10 isolates with maximum SI were screened for quantitative approach. Similar isolates were also screened for gibberellic acid production, both qualitatively and quantitatively. Maximum activity was obtained as 1208.57 µgP/ml and 82.820 mg/ml for phosphate solubilization and gibberellic acid production respectively. Most potent rhizobacterium was identified as *Stenotrophomonas maltophilia* using Fatty Acid Methyl Esterase (FAME) analysis. Isolates were also screened for Ammonia production.

Keywords: Plant Growth Promoting Rhizobacteria, Phosphate solubilization, Gibberellic acid production, FAME, Ammonia

India is one of the leading producers of agricultural crops and second largest producer of wheat and rice (Dey et al. 2020). Agricultural microbiology is a present principal research field responsible for the transfer of knowledge from general microbiology and microbial ecology to agricultural biotechnologies (Wang et al. 2009). Decrease in crop productivity and depletion of nutrients are the main drawbacks of intensive cultivation. Chemical fertilizers have depleted the natural resources and soil fertility. Thus, biofertilizers have become an important source to overcome these problems. Biofertilizers can be categorized as an organic product consist of a specific microorganism in concentrated form derived from rhizosphere or interior regions of the plant (Mishra 2014). Plants exhibit complex network of interactions with the soil microorganisms. Plant growth promoting rhizobacteria (PGPR) possess certain characteristics which directly or indirectly affect the growth of the plants (Arunjith and Sheeba 2021). Thus, soil bacteria play the key role in biogeochemical cycles and have been used for crop production for decades. The direct and indirect mechanisms of PGPR include nitrogen fixation, phosphate solubilization, auxin production, ammonia production, etc. Diverse group of microorganisms have been reported to solubilize insoluble phosphorous complexes and make it available in more usable form (Jha and Saraf 2015). Organic Phosphorous solubilization is also termed as mineralization of Phosphorous. This process arises in soil because of plant and animal remains, which happen to be the source of large amounts of organic Phosphorous compounds (Rodriguez and Fraga 1999). Gibberellins (GA_3) are prevalent phytohormones that elicit multiple metabolic functions requisite for plant growth. Such include flowering, fruit ripening and senescence, etc (Kim et al 2009). Bacteria such as *Azotobacter*, *Bacillus*, *Serratia*, *Pseudomonas*, *Enterobacter* have been shown to posses the abilities of Gibberellin production and Phosphate solubilization (Ahemad and Kibret 2014, Ambawade and Pathade 2015).

Present study deals with the isolation and characterization of microorganisms from the rhizosphere of Rice and Chickpea. Being seasonal crops, soil sampling was done in different months, different climates. Potent isolates were checked for their phosphate solubilization activity and gibberellic acid production activity. Microorganisms, since being rhizobacteria, happen to be a good biofertilizers option and can overcome the problems associated with agricultural aspects such as chemical fertilizers, soil infertility and minimum crop production.

MATERIAL AND METHODS

Sampling: Rhizosphere soil samples of rice (*Oryza sativa* L.)

and chickpea (*Cicer arietinum* L.) were collected from different regions of paddy fields of Karjat, Maharashtra, India. Approximately 0.5 to 1cm of the surface soil was scrapped off by means of spatula to avoid the contamination by surface microflora. A total of 45 samples each were collected from the rhizospheres of both rice and chickpea. Samples were brought to the laboratory in a zip lock bag and stored at 4°C until further processing. No particular sterility is maintained while sampling because of less chance of inclusion of air microflora (Reetha et al 2014).

Enrichment and isolation: One gm of each soil sample was inoculated in 40 ml of sterile Nutrient broth and incubated at room temperature for 48 hours on shaker. After incubation, loopful from each enriched broth was streaked onto sterile Nutrient agar plates. Plates were incubated for 48 hours at 28°C and the isolated colonies were further purified and maintained on Nutrient agar (Bharucha et al 2013).

Qualitative screening for phosphate solubilization: Purified isolates were spot inoculated on sterile Pikovaskaya's agar medium. Plates were incubated for 48 hours at room temperature. Plates were observed for the zone of clearance around the colonies (Suman et al.2016).

Qualitative screening for gibberellic acid (GA_3) production: GA_3 production was assayed qualitatively by phosphomolybdic acid method (Graham and Henderson 1960). Isolates giving positive results on Pikovaskaya's plates were grown in sterile Nutrient broth with Tryptophan and kept for incubation at room temperature for 48 hours. Cell free supernatant was obtained by centrifugation of enriched broth at 10000 rpm for 10 minutes. 10ml of supernatant was mixed with 5 ml of Phosphomolybdic acid reagent (12gm Phosphomolybdic acid in 250ml Ethanol). Mixture was boiled in a boiling water bath for 1 hour and tubes were observed for green coloration.

Quantitative screening for phosphate solubilization: Isolates giving clear halo around the colonies on Pikovaskaya's medium were checked further for quantitative study. Positive isolates were enriched in 40ml sterile Pikovaskaya's broth on shaker for aeration. After 48 hours of incubation at room temperature, cell free supernatant was obtained by centrifugation of enriched broth at 10000 rpm for 10 minutes. It was then subjected to Molybdenum blue method for quantification. 10ml of 1:10 diluted supernatant was mixed with 20ml Ammonium Molybdate solution and 0.25 ml of 2.5% Stannous Chloride. Absorbance of color developed was measured spectrophotometrically at 660nm and concentration was determined using standard Phosphate graph (Wei et al 2017).

Quantitative screening for gibberellic acid (GA_3) production: Positive isolates were grown in sterile nutrient broth with tryptophan. Samples were kept for incubation at room temperature for 48 hours in shaking condition. Cell free supernatant was obtained by centrifugation of enriched broth at 10000 rpm for 10 minutes. 10ml of cell free supernatant was mixed with 5ml of phosphomolybdic acid reagent. Mixture was then placed in boiling water broth for 1 hour. After boiling, tubes were cooled in an ice water bath. Absorbance was measured spectrophotometrically at 660 nm and concentration was determined by standard Gibberellic acid graph (Graham and Henderson 1960).

Ammonia production: Isolates were grown in sterile Peptone water broth and kept for incubation for 24 hours at room temperature. Nesseler's reagent was added to the tubes after incubation and checked for deep orange yellow colouration (Shobha and Kumudini 2012).

Identification of potent bacterial isolate: Most potent bacterium was analyzed for the identification by fatty acid methyl esterase (FAME) analysis using MIDI Sherlock microbial identification system. Isolates were analyzed with gas chromatography method and isolates were identified by their fatty acid composition. Procedure was followed as per protocol. Cells were harvested and are placed in a clean test tube. This follows the method of saponification where reagent mixture containing Sodium Hydroxide, Methanol and distilled water is added to the tubes containing cells. Tubes are vortexed and put in a water bath for 30 minutes and cooled further. After saponification, methylation process involves the addition of reagent 2 which is a mixture of 6N HCl and Methyl Alcohol. Tubes are again heated and further cooled. Extraction process involves the addition of reagent 3 (Hexane and tert-butyl ether) which extract the fatty acid methyl ester into the organic phase to be used further for gas chromatography. Before chromatography analysis, samples are washed using Sodium Hydroxide and distilled water. Samples were subjected for Gas chromatography analysis of fatty acid methyl esterase.

RESULTS AND DISCUSSION

Enrichment and isolation: After enrichment of soil samples, total of 319 different isolates were obtained on Nutrient agar. Isolates were purified further and stored on Nutrient agar slants at 4°C.

Qualitative screening for phosphate solubilization: Out of 319, 58 isolates showed clear zone on Pikovaskaya's agar after incubation. Solubilization index (SI) of each isolate was calculated (Table 1). Final 30 microorganisms showing maximum SI were processed further for quantitative study. Clear halo zone by the isolate was obtained (Fig. 1).

Qualitative screening for gibberellic acid (GA_3) production: Thirty isolates giving Phosphate solubilization index above 1.50 also showed positive results for Gibberellic acid production. Green coloration was observed in the tubes after boiling the mixture in the water bath.

Quantitative screening for phosphate solubilization: All 30 isolates were subjected for quantitative study by molybdenum blue method and the 10 isolates showing maximum solubilization activities were selected for future study (Table 2).

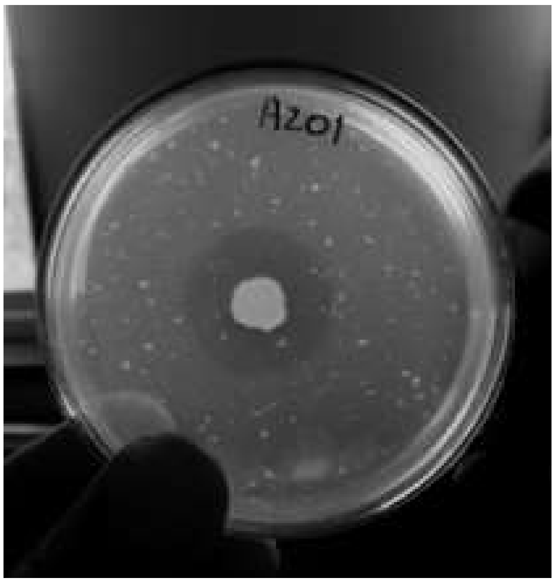

Fig. 1. Organism showing clear zone around the colony

Quantitative screening for gibberellic acid (GA_3) production: All the 30 isolates were subjected for Gibberellic acid quantification by Phosphomolybdic acid method. Above potent isolates showed similar results for the GA_3 production described in Table 2.

Ammonia Production

Above potent isolates which were incubated in Peptone water developed deep yellow-orange coloration after addition of Nesseler's reagent indicating Ammonia production (Table 3).

Identification of isolate: The most potent isolate BDC23 was identified as *Stenotrophomonas maltophilia* on the basis of fatty acid composition. Gas chromatogram of the isolate and dendrogram is given below in Figure 4 and 5 respectively. Distribution of the data set and histogram was displayed in Figure 6. Figure 7 depicts the rooted NJ tree which shows distance of isolate from related organisms.

Phosphate solubilizing bacteria (PSB) as inoculants increases the Phosphorous uptake by the plant roots. Amount of solubilized Phosphorous was 1208.537 ± 34.880 µgP/ml for isolate BDC23. These results agree with the values by Liu et al (2014). Their study obtained the results of phosphorous solubilization as 717 ±12.7 µgP/ml from the

Table 1. Solubilization indices of the isolates

Isolate	Solubilization index	Isolate	Solubilization index	Isolate	Solubilization index
BAC 11	2.09	BDC 31	3.62	SAC 31	2.05
BAC 12	1.62	BDR 22	1.33	SAR 21	2.20
BAC 13	1.01	BDR 31	2.09	SAR 22	1.32
BAC 21	1.13	BDR 32	1.41	SBC 12	1.95
BAC 22	1.53	MAC 11	1.62	SBC 31	1.44
BAR 11	1.99	MAC 12	2.04	SBC 32	1.55
BAR 13	1.25	MAC 13	1.05	SBR 11	1.10
BAR 21	1.56	MAC 22	3.55	SDC 11	3.42
BAR 22	1.33	MAR031	2.33	SDC 13	2.04
BAR 32	1.55	MAR 33	1.19	SDC 21	2.11
BBC 12	2.75	MBC 12	1.77	SDC 22	1.03
BBC 13	1.81	MBC 13	1.13	SDC 23	1.39
BBC 21	1.09	MBC 31	1.26	SDR 12	1.54
BBC 22	1.83	MBC 32	1.82	SDR 13	1.95
BBC 31	1.22	MBR 21	1.31	SDR 21	1.36
BBC 32	1.75	MDC 11	2.09	SDR 23	1.74
BDC 12	1.47	MDC 12	1.19	SDR 32	2.21
BDC 13	1.84	MDC 31	2.50	SDR 33	1.11
BDC 14	1.12	SAC 21	2.33		
BDC 23	3.71	SAC 23	1.12		

microorganisms obtained from *Areca catechu* L. (Betel nut). Experiment conducted by Zamoum et al (2015) demonstrated the P solubilization activity of 702 mg/L from the isolate ZL2 which was isolated from native plants of Algerian Sahara. Goudjal et al (2016) agrees with the method

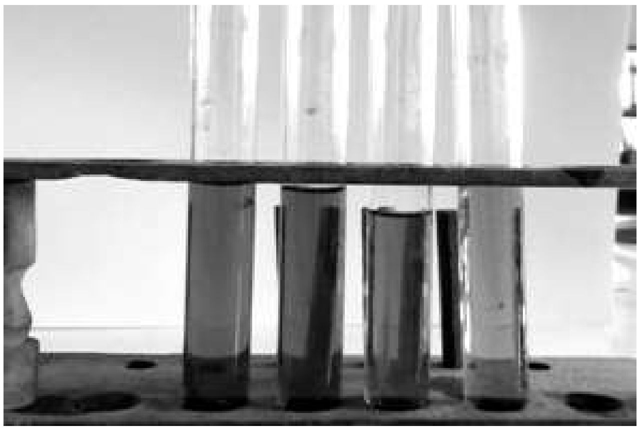

Fig. 2. Green coloration for GA_3 production

Table 2. Phosphate solubilization and Gibberellic acid production by potent isolates(Mean ± standard Deviation

Isolate	Phosphate solubilization (µgP/ml)	Gibberellic acid production (µg/ml)
BBC 12	508.883 ± 16.679	58.563 ± 4.016
BDC 23	1208.573 ± 34.880	82.820 ± 2.316
MDC 31	615.757 ± 9.764	87.052 ±1.905
SDC 11	485.093 ± 23.424	72.709 ± 1.240
BDC 31	740.470 ± 23.480	48.594 ± 0.739
SAC 21	804.187 ±12.163	78.076 ± 1.293
MAR 31	786.007 ± 33.741	49.402 ± 1.337
MAC 22	495.800 ± 41.764	69.132 ± 2.737
SAR 21	1194.980 ± 15.301	80.486 ± 1.251
SDC 21	800.450 ± 17.182	54.440 ± 1.902

Table 3. Production of ammonia by potent microbial isolates

Isolate	Result
BBC 12	+
BDC 23	+
MDC 31	+
SDC 11	+
BDC 31	-
SAC 21	+
MAR 31	-
MAC 22	+
SAR 21	-
SDC 21	-

Key: + = Ammonia production; - = No production

and the results obtained from our findings. Values described in table 1 for isolate BDC23 and other isolates were found to be much higher than those obtained by Perez et al (2007) and Pradhan and Shukla (2005). Gibberellins (GA_3) are important plant regulators which are concerned with the regulation of plant responses to external environment (Shah et al 2007).

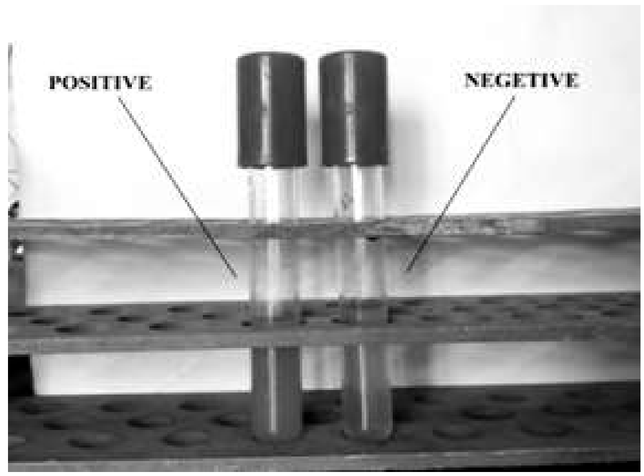

Fig. 3. Ammonia production

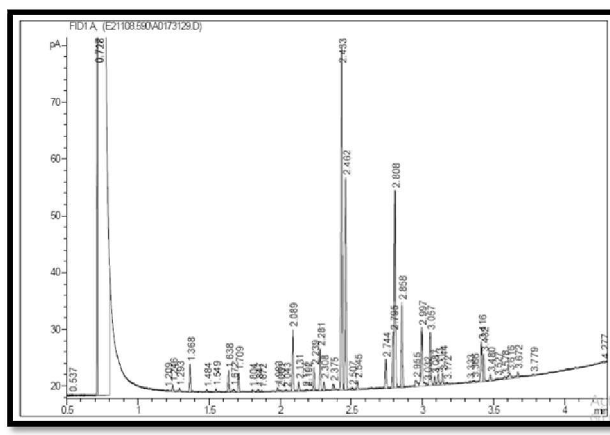

Fig. 4. Gas chromatographic run of BDC23

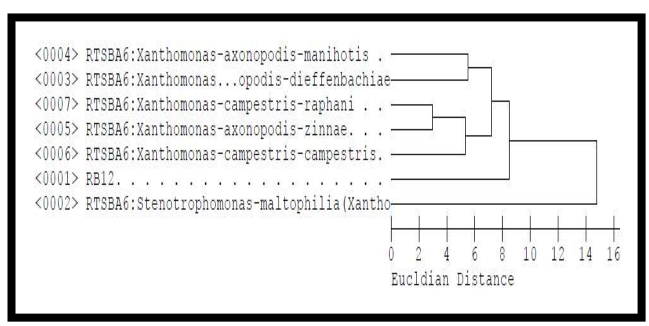

Fig. 5. Dendrogram (Pair matching based on fatty acid composition)

Fig. 6. Histogram (Distribution of the data set and graphical summary)

Index	Se l	Volume:Filename#Cntr	Bottl e	ID Num	Sample ID
1	Y	DATA:E211085.90A#17	15	3129	RB12
2	Y	RTSBA6 # 802		802	Stenotrophomonas-maltophilia(Xanthomonas, Pseudomonas)
3	Y	RTSBA6 # 878		878	Xanthomonas-axonopodis-dieffenbachiae
4	Y	RTSBA6 # 882		882	Xanthomonas-axonopodis-manihotis
5	Y	RTSBA6 # 891		891	Xanthomonas-axonopodis-zinnae
6	Y	RTSBA6 # 893		893	Xanthomonas-campestris-campestris
7	Y	RTSBA6 # 894		894	Xanthomonas-campestris-raphani

Gibberellins production by microbial inoculants increases the seed germination, floral induction, fruiting and various other regulations, etc. (Bottini et al 2004). Isolates MDC31 and BDC23 produced Gibberellic acid as 87.052 ± µg/ml and 82.820 ± µg/ml respectively. Pandya and Desai (2014) Gibberellic acid production which was in the range of 7.5

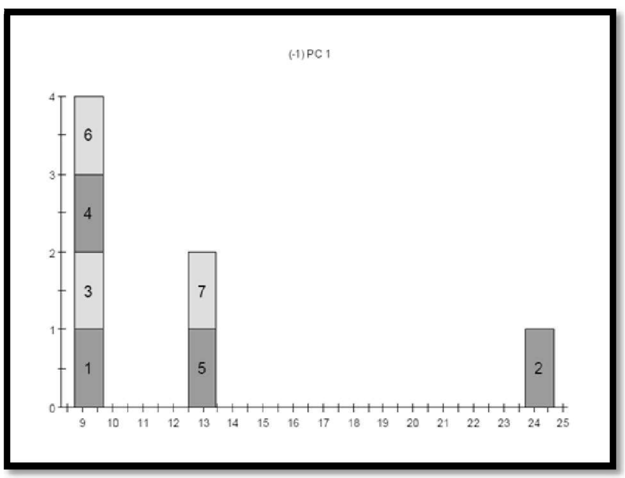

Fig. 6. Histogram (Distribution of the data set and graphical summary)

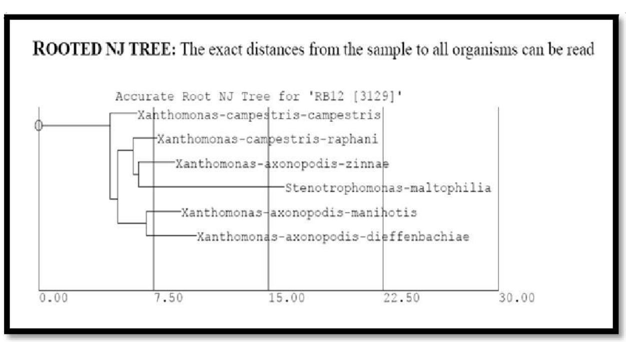

Fig. 7. Rooted NJ Tree to display the exact distance of sample from all related organisms

mg/L to 93.93 mg/L. Sivasakthi et al (2013) observed that isolate *Pseudomonas fluorescens* L. reported maximum Gibberellic acid production of 5.96µg/ml and least production (2.89µg/ml) were obtained by *Bacilus subtilis* L.

Out of 10 isolates, 6 microorganisms were positive for Ammonia production. Ammonia production increased the plant biomass significantly by *Bacillus subtilis* MA-2 and *Pseudomonas fluorescence* MA-4 (Mishra et al 2010). Study carried out by Singh et al. (2020) states that out of 56 rhizobacterial strains, 16 were found positive for Ammonia production. Results obtained by Suman et al. (2016) wherein isolate PLP and DMP 1 were able to produce significant amount of Ammonia (Suman et al. 2016). Despite being an opportunistic human pathogen, *Stenotrophomonas maltophilia* has been found beneficial for plant interactions. Messiha et al. isolated bacterial samples from the rhizosphere of Eggplant and after FAME analysis, potent isolate was identified as *S. maltophilia* (Messiha et al 2007).

CONCLUSION

Present investigation focuses on the bacteria which are capable for producing phytohormones such as Gibberellic acid and other Auxins along with Phosphate solubilization activity and could be easily isolated and further exploited for agricultural use. Synthetic fertilizers degrade the quality of soil, pollute surface and groundwater, and exert harmful effects on soil microflora. Thus, microbial applications, so called biofertilizers, have been proven to be the best remedy towards these problems. Microbial communities carry out essential part of nutrient recycling, pathogen suppression, etc. Isolates obtained in this study can be used as potential biofertilizers and can increase the crop productivity over mineral fertilizers.

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Isolation, Identification and Applications of *Schizophyllum commune* ns29: A Chambal Ravine Soil Isolate

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Abstract: *Schizophyllum commune* is one of the versatile and important mushroom funguses, used in numerous applications. This study explored the occurrence and molecular identification of *Schizophyllum commune* in ravine soils and their potential applications with pharmaceutical importance. During cultivation studies the mushroom isolate exhibited moderate growth in used compost. The fungal isolate produces alkaloids, flavonoids and vitamin C which are useful in various applications, Fe metal Chelation and DPPH free radical scavenging activities were also investigated. The maximum Fe metal chelation activity was 69.32% whereas the maximum inhibition of free radical was 41.86%. Extracellular bioactive molecules of this strain under stationary phase were identified by Gas chromatography Mass Spectroscopy (GCMS). Polysiloxanes are the major compounds out of which cyclohexasiloxane is the major contributor with 57.17% of total. Through this study it could be concluded that the isolated fungal strain *Schizophyllum commune* ns29 has many medicinal properties that could be a base for further studies and cyclohexasiloxane made this isolated industrial potable because it is used in various cosmetic formulations.

***Keywords*:** DPPH radical scavenging activity, Fe metal chelation, GCMS, *Schizophyllum commune*, Mushroom cultivation

Soil is a reservoir of microbes, and they are the key component of soil ecosystem (Stefanis et al 2013, Raja et al 201). Ravines are the landforms which comprise of undulating surfaces steep sharp hillocks, and cut slopes formed due to extensive water erosion and soil loss (Chitranshi & Bhat 2018a). Fungi are the natural source of bioactive molecules of therapeutic and industrial potential, they play key roles in regulation & maintenance of ecosystems and have shown promising results in food, medicine, agriculture, textile, and bioremediation etc., though fungal biotechnology is an integral part of human welfare (Chitranshi & Bhat 2018b). Thus, the identification and exploration of microbial flora from unexplored geographical distribution is utmost important. Mushrooms are worldwide renowned for their medicinal properties (Karthikeyan & Gopalakrishna 2014). They are the source of non-toxic and physiological importance medicines (Stefanis et al 2013, Raja et al 2017) and contain a variety of antioxidants such as carotenoids vitamin C and E, free radical scavenging bio molecules, like polyphenols and polysaccharides (Liu et al 1997, Wasser and Weis 1999) that have created interest of protection against degenerative diseases (Mau et al 2002).

Shizophyllum commune is an edible mushroom which is majorly consumed in Thailand, Malaysia and East India (Kalac 2009). *Schizophyllum commune* reported as a good source of vitamin C as well as the fungus has ability to produce schizophyllan which has shown good anti-cancerous potentiality. Therefore, the mushroom can be used in treatment of cancer. Simultaneously, the fungus has many industrial approaches like beauty and care because it has got good free radical scavenging activity and vitamin C is widely used in manufacturing of beauty care products. The production of *S. commune* and other medicinal mushrooms has increased due to the ease of cultivation, increase in popularity and its nutritional value(Silva et al 2013, Kholoud et al 2014). Molecular characterization is becoming a recent and useful tool for identification of unknown fungal samples. Since the microbial flora of ravine soil of Chambal has not been explored very much, hence the exploration of microbial communities from ravine soils of Chambal, Morena, India is very limited thus the basidiomycetous fungus documented from Chambal ravine soil for the first time. The isolation and identification of *S. commune* ns29 was done so far simultaneously the pharmacological potentials, the production of bioactive molecules such as alkaloid, flavonoid, phenols, and vitamin C was assessed and Fe metal chelation and DPPH free radical scavenging activity of the isolate were evaluated. This present work comprises molecular characterization of obtained fungal isolate and assessment of the pharmacological potentials and industrial importance of *Schizophyllum commune* ns29 Chambal ravine soil basidiomycetous fungal isolate.

MATERIAL AND METHODS

Sample collection and isolation: The soil sample was collected from ravines of Morena located at Latitude 26º42' North, Longitude, 77º44' East. The samples were collected in sterile bags and transferred to the laboratory kept at 4^{O}C, prior to use.

Isolation of fungal isolate: 0.1 g of the soil sample was serially diluted and each dilution was spread inoculated on agar plate supplemented with 1% streptomycin, incubation was held at 25 ±2 ^{O}C for seven days (Gaddeyya et al 2018, Reddy et al 2018). After incubation pure colony was obtained by subsequent inoculation of single colony on potato dextrose agar plate, for further studies slants were prepared and maintained (Javadi et al 2012, Jasuja et al 2013, Gaddeyya et al 2018).

Morphological and microscopic identification: Morphological (size, color, hyphae, pigmentation) and microscopic attributes (lactophenol cotton blue stain) were observed and recorded (Gaddeyya et al 2018).

Molecular identification: Genomic DNA was isolated from a week old fungal culture kit method was used for extraction and PCR amplification, ITS1 and ITS4 primers were used for amplification of ribosomal internal transcribed spacer (Mazutti et al 2017, Sohhail et al 2018) purification of PCR product was done by using Montage PCR clean up kit (Millipore) following the instructions given by manufacturer. The obtain amplicon were sequenced by using ABI PRISM Genetic Analyzer (Applied Biosystems) (Mazutti et al 2017, Staden et al 2003). BigDyeTM Terminator Cycle Sequencing Kits with AmpliTaq, DNA polymerase (FS enzyme) (Applied Biosystems) was used. The fragments were analyzed to obtain a consensus sequence which is compared with the other related sequence by BLAST search, obtained from the sequence deposited to the Genbank (NCBI) (Javadi et al 2012, Landeweert et al 2003 and Liu et al 2000). MUSCLE 3.7 is used for multiple alignment (Edgar 2004) and the resulting aligned sequences were cured using the program Gblocks 0.91b. This Gblocks eliminates poorly aligned positions and divergent regions (removes alignment noise) (Talavera & Castresana 2007) Finally, the program PhyML 3.0 aLRT was used for phylogeny analysis and HKY85 as a Substitution model. The program Tree Dyn 198.3 was used for tree rendering (Dereeper et al 2008).

Mushroom cultivation: *S. commune* is described as an edible mushroom among the Malay community, thus the attempts were made for production of fruiting body, the process accomplished in following steps:

Mother culture preparation: Mother culture was prepared *via* inoculating the fungus on Sabouraud's Dextrose Agar (SDA) then incubated for thirteen days at 30±2ºC. After that the culture was used for production of spawn.

Spawn preparation: 200gm of wheat grains were poured into boiling water and kept there for 20 minutes, after pouring the grains were sieved till the humidity reached 50%, 0.5% of $CaCO_3$, and CaSO4 were added to it, mixed together and distributed in a spawn bag, autoclaved. Mother culture of *Schizophyllum commune*ns 29 was added to the bag and incubated at 25±2ºC.

Development of fruiting body: Wheat straw with sawdust (3:1) as compost was used, appropriate amount of compost was taken then chemically treated (overnight soaked in formalin) to remove other microbial contaminants, then the soaked composed cleaned by washing with double distilled water (DDW) & transferred into sterile polybags. Produced fungal spawn was placed in containers containing compost and containers were kept at 28 ±2ºC for 60 days.

Production of bioactive compounds: The fungal isolate was grown on SDA plate after five days of incubation disc of actively grown isolate culture was cut and inoculated into nutrient medium (Prasher 2017) 50 ml of sabouraud's dextrose broth in an Erlenmeyer flask (250 ml), the flask were incubated at 30±2℃ for seven days as stationary culture after incubation from fermentation broth the mycelium was filtered through Whatmann filter paper no.1 (Kaur et al 2020) and by centrifugation at 4000 rpm for 15 minutes (Teoh & Mashitah 2013) thereafter the extraction was followed with equal volume of ethyl alcohol at room temperature the obtained extract was allowed to evaporate in a vacuum evaporator.

Phytochemical screening: Presence of bioactive molecule such as alkaloid, Tannins, Steroid, Phenolic compounds, Saponins and flavoniods in mycelial extract of *S. commune* ns29 was evaluated, following the methods was used present in the extracts following alkaloids (Mayor's test), saponins (froth test), flavonoids (alkaline reagent test) steroid, tannins and phenol (Ferric chloride test) followed the standard procedures (Tiwari et al2011, Ghani 2013).

Evaluation of vitamin C synthesis: To determine the presence of Vitamin C AOAC titrimetric method was used as explained by Nielsen. Five milliliter of fungal extract was titrated with DCPIP reagent, appearance of distinct light pink color for more than 5 seconds confirms the presence of vitamin C, experiment was performed in triplicates and ascorbic acid expressed as mg of L-ascorbic acid equivalents (AAE) per 100 g of fresh weight of the fungus (Abeysuriya 2020).

Metal chelating activity: Metal chelating activity was determined by method described by Chew et al 2009. 200µl of fungal extracts at different concentrations, 0.2 ml FeSO4 (0.1 mM) and 0.4 ml ferrozine (0.25 mM) was added and incubated at room temperature for 10 minutes after the absorbance was recorded at 562 nm. Metal chelating capacity was measured using the following equation

$$(A_{control}-A_{sample})/A_{control} \times 100$$

DPPH assay: The DPPH free radical scavenging activity of the fungal extract was investigated by the Blois method described by Esmaeilli & Sonoboli, 2010 with minor modifications. 1:1 ratio of fungal aqueous of each concentration was added to 1ml of 0.1mM methanolic solution of DPPH, incubated for 30 min. in dark. Absorbance was recorded at 517 nm and the % inhibition activity was estimated from $[(A_o-A_1)/A_o] \times 100$, where A_o is the absorbance of the control (DPPH solution) and A_1 is the absorbance of the extract/standard. The DPPH free radical scavenging activity curves were prepared.

Gas Chromatography Mass Spectroscopy (GCMS): Obtained aqueous extract was subjected for GC-MS analysis to reveal its bioactive compounds composition. The column TG 5MS (30m X 0.25mm, 0.25µm) with injector S/SL was used injector temperature was 250ºC, MS transfer line temperature was 300ºC, ion source temperature was 230ºC. Helium was used as carrier gas and carrier flow was 1 ml/min. The temperature was 60˚C for 2.0 min; 10˚C/min 280˚C by10.0 min and the detector used was MS TSQ 8000 TRIPLE QUADRUPOLE MS. Injection volume had 1.0µl prepared in ethanol having Split flow 1ml/min. The mass spectra had taken at 75 eV with mass scan range from m/z 40-500 amu. The individual constituents had identified by comparing their mass spectra with those of standard using NIST (National Institute of Standards and Technology, U.S. Department of Commerce) compounds Identification was accessed by comparing the obtained spectrum of unknown with known compounds spectra with those of standard available at NIST (National Institute of Standards and Technology, U.S. Department of Commerce) library database.

RESULTS AND DISCUSSION

In the present study soil fungal isolate *Schizophyllum commune* ns29 of Chambal ravine isolated and characterized. The colony appears wooly, whitish in 4 – 5 days on SDA at 25 ±2^{o}C, reverse brown-black edges, growth moderate mycelium monomitic, hyphae hyaline/white, thin walled septate, have clamp connection 1.5-4.0 µm in diam (Fig. 1). After morphological and microscopic identification 18S rDNA analysis was done for further characterization. PCR amplification of extracted DNA was performed with ITS1 and ITS4 primers. The amplified ITS region of *Schizophyllum commune* ns29 isolates was sequenced and the obtained nucleotide consensus sequence was subjected to a similarity search by using BLAST programme. The result supported and confirmed by morphological and microscopic identification of obtained Chambal ravine soil fungal isolate. The comparison of ITS region (ITS1, 5.8SrDNA, and ITS4) was evaluated with the sequence previously deposited to the GenBank, the consensus sequence of *S . commune* ns29 (1001 bp) showed that the highest and nearest genetic similarity (100%) with the record sequence of *Schizophyllum commune* from Tamilnadu, India KX04183 of 1772 bp and *Schizophyllaceae* sp. of 1782 bp from China (Table 1, Fig. 2). In the present study for identification ITS sequencing molecular identification was followed similar method was adopted by Mazutti et al (2017) and Sohhail et al (2018).

Mushroom cultivation: Fruiting body fan shaped shell-like leathery, sessile. Upper surface is light grayish brown when moist and ash gray when dry, hairy. Lower surface light gray, longitudinal split gills, stipes absent, flesh thin gray to brown, 0.5 – 2.0 cm in height and 0.4 to 1.5 cm diam. Basidia clavate, thin walled, club-shaped, hyaline. Basidia typically produces four basidiospores from four sterigmata, basidiospores, oval to cylindrical, smooth, hyaline, having lateral scars at lower end, 4-6 X 1.5-2.5 µm. Though, *S, commune* is known as edible mushroom and widely consumed in Malaysia, Thailand etc. thus the cultivation was performed and the healthy fruiting bodies were developed in compost (wheat

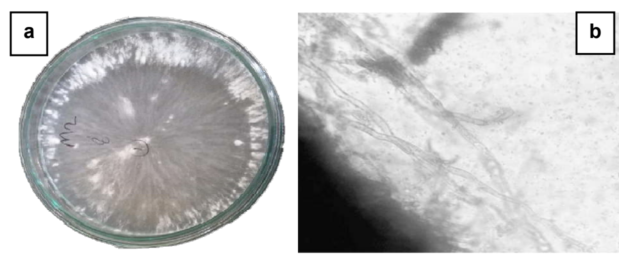

Fig. 1. *Schizophyllum commune* (a) Colony on SDA plate and (b) Mycelium

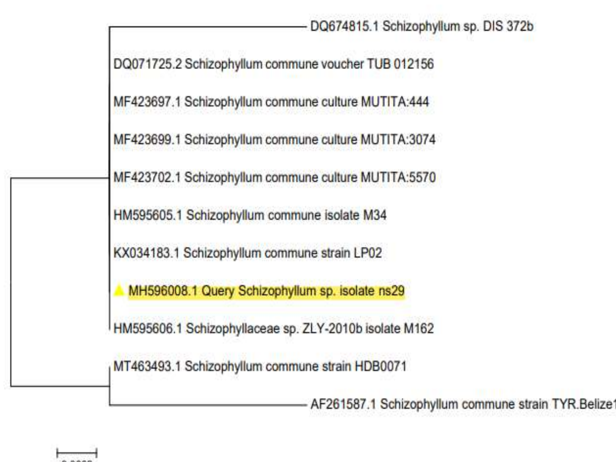

Fig. 2. Phylogenetic tree constructed

straw and sawdust) within 45 days of incubation at 30 °C. In the present study the growth of fruiting body was moderateby Bran-González et al (2009) also suggested the similar cultivation period of 28-48 days whereas Figlas et al (2014) reported cultivation period of 36 days.

In this study wheat straw and sawdust was used as compost whereas Dasanayaka & Wijeyarntne (2017) observed sawdust as the good compost for cultivation of *Schizophyllum commune* at 35ºC, sunflower shells by Figlas et al (2014,) maize stalks and cobs in (1:1) ratio by Bran-González et al (2009) whereas Silvia et al (2018) observed enhanced basidiocarp while using coconut fibers and cocoa shell for cultivation.

Production of bioactive compounds and screening of vitamin C: The extracellular bioactive molecules production was studied, Phenols, and flavonoids were shownpositive. The isolate is capable to produce vitamin C during submerged fermentation in the stationary phase. The amount of vitamin C produced by mycelial extract of fungal isolate *S. commune*ns29 is 0.43mg/l which is similar to the findings were reported by Okwulehie et al 2007, they have reported 0.49mg/100g of dry weight vitamin C. Duthie & Crozier (2000) and Choi et al (2000) reported the presence of vitamin C in fungus *S. commune*, supported the present findings.Similar findings have been suggested by Mirfat (2001) and Kumar et al (2019) observed the presence of alkaloid and flavonoid in extract of *S. commune.*

Iron metal chelation activity: The presence of Fe metal chelating activity of *S. commune* ns29 (fermented broth) mycelial extract against various concentration ranges from 100-500 µg/ml and all the concentration exhibited Fe metal chelation activity (Fig. 3). The maximum activity of 69.32% was displayed at 500 µg/ml concentration and the lowest 27.13% at 100 µl/ml. Although Mayakrishnan et al (2013) reported 81.29% of Fe metal chelation activity (in fruiting body extract).

DPPH free radical scavenging activity: This method is widely used to evaluate antioxidant activity in a short in comparison to other methods. DPPH free radical scavenging activity exhibited by fungal extract of *S, commune* ns29 the activities were demonstrated in concentration dependent manner (Fig. 4). The maximum inhibition 41.86%was demonstrated at 500µg/ml concentration. Mayakrishna et al (2013) reported 70.52% of free radical scavenging activity.

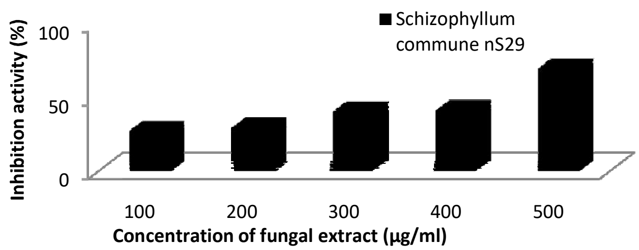

Fig. 3. Metal chelating activities of fungal extract at different concentrations

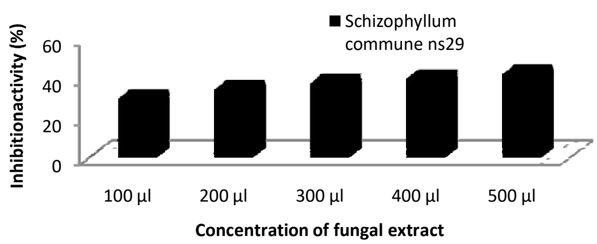

Fig. 4. DPPH radical scavenging activities of fungal extracts at different concentrations

Table 1. Similarity index of consensus sequence with NCBI database

Fungus	Name of strain or isolate	Origin	Most similar sequence (GenBank database)	
			Accession no.	Sequence similarity (%)
**Schizophyllum sp.*	ns29	India	MH596008.1	-
Schizophyllum commune	LP02	India	KX034183.1	100
Schizophyllaceae sp.	M162	China	HM595606.1	100
Schizophyllum commune	M34	China	HM595605.1	100
Schizophyllum commune	SKB0071	Korea	MT463493.1	100
Schizophyllum commune	MUT<ITA>:5770	Italy	MF423702.1	100
Schizophyllum commune	MUT<ITA>:3074	Italy	MF423699.1	100
Schizophyllum commune	MUT<ITA>:444	Italy	MF423697.1	100
Schizophyllum sp.	DIS 372b	USA	DQ674815.1	100
Schizophyllum commune	TUB 012156	Germany	DQ071725.2	100
Schizophyllum commune	TYR Belize 1	USA	AF261587.1	100

* = represents the obtained query sequence

Devi et al (2014) reported 50% DPPH scavenging activity at 1.5 mg/ml concentration. Mirfat et al (2014) observed the phenolic content of *S. commune* is the main contributor of radical scavenging activity.

GCMS analysis: GCMS is one of the most accurate methods for compound analysis. The ethanol extract of *S. commune* ns29recorded a total of five peaks corresponding to the bioactive metabolites that were recognized by relating their peak retention time, peak area (%), height (%) and mass spectral fragmentation patterns to that of the known compounds described by the National Institute of Standards and Technology (NIST) library. GC–MS chromatogram of the ethanol extract from *S. commune* ns29 recorded five peaks. Overall, the major metabolites identified in the ethyl alcohol along with their retention timeare presented in Table 2. The GCMS chromatogram of fungal extract is displayed in Figure 5. The prevailing chemical constituents were characterized by GCMS analysis as shown in Figure 6. The obtained data shows the presence of polysiloxane compounds. *S.commune* ns29 produced three major metabolites the prevailing compound is cyclohexasiloxane (57.71%), followed by octasiloxane (23.17%) and cyclodecasiloxane (19.12%) recognized with persistence of important biological activities in many applications. Mayakrishnan et al (2013) reported 44 different constituents in fruiting body extract of *S. commune* out of which octadecanamide was the prevailing compound. In the present study derivatives of siloxanes are the principal constituent of obtained strain *S. commune* ns29 (Mycelia extract) though it could be interpreted that in mycelia stage siloxanes are the major constituent of *S. commune* whether in fruiting body/ basidium number of constituents increased gradually. Sabri et al 2020 were performed metabolites assessment by GCMS analysis mycelium of *Agaricus bisporus* and *Pleurotus ostreatus* was exhibited 17 and 15 chemical compounds with acetol as a prevailing compound in both fungal extract whereas Qiu et al 2019 followed GCMS analysis for metabolite assessment of bio-control fertilizer production by fungal strain. In the present

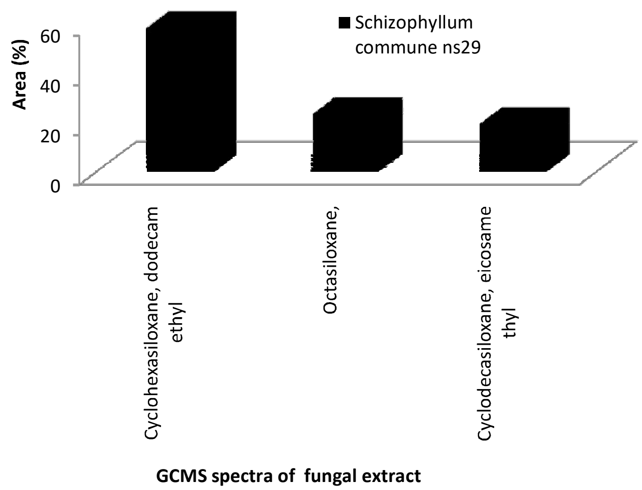

Fig. 6. GCMS chromatogram of volatile metabolites produced by *Schizophyllum commune* ns29

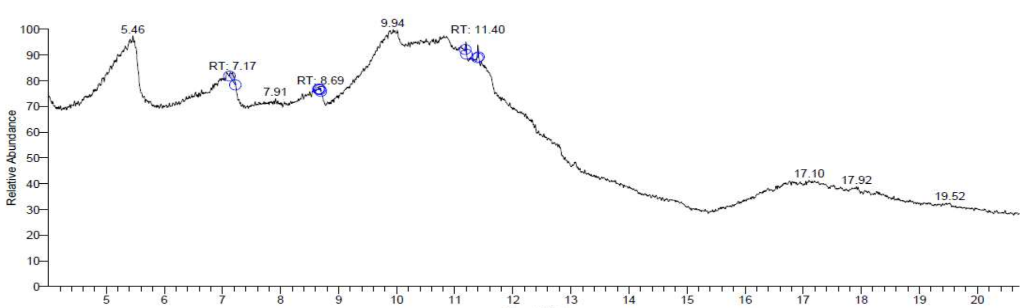

Fig. 5. GCMS peak summary of volatile metabolites produced by *Schizophyllum commune* ns29

Table 2. GCMS Qual peak summary of compounds produced by *Schizophyllum commune*

RT	Moleular formula	Compound	Area (%)
7.17	$C_{12}H_{36}O_6Si_6$	Cyclohexasiloxane, dodecamethyl	57.71
8.66	$C_{16}H_{50}O_7Si_8$	Octasiloxane,	2.08
8.69	$C_{16}H_{50}O_7Si_8$	Octasiloxane,1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15 hexadecamethyl	3.19
11.19	$C_{16}H_{50}O_7Si_8$	Octasiloxane,1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15 Hexadecamethyl	17.90
11.40	$C_{20}H_{60}O_{10}Si_{10}$	Cyclodecasiloxane, eicosamethyl	19.12

study siloxanes were found as the dominating metabolites which are of industrial concern (have application in cosmetics) the compound cyclohexasiloxane reported as hair and skin conditioners.

CONCLUSION

This is the first report of isolation and identification of *Schizophyllum commune* from ravine soil of Chambal, Morena, M.P., India. Wheat straw and sawdust showed moderate growth of the fruiting body while used as compost. GC-MS revealed the bioactive molecules spectra of produced by *Schizophyllum commune* ns29 has industrial potential and reported for the first time under static submerged fermentation, the extract exhibited valuable biological properties such as synthesis of vitamin C, alkaloid, flavonoid and displayed good DPPH free radical scavenging and metal ion chelation activity. The study presented *Schizophyllum commune* NS29 as a natural fungal source of pharmacological importance thereby producing a variety of antioxidants, showing good free radical scavenging and Fe metal chelation activity. The authors suggested that further studies are required to obtain cyclohexasiloxane (at large scale of) cosmetic potential from fermented broth, iron (Fe) metal chelation activities to be investigated in detail.

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Effect of Different Land Use Pattern on Soil Characteristics, Microbial Biomass Carbon and Nitrogen in Red Soils of Vikarabad District

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***Abstract*:** This study is aimed to determine the impact of different land use patterns *i.e.,* forest land, 100% cropping intensity (redgram-fallow), 200% cropping intensity (rice-rice) and fallow land on soil microbial biomass carbon and nitrogen. A survey was conducted in the year (2019-20 and 2020-21) in red soils of Vikarabad district covering eight mandals and soil samples were collected from four different land use pattern at two depths (0-15 and 15-30cm). Soil characteristics like bulk density, pH, EC, organic carbon, total nitrogen varied significantly with land use patterns and soil depth was significantly higher in forest soils compared to other land use patterns. The mean microbial biomass carbon was 242.8 mg kg^{-1}, 128.1 mg kg^{-1}, 119.0 mg kg^{-1}, 69.0 mg $kg^{-1}$and the mean soil microbial nitrogen was 35.6 mg kg^{-1}, 21.9 mg kg^{-1}, 17.7 mg kg^{-1} and 11.0 mg kg^{-1} respectively for forest, 100% and 200% cropping intensity and fallow land. There was significant positive correlation of microbial biomass carbon with per cent clay (0.998**), soil organic carbon (0.992**), total nitrogen (0.984**) and microbial biomass nitrogen (0.997**). The results confirm that alterations in soil physical and chemical properties due to deforestation and intense anthropogenic activity at agriculture lands may cause disturbances and ultimately affect the soil microbial biomass.

***Keywords*:** Microbial biomass C, Microbial biomass N, Land use pattern, Red soils, Forest

Soil organic matter is an important component of soil quality and productivity. However, its measurement alone does not adequately reflect changes in soil quality and nutrient status. Measurements of biologically active fractions of organic matter, such as microbial biomass carbon (MBC) and nitrogen (MBN) and potential C and N mineralization, could better reflect changes in soil quality and productivity that alter nutrient dynamics. This reflection is based upon rapidly changing capacity of both C and N forms (Pal et al 2020). These fractions gives an indication of soil organic matter changes induced by management practices. The importance of microorganisms in ecosystem functioning has led to an increased interest in determining soil microbial biomass. The soil microbial biomass is the active component of the soil organic pool, which is responsible for organic matter decomposition affecting soil nutrient content and consequently, primary productivity in most biogeochemical processes in terrestrial ecosystems (Haney et al 2012). Therefore, measuring microbial biomass is a valuable tool for understanding and predicting long-term effects under the influence of different land use pattern and associated soil conditions (Sharma et al 2011). The present study was conducted to assess the impact of different land use patterns on soil characteristics, microbial biomass carbon and nitrogen in red soils of Vikarabad district.

MATERIAL AND METHODS

Vikarabad district is one of the newly carved district from erstwhile Rangareddy in Telangana state. The geographical area of the district is 3,386 sq.km and is situated between 17°20'11.15"N latitude and 77°54'17.45"E longitude. The net cropped area in the district is about 20.4 lakh ha and has a forest cover of 44,548 ha and fallow land to an extent of 20,769 ha. The main crops cultivated in the district are redgram, maize, rice and vegetables. The main tree species found in the forest were *Tectona grandis, Eucalyptus, Acacia nilotica, Tamarindus indica, Leucaena leucocephala, Dalbergia sissoo, Ficus benghalensis, Pongamia pinnata, Syzygium cumini etc.* Fallow land was not disturbed and unmanaged and they were having mixed grasses other plant species and weeds. The climate in this region is semi-arid and characterized by warm summers. According to the climatological data gathered over the past 30 years, the mean maximum and minimum temperatures found to be in the range of 28-45^{0}C and 12-26^{0}C (Directorate of Economics and Statistics, 2021).

Soil sampling: A survey was carried out in the year (2019-20 and 2020-21) and soil samples at two depths (0-15 and 15-30cm) were collected from eight mandals in Vikarabad district predominantly covered by red soils. Five villages in each mandal were selected and from each village, four land use patterns were selected out of which two were from agricultural land use with different cropping intensity *i.e.,* 100% cropping intensity (redgram-fallow cropping system), 200% cropping intensity (rice-rice cropping system) and two from natural conditions *i.e.,* forest and fallow land. A total of 320 soil samples were collected at two depths. The microbial biomass carbon and microbial biomass nitrogen were analysed in fresh soil samples within 24h. For determination of other soil properties, the soil samples were air dried, pounded and stored in polythene bags for further analysis.

Soil analysis: The soil samples were analysed for salient characteristics like texture, pH, EC, bulk density, soil organic carbon (g kg^{-1}) and total nitrogen (kg ha^{-1}) following standard procedures. For determination of Soil Microbial Biomass Carbon, field-moist soil samples (10.0 g) were exposed to $CHCl_3$ vapour for 24 h and extracted with 0.5 M K_2SO_4. A second set of non-fumigated samples was also extracted under similar conditions. The difference between C obtained from the fumigated and from the non-fumigated ones was taken to represent the microbial C-flush and converted to MBC using the relationship : MBC = 1/0.41 C-flush (Christian et al 2000).All results are expressed on an oven-dry soil basis (105°C, 24 h).

Microbial biomass nitrogen was also estimated using the same principle of microbial biomass carbon. The K_2SO_4 extractant of both fumigated and un-fumigated soil was digested for 3 h with addition of digestion mixture and sulphuric acid. After cooling, distillation was carried out to find the total nitrogen content. The difference between fumigated and un-fumigated extracted nitrogen of soil divided by a calibration factor (KEC) 0.38 gives the measure of microbial biomass nitrogen in soil and expressed as micro gram of microbial biomass-N per gram of dry soil (Beck et al 1997).

Statistical analysis: The data collected was statistically analysed using SPSS statistical package version 18.0.

RESULTS AND DISCUSSION

The data on salient soil characteristics *viz;* bulk density, pH, EC, organic carbon and total nitrogen obtained are presented in (Table 1). The soil samples in general were sandy loam to sandy clay loam in texture with clay per cent ranging from 35.96 to 40.28 %.

Bulk density (Mg m^{-3}): The average bulk density indicated that 200% cropping intensity (rice-rice) recorded the highest bulk density (1.45 Mg m^{-3}) followed by 100% cropping intensity (1.41 Mg m^{-3}), fallow land (1.39 Mg m^{-3}) and forest land recorded the lowest bulk density (1.33 Mg m^{-3}). The interaction effect between depth and land use pattern for soil bulk density was significant. Across the depth at 15-30cm the highest BD was obtained by 200% cropping intensity (1.48 Mg m^{-3}) this was followed by 100% cropping intensity, fallow land and the lowest were recorded under forest land use (1.36 Mg m^{-3}). There was an increase in bulk density from 0-15cm (1.37 Mg m^{-3}) to 15-30cm (1.43 Mg m^{-3}). The increase in bulk density with increase in depth in all the land use system may be attributed to lower organic matter content and soil compaction from the pressure of upper soil layer (Devi et al 2013).

Soil pH and EC: The soil pH under different land use pattern on an average, indicated that the soils under forest land use recorded the lowest soil pH (6.68) followed by fallow land, 100% cropping intensity (redgram-fallow) and the highest was recorded in 200% cropping intensity (rice-rice) (7.72). Among the depths there was increase in soil pH from 7.27 to 7.43. Interaction effect between soil pH and land use pattern was significant with forest soils recording the lowest soil pH (6.56) followed by fallow land, 100% cropping intensity, 200% cropping intensity at 0-15cm.At 15-30cm soil depth the pH of the soil increased and same trend was followed among all the land use patterns.

The highest soil electrical conductivity was recorded under 200% cropping intensity (rice-rice) (0.28 dSm^{-1}) this was followed by 100% cropping intensity (redgram-fallow) cropping pattern, fallow land and the lowest was recorded under forest land use (0.18 dSm^{-1}).With increase in soil depth the EC of the soil decreased in all the land use pattern. The interaction between depths and land use pattern for soil EC was significant with highest EC being recorded by 200% cropping intensity (rice-rice) (0.30 dSm^{-1}) at 0-15 depth. A close perusal of the data on soil pH and EC indicates that the soils sites having lower pH shows lower EC values especially in forest and fallow lands. Similar results were obtained by (Barros and Chaves 2014 and Shah et al 2013). An increase in total soluble salt content has been reflected by an increase in EC under cultivated soils this could be due to the addition of fertilizers and other amendments.

Soil organic carbon (g kg^{-1}): The data pertaining to soil organic carbon is presented in (Table 1). Irrespective of soil depth on an average, the highest soil organic carbon content was under forest land (7.05 g kg^{-1}) which was followed by 200% cropping intensity (rice-rice), 100% cropping intensity (redgram-fallow) and lowest was seen in fallow land (2.68 g kg^{-1}). However with increase in depth the mean organic carbon decreased from (4.72 gkg^{-1}) to (3.87 g kg^{-1}). Interaction effect between soil depth and land use pattern was significant and it varied from 7.30 g kg^{-1} in forest soils at 0-15cm to 2.24 g kg^{-1} in fallow land at 15-30cm.

Higher amount of organic carbon under forest land could be attributed to leaf litter decomposition at the surface. It was observed that about 60-80% total carbon resources are in oxidizable form due to the presence of higher amount of soluble extractives like fat, waxes and alcohol soluble extractives in forest residues. Among the cropping systems, 200% cropping intensity (rice-rice) has shown significantly higher SOC. This might be due to continuous submergence of soils for 8-9 months in an year under rice-rice cropping system, prolonged water logging conditions may reduce the decomposing of added crop residues (Mandal et al 2008). However the lower values of SOC under fallow lands could be attributed to the very low amount of addition of residues in the form of leaf litter to the soil though the soil was not disturbed for longer period of time. Significant decrease in organic carbon in the lower layers could be due to the decreasing input of surface litter in the lower depth.

Total nitrogen (kg ha^{-1}): The total nitrogen varied across the land use patterns and soil depth. The forest land recorded the highest mean total nitrogen (1577.1 kg ha^{-1}) followed by 100% cropping intensity (redgram-fallow) (1250.5 kg ha^{-1}) and 200% cropping intensity (rice-rice) (1212.5 kg ha^{-1}) but were on par with each other and lowest was under fallow land .With increase in depth of soil the total nitrogen content reduced from 1346.8 kg ha^{-1} (0-15cm) to 1150.8 kg ha^{-1} (15-30cm).Interaction effect between depth and land use pattern was significant with highest total nitrogen content in forest land at 0-15cm (1679.4 kg ha^{-1}) and lowest was recorded in fallow land at 15-30cm depth (897.6 kg ha^{-1}). The higher total nitrogen in the surface soil layers of forest land might be due to lack of disturbance which reduced the mineralization rate which contain plenty of plant litter. Similar results showing

Table 1. Effect of land use patterns on soil characteristics in Red soils of Vikarabad district

Depth	Bulk density (Mg m^{-3})	pH	EC (dSm^{-1})	Organic carbon (g kg^{-1})	Total nitrogen (kg ha^{-1})
D_1 (0-15cm)	1.37^{A}	7.27^{B}	0.25^{A}	4.72^{A}	1346.8^{A}
D_2 (15-30cm)	1.43^{B}	7.43^{A}	0.23^{B}	3.87^{B}	1150.8^{B}
Land use pattern					
L_1:100% cropping intensity (redgram-fallow)	1.41^{b}	7.59^{b}	0.25^{ab}	3.42^{c}	1250.5^{b}
L_2:200% cropping intensity(rice-rice)	1.45^{a}	7.72^{a}	0.28^{a}	4.14^{b}	1212.5^{b}
L_3:Forest land	1.33^{d}	6.68^{d}	0.18^{b}	7.05^{a}	1577.1^{a}
L_4:Fallow land	1.39^{c}	7.43^{c}	0.23^{c}	2.68^{d}	955.0^{c}
Interaction					
D_1L_1	1.39 ± 0.01^{d}	7.50 ± 0.05^{c}	0.27 ± 0.04^{ab}	3.90 ± 0.21^{d}	1375.0 ± 96.8^{d}
D_1L_2	1.43 ± 0.02^{bc}	7.64 ± 0.07^{b}	0.30 ± 0.03^{a}	4.54 ± 0.18^{c}	1320.3 ± 56.35^{c}
D_1L_3	1.30 ± 0.02^{f}	6.56 ± 0.09^{f}	0.19 ± 0.01^{de}	7.30 ± 0.14^{a}	1679.4 ± 97.53^{a}
D_1L_4	1.36 ± 0.01^{e}	7.38 ± 0.09^{d}	0.25 ± 0.02^{bc}	3.12 ± 0.16^{e}	1012.5 ± 85.08^{f}
D_2L_1	1.44 ± 0.01^{b}	7.66 ± 0.04^{b}	0.24 ± 0.04^{bc}	2.94 ± 0.26^{e}	1125.1 ± 95.69^{f}
D_2L_2	1.48 ± 0.02^{a}	7.79 ± 0.05^{a}	0.26 ± 0.03^{ab}	3.73 ± 0.24^{d}	1105.7 ± 65.04^{e}
D_2L_3	1.36 ± 0.03^{ef}	6.80 ± 0.06^{e}	0.17 ± 0.01^{e}	6.80 ± 0.15^{b}	1474.8 ± 83.00^{b}
D_2L_4	1.42 ± 0.01^{b}	7.48 ± 0.03^{c}	0.22 ± 0.02^{cd}	2.24 ± 0.16^{f}	897.6 ± 90.25^{g}

Mean values with different lower case superscript letters indicate significant difference between land use patterns for each soil depth and all land uses.Uppercase superscript letters indicate significant difference between depths for all land use system respectively at ($P<0.05$).± indicates standard deviation of mean

Table 2. Correlation matrix between different soil properties, microbial biomass carbon and nitrogen

Parameters	Clay	pH	EC	Bulk density	Organic carbon	Total nitrogen	MBC	MBN
Clay	1							
pH	0.220	1						
EC	0.602	0.810	1					
Bulk density	0.886	0.292	0.775	1				
Organic carbon	0.992**	-0.320	-0.699	-0.917	1			
Total nitrogen	0.984*	-0.101	-0.560	-0.920	0.990**	1		
MBC	0.998**	-0.240*	-0.631	-0.905	0.996**	0.992**	1	
MBN	0.997**	-0.217	-0.630	-0.922	0.993**	0.994**	0.973**	1

*Correlation is significant at the 0.05 level; **Correlation is significant at 0.01 level higher total nitrogen concentrations in the top soils under forestland than agricultural land use was also been reported by (Bohra and Ghosh et al 2013).

Effect of land use pattern on soil microbial biomass carbon and nitrogen (mg kg^{-1} soil): Among all the land use patterns studied the highest microbial biomass carbon was recorded in forest land (242.8 mg kg^{-1}) which was followed by 100% cropping intensity (redgram-fallow), 200% cropping intensity (rice-rice) and lowest was recorded in fallow land (69.0 mg kg^{-1}) (Fig. 1). While considering the land use pattern across the depths the interaction effect for microbial biomass carbon was significant and forest land use recorded the highest value (262.10 mg kg^{-1}) followed by 100% cropping intensity, 200% cropping intensity and lowest was in fallow land (82.8 mg kg^{-1}) at 0-15cm. At 15-30cm similar pattern was seen where forest soils recorded the highest MBC (223.6 mg kg^{-1}) and lowest was in fallow land (55.2 mg kg^{-1}). With increase in depth the average, microbial biomass carbon decreased from (158.2 mg kg^{-1}) to (121.3 mg kg^{-1}). The higher content of microbial biomass carbon under forest as compared to other land use could be possibly due to the effect of more addition of litter in the form of fine roots biomass and aerial plant residues. Among the cropping systems comparatively higher MBC under redgram-fallow cropping system could be due to the diversity of organic materials which contained greater concentration of MBC and enzymes under redgram especially under long term experiment in semiarid tropics. The MBC under 200% cropping system (rice-rice) were lower than that of 100% cropping system (redgram-fallow). The shift in microflora from aerobic to facultative anaerobes and weak microbial metabolism caused by oxygen limitation as a result of continuous water logging resulted in decreased biomass carbon in rice-rice system (Pal et al 2020). Compared to all the land use patterns the fallow land contained lower values of biomass carbon this could be attributed to the very little turnover of plant residues to the soil and also could be attributed partly due to less input of organic matter resulting in lack of substrate of growth of microbes in soil (Pal et al 2020).

Microbial biomass nitrogen (mg kg^{-1}): Among all the land use pattern studied the highest microbial biomass nitrogen (MBN) was recorded in forest land (35.6 mg kg^{-1}) which was followed by 100% cropping intensity (redgram-fallow), 200% cropping intensity (rice-rice) and lowest was seen in fallow land (11.0 mg kg^{-1}). While considering the land use pattern across the depth the interaction effect for microbial biomass nitrogen (Fig. 2) was significant and forest land use recorded the highest mean (40.0 mg kg^{-1}) which was followed by 100% cropping intensity (redgram-fallow), 200% cropping intensity (rice-rice) and lowest was recorded in fallow land (13.9 mg kg^{-1}) at 0-15cm. At 15-30cm the similar pattern was seen where forest soils recorded the highest MBN (31.2 mg kg^{-1}) and lowest was recorded in fallow land (8.2 mg kg^{-1}). With increase in depth the average, microbial biomass nitrogen decreased from (24.7 mg kg^{-1}) to (18.2 mg kg^{-1}). MBN was much lower in fallow soils as compared to other land use pattern. The higher amount of MBN in 100% cropping intensity than 200% cropping intensity could be attributed to the biological N fixation by rhizobia in root nodules of redgram in addition to the fertilizers addition to the soil which might have been utilized by microbes for their growth. A close perusal of the data indicated that MBN followed the same trend as MBC indicating that the dynamics of nitrogen in soil is closely linked to carbon which is present in the organic form for their energy which in turn influences the microbial activity in soil.

Correlation matrix between different soil properties, microbial biomass carbon and nitrogen: The per cent clay had a significant positive correlation with organic carbon (r=0.992**), MBC (r=0.998**), MBN (r=0.997**) and the total nitrogen (r=0.984**). The microbial biomass carbon values showed significant positive correlation with MBN (r= 0.973**), organic carbon (r=0.996**), total nitrogen (r

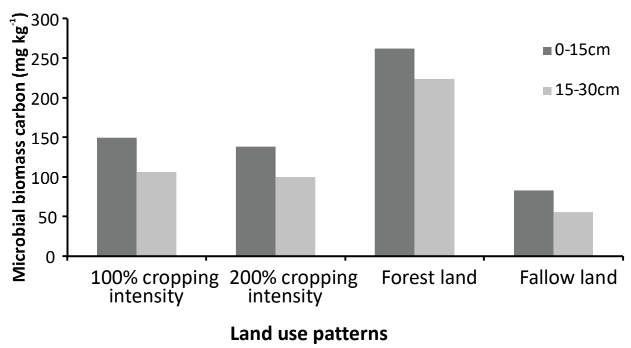

Fig. 1. Effect of land use pattern on soil microbial biomass carbon (mg kg^{-1} soil)

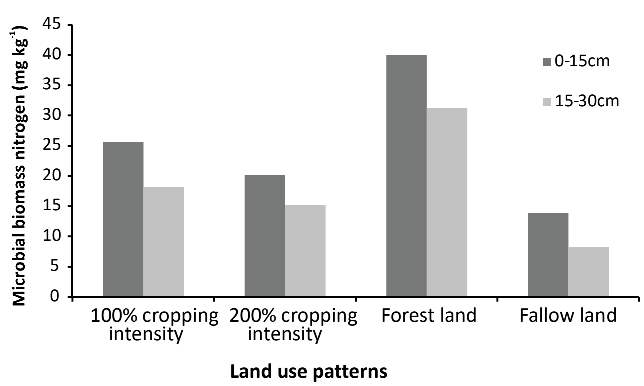

Fig. 2. Effect of land use pattern on soil microbial biomass nitrogen (mg kg^{-1} soil)

=0.990**). Significant positive correlations have also been recorded between MBN and organic carbon (r =0.993**), total nitrogen (r = 0.994**).

CONCLUSIONS

Land use pattern and soil depth significantly influenced soil physical, chemical properties, microbial biomass carbon and nitrogen. Organic matter or litter layer in forest land increased soil carbon thereby helping in the restoration of better soil health and fertility. Land use pattern and soil depth strongly influenced the top soil of all the study sites. Forest had the highest microbial biomass C and N, suggesting better C and N immobilization in the land use. Low SOC and MBC in fallow land confirmed that the lack of organic matter inputs and external factors like erosion, grazing by animals decreased soil fertility and in turn microbial activity in soil. The study suggests that MBC, MBN may be considered as a key indicator of soil fertility, while land uses are a major cause for loss of microbial biomass.

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Modeling of 36Cl Transport and Water Flow in Amended Gypsiferous Calcareous Soil

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Abstract: Dissolution of gypsum has great influence on water flow and solute transport occurring in gypsiferous-calcareous soils. The objectives of this study, were to model the transport of solute (^{36}Cl) in gypsiferous-calcareous soil treated with fuel oil (FO) based on the convection-dispersion transport model (CDE), and determine the effect of FO on dissolution of gypsum associated with calcium carbonate content. Radiotracer of chloride as carrier free of ^{36}Cl was applied to surfaces of saturated soil columns that have 20, 250 and 500 g kg^{-1} gypsum treated with 0, 1, 2, and 4% of fuel oil and leached with water until complete displacement of chloride. The application of 1 to 2% FO improved the transport properties due to modification in soil structure. The applied models gave good fit between measured and predicted breakthrough curves of Cl with significant linear correlation coefficient (r) that ranged between 0.972 and 0.999. They gave a calculated dispersion coefficient (D) ranging from 2.1 to 79.2 cm^2 /day, and retardation factor (R) ranging from 0.92 to 1.58. It was found that D was also linearly related to pore water velocity (v). Also, the results indicate the possibility of predicting the distribution of chloride in gypsiferous-calcareous soil for different time periods using correct boundary conditions. Experimental results show that gypsum dissolution in the soil columns is mainly determined by the flow velocity, soil saturation and then partially coating with FO.

Keywords: Gypsiferous-calcareous soil, ^{36}Cl, Solute transport, CDE equation, Breakthrough curves

Gypsiferous soils are soils that contain gypsum which is hydrated calcium sulphate ($CaSO_4$, $2H_2O$) in considerable amounts. According to Al- Aziz and Ma (2011) gypsiferous soils cover about 27-36% of the territory of Iraq. When gypsum is present in considerable quantities, the physical and hydrological properties of soil are adversely affected. The dissolution of gypsum is one of the very unfavorable properties of soil. When gypsum dissolves, irregular of land surface sink-holes are formed. Eventually, due to disturbance of soil structure and mixing that occurs due to the migration of clay particles from the surface horizons of the soil and gypsum crystals to the subsurface horizons of the soil, this causes serious problems in movement of water and solute . The field findings indicate that the presence of calcium carbonate and gypsum are conversely found in soil. Number of attempts was made to clarify this phenomenon on the basis of the variation in structure between the two compounds and the presence of dissolved salts in the soil (Al- Barrak and Rowell 2006, Schonsky et al 2013). Al- Barrak and Rowell (2006) concluded that the protection of gypsum from dissolution by the formation of calcite coatings has been found to depend on the amount of gypsum initially present and on the conditions under which dissolution takes place. The prediction of solute transport is very important in management of gypsiferous-calcareous soil. This could be done by the application of models particularly those based on convection-dispersion processes. These models consider solute transport mechanisms are due to diffusion plus dispersion and by mass flow or convection with water as the water moves through the soil (Radcliff and Simunek 2010). Experimental investigations are mainly been focused on data characterizing dissolution of gypsum and their effects on soil characteristics. It is necessary to test how far gypsum transport may facilitate solute transport in gypsiferous soils. Shihab and Mehdi (2018) found that convection-dispersion equation (CDE) can be used to describe dissolution and transport of gypsum through gypsiferous-calcareous soil. It gave a good correlation to predict gypsum breakthrough curves (BTC) and its content in effluent. Shihab and Fattah (2018) observed that the retardation coefficient (R) and dispersion coefficient (D) values for NO_3^- increased with increase of gypsum content at constant lime content. The NO_3^- transport decreased with increasing of gypsum content. Chloride-36 (^{36}Cl) is one of the radioactive isotopes of chloride (Cl-35) with half-life ($T_{1/2}$=301000 years). Many studies have been done on Cl^- transport in field and soil columns experiments under saturated and unsaturated flow conditions (Abu-Zreig and Abu-Ashour 2004, Badv and Mahooti 2005, Gonzalez and Shukla 2011, Zhou et al 2014, Dou et al 2020). However, it is doubtful, whether CDE is appropriate for describing solute transport in gypsiferous-calcareous soil due to gypsum dissolution and movement. Among soil conditioners that have been used to improve soil characteristics is fuel oil. Fuel oil as a cheap, available, and high carbon content petroleum by-product can be used in small amounts to improve the characteristics of gypsiferous soil (Shihab et al 2002, Aziz and Ma 2011). Studies are needed to examine the behavior of chloride in soils with a high content of gypsum and lime in order to effectively predict solute transport by water movement and the modification of soil structure would include solute displacement and transport parameters. Therefore, the objectives of this study were to i) estimate the transport parameters of soil treated with fuel oil using ^{36}Cl as a tracer, evaluate the applicability of convection-dispersion model in describing solute transport to predict chloride breakthrough curves (BTC) in columns of gypsiferous-calcareous soil and determine the effect of FO on dissolution of gypsum associated with lime content during leaching.

MATERIAL AND METHODS

Theoretical consideration: The models were based on the analytical solution of convection-dispersion equation:

$R\partial C/\partial t = D\partial C^2/\partial x^2 - v\partial C/\partial x$ ....(1)

and R is retardation factor,

$R = v_w/v_s$ .... (2)

where C is the volume-averaged solute concentration, t is time, D is dispersion coefficient, X is distance, v is the average pore water velocity, approximated by the ratio q/θ (where q is volumetric fluid flux density, θ is the volumetric water content), and v_w v_s are the velocity of water and solute, respectively.

Equation 1 can be solved analytically for the initial boundary condition:

$C(O, t) = C0$ and $\partial C/\partial X(\infty, t) = 0$ ....(3)

By assuming that solute distribution inside the column are not affected by an outflow boundary or effluent collection system, and considering the column to be part of an effectively semi-infinite system. Also, by assuming that the concentration is continuous at X= L (length of soil column) (0 ≤ X ≤ L), the following equation can be used for solute transport in soil column in one dimension

$$C_e = \frac{1}{2} erfc\left[\frac{RL - vt}{2(DRt)^{0.5}}\right] + \frac{1}{2}\exp\left(\frac{vL}{D}\right) erfc\left[\frac{RL + -vt}{2(DRt)^{0.5}}\right] \quad (4)$$

where C_e is relative effluent concentration (C/Co) and erfc (x) is the error function complementary defined as:

$$erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty \exp(-\varepsilon)\, d\varepsilon \quad (5)$$

An expression for the relative effluent concentration in terms of the number of the pore volumes, V, leached through the column and column Peclet number, P,

P = vL/D .... (6)

is defined as

$$C_e(V) = \frac{1}{2} erfc\left[\left(\frac{P}{4RV}\right)^{0.5}(R - V)\right] + \frac{1}{2}\exp(P)\, erfc\left[\left(\frac{P}{4RV}\right)^{0.5}(R + V)\right] \quad (7)$$

The boundary conditions of

$$-D\frac{\partial C}{\partial X} + vC = vC_0, \frac{\partial C}{\partial X}(\infty, t) = 0$$

and for initial conditions of $C(0,t) = C_0$ equation 1 analyzed to represents volume-averaged or resident concentration, the result is (Radcliff and Simunek 2010).

$$C_e = \frac{1}{2} erfc\left[\frac{Rx - vt}{2(DRt)^{0.5}}\right] + \left(\frac{v^2 t}{\pi DR}\right)^{0.5} \exp\left[-\frac{(Rx - vt)^2}{4DRt}\right]$$

$$\frac{1}{2}\left[1 + \frac{vx}{D} + \frac{v^2 t}{DR}\right]\exp\left(\frac{vx}{D}\right) erfc\left[\frac{(Rx + vt)^2}{(2DRt)^{0.5}}\right] \quad (8)$$

Soil characteristics and column experiments: Soil with 20, 250 and 500 g kg^{-1} gypsum and 336, 217 and 180 g kg^{-1} carbonate calcium minerals (lime), respectively were prepared by mixing soil sample from the shallow Ap surface horizon with sample from subsurface C1 from Al-Dor District 150 km north Baghdad, Iraq located at 34°27′27″N 43°47′54″E. The soil is a gypsiferous-calcareous soil classified as a Typic Calcigypsids. Some characteristics of the soil are given in Table 1. The pre moist soil with 20, 250, and 500 g kg^{-1} gypsum was mixed with 1, 2 and 4% of fuel oil (petroleum byproduct) at 33 kPa, mixed thoroughly to reach homogeneity and incubated at room temperature for one month. During incubation water was added to maintain water content at 33 kPa. The fuel oil was characterized by specific gravity of 0.95, viscosity of 120 C stock and carbon content of 850 g kg^{-1}. Samples of the untreated (control) and the treated soils were sieved using 2mm sieve and packed uniformly in Perspex tubes 0.5 m long and 0.12 m inner diameter to depth of 0.30 m with bulk density ranged from 1.27 to 1.30 Mg m^{-3}. To perform leaching experiments, the soil columns were saturated from the bottom with saturated gypsum solution to establish a known initial condition with respect to the ionic concentration of solution phase.

Leaching and measuring of Cl-36: Twenty mL of carrier-free $Na^{36}Cl$ solution containing 1.85 MBq (50 µCi) of ^{36}Cl was evenly distributed on the surface of each soil column. The columns were then leached by maintaining 0.025 m depth of river water on surface of soil column by Marriott siphon. Samples of the effluent were collected during leaching using fraction collector for measuring activity of ^{36}Cl using liquid scintillation counter (LKB 1218 Sweden). Maximum velocity of ^{36}Cl (v_s) was calculated from time (t) required for first appearance of ^{36}Cl in effluent samples and the length of soil column (L). Hydraulic conductivity was also measured as described by Reynolds et al (2002). Three replicates were used, two close replicates were selected and the third was ignored.

Fitting of models to breakthrough curves: Breakthrough curves (BTCs) were obtained by plotting the relative concentration (C/Co) of solute vs. pore volume (V) and time (t) of leaching. The number of pore volumes is calculated by dividing the amount of water leached through the column (Vt) by the liquid capacity Vo, (Vo= AθL) of the column:

$$V = V_t/V_0 = V_t/L \ldots\ldots\ldots(9)$$

where A the cross-sectional area of the column. Data were analyzed by MATHCAD software. Estimates for Peclet number (P) and retardation factor (R) were obtained by comparing the experimental curve directly with a series of calculated distributions from Eq.7 and selecting those values of P and R that provide the best fit with one of the theoretical curves (trial and error) and D was calculated from Eq.6. An approximate estimate for R can be obtained first from Eq.2. The relative concentration (C/Co) as a function of time (t) of leaching was also fitted to Eq.4. Soil granules having diameter between 4-9 mm were used to measure mean weight diameter (MWD). Another two sets of air dry and saturated soil columns that have gypsum content of 250 g kg^{-1} treated with 2% FO were leached in order to verify the accuracy of equation 8 in determining the concentration of chloride remaining in the soil by measuring its concentration in the leachate. Soil from each column was taken out at various times of the leaching course. Radioactive chloride was measured in a saturation extract. The concentration of chloride measured was compared with that determined from equation 8. Equation 8 was then used to estimate the distribution of chloride in air dried and saturated soil columns at various depths.

RESULTS AND DISCUSSION

Leaching of Cl-36 and breakthrough curves: The measured and predicted ^{36}Cl breakthrough curves (BTC) as function of pore volume (V) for different gypsum and fuel oil content are given in Figure 1. The shape and position of BTC were differed due to differences in gypsum and fuel oil (FO) content. These differences in BTC reflect the modification occurred in soil structure. Typical BTC (sigmoid shape) are for the untreated soil of 20 and 500 g kg^{-1} gypsum content. In these curves the passage of one pore volume was sufficient to displace approximately 50% (C/Co=0.5 at 1 pore volume) of ^{36}Cl out of columns. The area under the curve up to one pore volume equals that above the curve.

Conversely, for 250 g kg^{-1} gypsum content, about 90% of Cl was displaced after passage of one pore volume. This level of gypsum was reported to be critical level where major (better) changes in physical properties of soil would have occurred. The shape of the BTC explains that Cl tracer is spread as a result of hydrodynamic dispersion (Bourazanis et al 2017). The dispersion is the dominant mechanism and hence the diffusion can be ignored. The shape of these curves may occur owing to solute mixing that take place by molecular diffusion and variations in water velocity at the

Table 1. Some characteristics of gypsiferous-calcareous soil used in the study

Character	Unit	Surface horizon Ap	Subsurface horizon C1
Texture		Clay loam	+
Sand	g kg^{-1}	309.8	+
Silt	=	382.4	+
Clay	=	307.8	+
Gravimetric water content	33 kPa	0.32	0.21
Electrical conductivity	dS m^{-1}	2.2	2.7
pH		7.7	7.9
Calcium carbonate	g kg^{-1}	336.0	173.9
Gypsum	g kg^{-1}	20.0	675.0
Cation exchange capacity	Cmole kg^{-1}	28.2	18.5
Ca	mmole L^{-1}	16.8	26.0
Mg	=	3.0	2.1
Na	=	2.4	1.7
SO_4	=	10.3	20.8
Cl	=	2.0	2.3

$^+$Data not available due to high gypsum content which inhibits dispersion of soil particles; Clay minerals 1. Palygorskite (dominant) 2. Chlorite-illite 3. Smectite microscope level within soil pores. Application of fuel oil greatly changes the shape and position of BTC. The BTC were displaced to the right of one pore volume BTC and showed more tailing and dispersion. These results were observed for the treatments of 1% FO with 20 g kg^{-1} gypsum and 2% FO with 250 and 500 g kg^{-1} gypsum (Fig. 1 and 2). Modification of soil structure due to application of FO caused an increase in aggregate stability. Mean weight diameter (MWD) increased with the increase in concentration of fuel oil for samples that contains 250 or 500 g kg^{-1} gypsum. The average values increased from 1.47 to 2.14 mm compared with 2.54 mm for samples of 20 g kg^{-1} gypsum (Table 2). The chloride transport was greatly affected by aggregate size in results similar to Zhou et al (2014). The aggregate size had a significant effect on the BTC. The asymmetry of BTC increased with the increase in aggregate size. These differences between curves may be due to changes in either water saturation or pore geometry associated with soil aggregation. The asymmetrical behavior of curves was attributed to increasing disequilibrium for diffusive solute transfer between intra- and inter-aggregate pore water regions. Some of the pore water may be not effective in solute transport due to dead-end pores, the presence of slower or immobile (stagnant) water region, or some other structural feature of geometry (Zhou et al 2014). The displacement of ^{36}Cl in the stagnant region is by diffusion since water is not flowing. Thus, the advection and mixing of tracer in these pore space negligible. This resulted in a slower movement of tracer, especially at later stage of leaching, and hence the tailing of the BCT. It is seen that time needed to displace C/Co=0.5 of ^{36}Cl is less for 1% FO treatment than for the rest treatments (Fig. 2a). According to Gonzalez-Delagado and Shukla (2011) BTC asymmetric shape also indicates a wide range in the distribution of pore water velocities. They also stated that large holdback area (the area under the curve up to pore volume 1) indicates difficult displacement, and the tailing or large holdup area (area between BTC and C/Co = 1 from pore volume 1 until end of experiment) indicates large amount of solute that was stored. The chloride BTC shift to right due to pore water velocity increases or holdback decreases. This should happen as more wetted pore spaces are contributed actively in water and solute transport. The results showed that the 2% FO needed less time for 250 and 500 g kg^{-1} gypsum for complete displacement (Fig. 2b and c). Therefore, the time required to displace most of the chloride in untreated soil has increased. These variations in time can be attributed to the fact that the effect of gypsum was greater in the later stages of displacement compared to the first stages due to the low pore water velocity as result of dissolution of part of the fine gypsum crystals. This dissolution led to the mechanical blocking of some pores and impeding the movement of water.

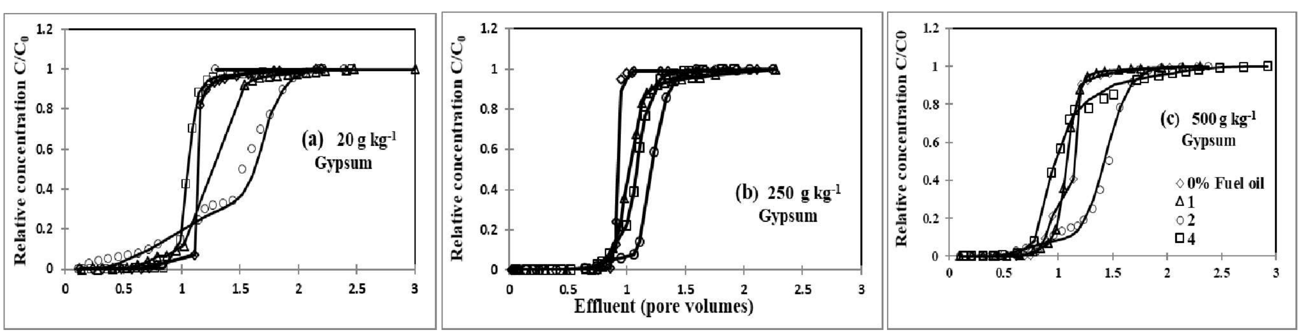

Fig. 1. Experimental (dotes) and predicted (solid) line breakthrough curves as function of pore volume for ^{36}Cl displacement at different gypsum and fuel oil contents

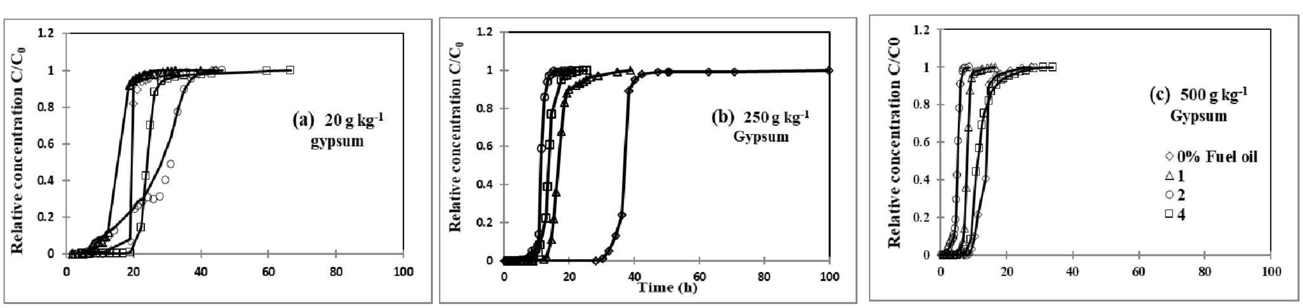

Fig. 2. Experimental (dotes) and predicted (solid) line breakthrough curves as function of time for ^{36}Cl displacement at different gypsum and fuel oil contents

Models fitting to Cl-36 breakthrough curves: The advection-dispersion model gave good fit between measured and predicted BTC data (Fig. 1 and 2) with significant linear correlation coefficient (r). The r values ranged between 0.970 and 0.999 with calculated Chi Square (X^2) value less than tabulated. This indicates a satisfactory applicability of the CDE model to describe the experimental results of gypsiferous-calcareous soil. The model gave dispersion coefficient (D) ranging from 0.5 and 79.2 cm^2 d^{-1}. Higher values were associated with 1% FO mixed with soil having 20 g kg^{-1} gypsum and 2% FO and for soil having 250 and 500 g kg^{-1} gypsum (Table 3). The D of 0.08 cm^2 hr^{-1} (1.92 cm^2 d^{-1}) was for untreated gypsiferous soil having 250 g kg^{-1} gypsum and 0.35-0.60 cm^2 hr^{-1} (8.4-14.4 cm^2 d^{-1}), treated with FO and incubated for 0-6 months. The dispersion coefficient can vary through several orders of magnitude, depending on the mean pore water velocity, its distribution and the size of structural units (Zhou et al 2014). The tailing increased with increasing D. This may lead to the expectation that the dispersion coefficient increased with the increases in average pore water velocity (v) and MWD. The v was increased with the increased FO and gypsum content. For a given velocity, the asymmetry in BTC increased with increasing aggregate size. Thus, increasing the aggregate size increase the apparent effect of the dispersion provided by the aggregates. Using aggregates with diameter of 0.5 to 4.0 cm and two water velocities, Zhou et al (2014) showed that increasing aggregate size for a given velocity decreased the diffusion path length, causing incomplete mixing between the chloride solute and pores within aggregates. In addition, they showed increasing pore water velocity decreased the usable residence time for diffusive mass transfer of solutes into and out of the slower flow or immobile region. However, when the soil columns contained larger aggregates (higher MWD), the presence of a large aggregate and the soil beneath it, which is influenced by its presence, caused an increase in the volume of the immobile region. Consequently, the mobile water fraction decreased with the increase in aggregate size.

The Fig. 3. shows the relation between v and D. the best fit (r^2= 0.6496) is given by the equation:

$$D = 0.4043v\text{……… [10]}$$

The larger dispersivity values causes more dispersion of the solute front will be as a result of a wide range of pore size distribution and pore water velocities (Radcliffe and Simunek 2010). Shukla et al (2000) showed that a holdback decreases with increasing pore water velocity. In other words, immobile water decreases with increasing v. He explained this can be due to the higher v which makes possible for chloride to invade stagnant or slowly conducting liquid zones. Schonsky et al (2013) reported that λ values for laboratory experiments with packed soil columns (disturbed) are between 0.5 and 2 cm and for undisturbed soil columns or field experiments are

Table 2. Mean weight diameter (MWD) and hydraulic conductivity (K) as influenced by gypsum and fuel oil content

FO %	MWD (mm)	K (cm d^{-1})
20 g kg^{-1} gypsum		
0	0.09	17.3
1	0.92	24.5
2	3.52	17.3
4	5.62	13.0
Average	2.54	18.0
250 g kg^{-1} gypsum		
0	0.09	8.6
1	0.16	18.7
2	1.03	28.8
4	4.60	23.0
Average	1.47	19.8
500 g kg^{-1} gypsum		
0	0.15	25.9
1	0.12	41.8
2	3.04	82.1
4	5.24	25.9
Average	2.14	43.9

Table 3. Transport parameters values estimated by the convection dispersion model at different gypsum and fuel oil content

Fuel oil %	Dispersion coefficient (D) (cm^2 d^{-1})	Peclet number (P)	Retardation factor (R)
20 g kg^{-1} gypsum			
0	13.0	84	1.03
1	31.7	48	1.58
2	30.7	30	1.21
4	7.2	144	1.05
250 g kg^{-1} gypsum			
0	2.1	660	0.92
1	8.6	135	1.00
2	16.5	135	1.20
4	14.4	132	1.08
500 g kg^{-1} gypsum			
0	14.4	100	0.96
1	15.8	156	1.08
2	79.2	80	1.40
4	54.7	31	0.98

between 5 and 20 cm. Comparing these values with our value of 0.4043 cm for λ can be interpreted by the homogeneity or uniformity of porous media and implies of normal spread of applied solute through the soil column. The equation demonstrates firstly a clear dependence of D on v, and secondly the diffusion is very small and can be neglected. Shihab and Mahdi (2018) showed an increase in D of gypsum with increasing the gypsum content in both continuous and intermittent leaching of undisturbed gypsiferous-calcareous soil columns and explained that the reason for this is due to the increase in the pore water velocity (v), which leads to an increase in the dispersion coefficient due to the decrease in the resident time between the water and the soil. The dissolution of gypsum leads to mixing the soil and the mobility of its components irregularly, which increases the dispersion coefficient D. This means that the dispersion is the dominant mechanism in dissolution and transport of gypsum. The relation between D value and Peclet number (P) (Eq.6) is another important factor for recognizing the effect of P on solute mixing. The Peclet number measures solute movement by mass flow, which is only vertical in the columns, compared with dispersion, which involves advection movement. Although, the effects of both diffusion and dispersion on solute mixing are difficult to be separated, that the P ranged from 30 to 660 (Table 3). This indicates that the dispersion and mixing is the dominate process in transport of ^{36}Cl. Zhou et al (2014) explained that the main reason for this was that the CDE model combines the effect of solute transport, and the dispersion coefficient between the mobile and immobile regions, into one term. In general, the small values of D (large P values) observed (Table 3) are indicative of the presence of narrow range in pore water velocities. The retardation factor (R) is another important parameter, which is included in the advection dispersion model and significantly altered the position of the BTC. R values ranged from 0.98 to 1.58 (Table 3). Values of R=1 indicating that no retardation had occurred. The values of R greater than l observed in the soil treated with 2% FO for different gypsum content indicates that retardation had occurred and reflected by the later arrival of tracer in the effluent with tailing. Conversely, values less than 1 indicates only a fraction of liquid phase participating in the transport process or chloride

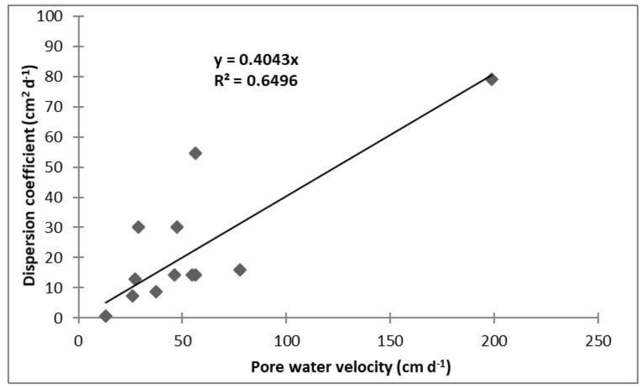

Fig 3. Dispersion coefficient of ^{36}Cl as function of pore water velocity for different treatments

Table 4. Relative concentration of chloride (experimental and predicted from Eq.8) remaining after displacement for different periods in soil having 250 g kg^{-1} gypsum treated with 2% FO

Time (h)	Relative concentration (C/C_0)		Relative error (%)
	Experimental	Predicted	
Air dry soil			
1	0.668	0.625	6.4
5	0.082	0.094	14.6
10	0.019	0.016	15.8
Saturated			
10	0.993	1.000	0.7
20	0.987	1.000	1.3
40	0.158	0.160	1.3

$$\text{Relative error} = \frac{\text{Experimental value} - \text{predicted value}}{\text{Experimental value}} \times 100$$

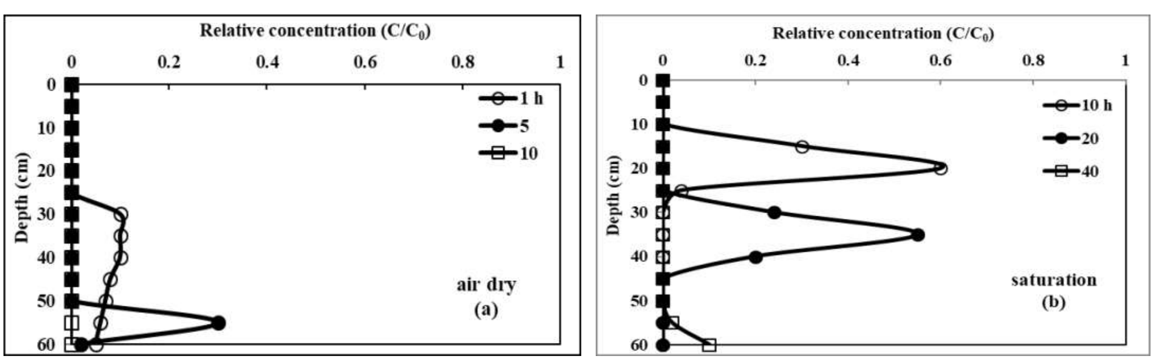

Fig. 4. Prediction of chloride concentration in soil at 250 g kg^{-1} gypsum content and 2% FO using eq.8

often undergoes anion exclusion from solution close to negatively charged soil particles (Abu-Zreig and Abu-Ashor 2004), which resulted in a faster leaching of ^{36}Cl or bypass from a significant portion of the soil solution. When gypsum dissolves, small holes and fissures are formed, and causes preferred-paths transport (Shihab and Mahdi 2018, Shihab and Fattah 2018). Differences in R values can be explained by changing of pore water velocity (v) in which lower R values were obtained at higher v. At higher v, mixing is less and Cl moves faster through the soil. Our results, however, explain that the relationship between v and R less clear, because the range of R is not large. This indicates that chloride behaved as a non-reactive tracer. The preferential flow in the upper part of soil column was increased with the increase in gypsum content and followed by reduction in flowing of water. This reduction was mainly due to mechanical plugging by small gypsum particles which had moved downward. The average hydraulic conductivity (over the three levels of gypsum content) was found to be 17.3, 28.3, 42.7 and 20.6 cm d^{-1} for 0, 1, 2, and 4% FO, respectively (Table 2).

Predicting of chloride concentration: Prediction of change in chloride concentration with depth showed two types of distribution. In the first type (Fig. 4a), a rapid and sharp decrease in the concentration of chloride with depth was found during short periods of time not exceeding 10 hours. As for the second type, the decrease in concentration with time was gradual (Fig.4b) and took a longer time that spanned forty hours. This change in concentration was influenced by initially soil moisture, although the two treatments have the same gypsum and fuel oil content. Soil moisture effects chloride transport. When the soil is air dry, the chloride quickly reaches the leachate, and the highest concentration of solute occurs at the wetting front, which leads to the transport of the solute with water in the pores. In this case, the transport is closer to the piston displacement. Upon saturation, the solute delays from the wet front and the water moves by displacing the water already present in the pores. This requires displacement of approximately one pore volume (that is, the volume of water held in the soil column) before the chloride begins to leave the column, and this requires more time. The wetting front in the saturated state moves faster than the air-dry state, but carries with it a small amount of solute. Equation 8 showed good agreement between measured chloride concentration in the leachate and that remaining in soil solution for different time periods soil, respectively. The increase in the relative error of the air dry treatment at 5 and 10 hours is due to the residual chloride remaining in the soil column at these two periods was very small compared to the first period (1 hour) and is represent only a small percentage of the total concentration (C/Co=1), and that any slight difference between the experimental and calculated concentration will lead to amplifying the relative error. This indicates the possibility of predicting the distribution of chloride in gypsiferous-calcareous soil using correct boundary conditions. Application of FO, which is a hydrophobic material, partially coated the soil aggregates, and increased their resistance to breakdown in water. These effects reduced specific surface area, capillary movement of water, and water sorptivity of soil aggregates and thus reduced the solubility of gypsum (Shihab et al 2002). These researchers found gypsum concentration in the effluent increased during the first stage of leaching, and then it decreased to a specified value which remained nearly constant with further leaching. Also, the obtained results showed that the remaining gypsum content in the soil after leaching course was greater in the columns treated with fuel oil. In addition, the gypsum was accumulated in the middle of the soil columns. Consequently, the above results indicate that dissolution of gypsum is surface phenomenon and the value of dissolution coefficient of gypsum and mass transfer rate depend mainly on the specific area as well as on the sorptivity of soil aggregates. The results show that role of lime was not clear enough in reducing gypsum dissolution. The occurrence of co-precipitation and interwoven between gypsum and lime crystals did not lead to the inhibition of the rate of gypsum solubility as described by Sudmalis and Sheikholeslami (2000) and Schonsky et al (2013).

These concluded that the presence of lime strengthened the weak structure of pure gypsum. In comparison with our results, where the content of lime in soils are 336, 217 and 180 g kg^{-1} for the 20, 250, and 500 g kg^{-1} of gypsum content, respectively. It appears that lime may cause an increase in gypsum hardening in the dry state only due to co-precipitation and interwoven. The precipitation of lime in the soil solution and coating of the gypsum particle surfaces leads to a decrease in the rate of dissolution of gypsum due to the reduction of the available surface area in contact with the solution phase. This depends on the amount of both gypsum and lime present in the soil and on the conditions under which the dissolution occurs, as well as depends on the field conditions at which the coating is formed. Al-Barrak and Rowell (2006) concluded that calcite did not manage to cover the gypsum surfaces when the rate of dissolution of gypsum was rapid, possibly because the surface was continually removed. Slower leaching conditions in the field are likely to help to form coatings and to minimize gypsum dissolution. The experimental results show that gypsum dissolution in the column is mainly determined by the flow velocity, soil water saturation and then partially coating with FO and lime.

CONCLUSIONS

The convection- dispersion model successfully used to predict the concentration of ^{36}Cl in the effluent of gypsiferous-calcareous soil. This model gave good fit between measured and predicted BTC data. Also, FO application modified physical properties of soil. This modification was reflected by the increase in D and R. Higher values of these two parameters were associated with 1% FO mixed with soil having 20 g kg^{-1} gypsum and 2% FO for soils having 250 and 500 g kg^{-1} gypsum. D was linearly related to pore water velocity (v). CDE also showed a good agreement between the measured chloride concentration for the different gypsum content in the leachate and the remaining soil concentration. This means that the distribution of chloride in gypsum soil can be predicted using correct boundary conditions. Application of FO, which is a hydrophobic material, partially coated the soil aggregates, and increased their resistance to breakdown in water. The role of lime was not well explained in reducing gypsum dissolution because the co-existence of gypsum and lime is not clear enough. This needs further research under field conditions to determine the extent to which gypsum dissolution can be reduced. Under these conditions using amendments and slower leaching can be managed and coating may more likely to form.

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Influence of Nano Zinc on Growth, Yield and Economics of *Rabi* Sorghum (*Sorghum bicolor* L.)

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Abstract: A field experiment was conducted during *rabi* 2019-20 to study the effect of various sources of zinc nano particles in sorghum under rainfed condition. The results revealed that foliar spray of both green and chemical zinc oxide nanoparticles (ZnO NPs) was superior to conventional zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) sources. Foliar spray of green ZnO NPs @ 1000 ppm recorded significantly higher grain yield (2664.26 kg ha^{-1}), stover yield (12102.93 kg ha^{-1}) and the results were on par with the treatment receiving foliar spray of chemical ZnO NPs @ 1000 ppm (2567.89 kg ha^{-1}) and (11817.80 kg ha^{-1}). The higher net returns and B:C was obtained with treatment receiving foliar spray of green ZnO NPs at 1000 ppm (₹ 56,876.64) and (3.26) and also inhibitory effect was observed in nano ZnO concentration >1000 ppm reveals the toxicity and hence need for judicious usage of nano particles in foliar applications.

Keywords: Chemical, Bulk, Foliar spray, Green, Yield, ZnO NPs

Nano technology is a recent innovation substituting traditional methods of fertilizer application by nano-fertilizers is an approach to release nutrients into the soil both gradually and in a controlled way. Sorghum (*Sorghum bicolor* L.) is the king of millets and third important crop in the country after rice and wheat. Sorghum is an important source of food, feed, fodder and ration for human, cattle and poultry. In India, the area under sorghum is approximately 3.84 million hectares with an annual production of about 3.76 million tonnes and an average productivity of 979 kg ha^{-1} (Anonymous 2018). Karnataka occupies second place with respect to area and production of sorghum in the country during the year 2018-19 with 0.87 million hectare of area and 0.91 million tonnes of production with productivity of 1048 kg ha^{-1}(Anon., 2018).

Micronutrients are important for maintaining plant health and for increasing productivity of crops. Zinc acts either as the metal component or as a functional, structural or a regulatory co-factor of a large number of enzymes. The indiscriminate application of Zn fertilizers to soil over years will lead to accumulation in soil to the level of toxic to the plants. At present there is a heavy emphasis on Zn in agriculture; care should be taken not to get over zealous with Zn applications. (Amin et al 2015) Gradual increase in Zn uptake could be observed with decreasing granule size and only the powder form could produce plants with Zn concentrations in the sufficient range. Since, granules of 1.5 mm size weigh less than that of 2.0- or 2.5-mm smaller granules were used for the same weight, resulting in a better distribution of Zn and the higher surface area of contact of Zn fertilizer resulted in better Zn uptake. Hence, the application of Zn fertilizer will give better results compared to bulk materials as nano particles which are atomic or molecular aggregates with at least one dimension between 1 and 100 nm, which can drastically modify their physic-chemical properties compared to the bulk material. Owing to its high surface area to volume ratio, exhibit significantly novel and improved physical, chemical and biological properties, phenomena, and its functions. Keeping these facts, the present investigation was carried out with an objective to evaluate the effect of different levels of Zn/Zn nano particles foliar spray on growth, yield and economics of sorghum.

MATERIAL AND METHODS

A field trial was carried out at farmer's field, Gabbur village near University of Agricultural Sciences, Raichur during *Rabi* 2019-2020. The sorghum variety M 35-1 with duration of 120 days was sown in *Rabi* with a spacing of 45cm x 15 cm. The design was Randomized Block Design with 12 treatments and replicated thrice. Soil application of NPK (50:25:0 ha^{-1}), FYM @ 2.5 t ha^{-1} and *Azospirullum* @ 500 g ha^{-1} is common for all the treatments except T_1. Foliar spray of ZnO NPs suspension at 20 and 40 DAS for all the treatments except T_1 and T_2.

The soil was clay loam in texture with a bulk density of 1.32 M gm^{-3} and with water holding capacity of 47.44 per cent. After thorough field preparation initial soil samples were taken to analyze the initial soil properties. The initial soil sample was analysed for available major nutrients; nitrogen (N), phosphorous (P), potassium (K) and sulphur (S), organic carbon (OC), pH and soluble salts. The pH of the soil was alkaline (8.26) with an electrical conductivity of 0.59 dS m^{-1}. The cation exchange capacity of soil was observed to be 51.34 cmol (p+) kg^{-1}. The soil was low in organic carbon status (3.57 g kg^{-1}) and in available nitrogen (265.2 kg ha^{-1}), medium in phosphorus (39.91 kg ha^{-1}), potassium (227.51 kg ha^{-1}) and sulphur (26.42 kg ha^{-1}). The exchangeable Ca and Mg in the soil were 24.20 and 10.91 cmol (p+) kg^{-1}. The DTPA extractable micronutrients *viz*., Zn, Fe, Cu and Mn were 1.20, 0.98, 4.20 and 3.01 mg kg^{-1}, respectively.

Surface soil samples (0-15 cm depth) were collected for chemical analysis after harvesting the crop from all plots. For available P, soil samples were extracted with 0.5 M $NaHCO_3$ (pH = 8.5) (Olsen et al 1954) and P content in the extracts was determined as described by Jackson (1973). Available S was determined by extracting soil samples with 0.15% $CaCl_2$ (Williams and Steinbergs 1959), and S in the extract was estimated by turbidimetric method (Chesnin and Yien 1951). The observations on plant height, number of leaves $plant^{-1}$ were recorded manually on five randomly selected representative plants from each plot of each replication separately as well as yield and yield attributing character were recorded as per the standard method. Yield attributes were also recorded at physiological maturity stage. The grain and straw yield was recorded from net plot area of each treatment. The data obtained from various characters under study were analysed by using SPSS software.

Green nano ZnO synthesised through biological approach by using spinach leaf extract (Sagili et al 2017). Commercial chemical nano ZnO procured from HI media Pvt. Ltd. Company and $ZnSO_4$ was procured from SRL laboratory used as reference. The required concentration of zinc nano-powder was dissolved in distilled water and kept for ultra-sonication @ 60 °C for 30 min to avoid aggregation before spraying. (Prasad et al 2012).

RESULTS AND DISCUSSION

Growth parameters: Foliar spray of green ZnO NPs @ 1000 ppm recorded significantly higher plant height (205.57 cm), number of leaves $plant^{-1}$(10.06), leaf area $plant^{-1}$ (2813.33 cm^2 $plant^{-1}$) and total dry matter accumulation (114.59 g $plant^{-1}$) at harvest of sorghum crop growth over the treatment T_4, followed by T_9 and T_{12}, respectively (Table 1) and least was recorded in control. The favourable effect of foliar spray of zinc on the proliferation of roots and thereby increasing the uptake of other plant nutrients from the soil, which in turn supplying it to the aerial parts of the plant and ultimately enhancing the vegetative growth of plants by zinc application which augmented the photosynthetic activity and dry matter accumulation of sorghum. As ZnO NPs having the diameter of less than 100 nm can easily penetrate through the stomata of leaves and were redistributed from leaves to stems through the phloem sieve elements (Wang et al 2012) and also Zn nutrition might have aggravated biosynthesis of indole-3- acetic acid (IAA) and subsequently IAA improved stem height. Indole-3-acetic acid might have caused acidification of cell wall. Henceforth, the degradation of pectin and cellulosic fibres in cell wall ultimately enhanced plant growth parameters by application of nano zinc formulations.

Table 1. Effect of nano zinc foliar application on growth attributes of sorghum crop

Treatments	Plant height (cm)	Number of leaves $plant^{-1}$	Leaf area $plant^{-1}$ (cm^2)	Dry matter accumulation (g $plant^{-1}$)
T_1: Control (water)	162.27	7.75	2125.61	90.98
T_2:$ZnSO_4$. $7H_2O$ @ kg ha^{-1} (RPP)	178.63	8.34	2290.37	101.99
T_3: Chemical ZnO NPs @ 500 ppm	189.34	8.60	2211.47	98.97
T_4: Chemical ZnO NPs @ 1000 ppm	201.06	9.36	2495.42	111.27
T_5: Chemical ZnO NPs @ 1500 ppm	192.16	8.09	2171.85	96.42
T_6: Green ZnO NPs @ 500 ppm	181.18	8.28	2155.43	95.67
T_7: Green ZnO NPs @ 1000 ppm	205.57	10.06	2813.33	114.59
T_8: Green ZnO NPs @ 1500 ppm	198.18	8.53	2202.86	96.87
T_9: Bulk ZnO @ 500 ppm	197.39	8.65	2399.82	108.90
T_{10}: Bulk ZnO @ 1000 ppm	193.04	8.35	2202.09	97.05
T_{11}: Bulk ZnO @ 1500 ppm	184.75	8.55	2210.80	94.77
T_{12}: 0.5% $ZnSO_4.7H_2O$	195.01	8.62	2383.44	104.97
CD (p=0.05)	21.66	1.04	308.47	13.51

In T_2 treatment soil application and in rest of treatments foliar spray of different zinc sources was done at 20 and 40 DAS

Yield parameters: The overall increase in the growth of the plant has been reflected ultimately in the yield and yield related parameters. The higher accumulation of assimilates in the treatment receiving foliar spray of green ZnO NPs @ 1000 ppm reflected in higher length of the ear (cm), weight of ear (g $plant^{-1}$), number of grains per ear, 1000 seed weight (g), grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) in (Table 2). Thus, indicating their yield superiority with values 21.85, 68.21, 1105.60, 31.37, 2664.26 and 12102.93, respectively. The significant increase in all the yield attributing characters might have contributed for increased grain yield (2664.26kg ha^{-1} and 2567.89 kg ha^{-1}) in the treatments which received foliar spray of green ZnO NPs @ 1000 ppm and T_4 was on par in T_3, T_5, T_7 compared to other treatments and lowest yield was observed in control. Increase in grain yield was due to increase in the weight of ear, number of grains per ear and 1000 grain weight. Subsequently, higher carboxy peptidase might maintain adequate carbohydrate availability by catalyzing irreversible reactions in glycolysis. Ultimately, sufficient carbohydrates partitioning towards grains improved grain yield. Moreover, Zn availability might have triggered activities of pyrophosphates over control. The results from experiments by (Prasad et al 2012) in groundnut, (Kisan et al 2015) in spinach and (Davarpanah et al 2016) in pomegranate also suggested that application of ZnO NPs at optimum concentrations increased the crop yields. These

Table 2. Effect of nano zinc foliar application on yield and yield attributes of sorghum crop

Treatments	Length of ear (cm)	Weight of ear (g $plant^{-1}$)	Number of grains per ear	Test weight (g)	Grain yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})
T_1	17.20	55.36	837.85	23.22	1710.98	8870.79
T_2	18.88	64.14	912.70	26.76	2143.12	10607.97
T_3	19.69	61.16	900.50	26.28	2101.98	10204.75
T_4	20.92	67.84	1002.46	29.58	2567.89	11817.80
T_5	18.70	60.95	874.80	25.98	2247.78	10490.56
T_6	19.05	59.37	881.60	25.77	2324.45	10493.56
T_7	21.85	68.21	1105.60	31.37	2664.26	12102.93
T_8	18.85	57.15	883.50	25.59	2411.58	10130.45
T_9	20.68	67.08	962.57	29.07	2456.90	10676.99
T_{10}	18.75	60.16	886.80	24.95	2001.89	10013.53
T_{11}	18.45	57.47	891.50	24.90	1992.98	9910.57
T_{12}	21.10	66.14	934.39	27.97	2214.98	10643.04
CD (p=0.05)	2.49	8.19	8.36	3.81	266.11	1393.34

See Table 1 for details

Table 3. Cost of cultivation, gross returns, net returns and B:C ratio as influenced by foliar application of nano zinc in sorghum

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit cost ratio
T_1	25070	54369	29299	2.17
T_2	25940	67346	41406	2.60
T_3	83820	65754	-18065	0.78
T_4	142570	79356	-63213	0.56
T_5	201320	69682	-131637	0.35
T_6	25170	71527	46357	2.84
T_7	25220	82096	56876	3.26
T_8	25270	73073	47803	2.89
T_9	25437	74981	49544	2.95
T_{10}	25805	63065	37260	2.44
T_{11}	26172	62697	36525	2.40
T_{12}	25215	69124	43909	2.74

In T_2 treatment soil application and in rest of treatments foliar spray of different zinc sources was done at 20 and 40 DAS results are in line with the findings of (Pankaj, 2017) in maize by the application of 1000 ppm ZnO NPs.

Economics: The cost of cultivation for sorghum crop per hectare was higher with foliar spray of chemical ZnO NPs @ 1500 ppm (₹ 2,013,20) in (Table 3). The increase in cost is due to higher price of chemical ZnO NPs. Higher gross returns and B:C of sorghum per hectare was observed with foliar spray of green Zn NPs @ 1000 ppm (₹ 82,096) and (3.26) which resulted higher yield of grain and stover in that particular treatment. These were evidenced by nano ZnO at 1000 ppm in cotton (Raj and Chandrasekhara 2019). The higher net returns were obtained with treatment receiving foliar spray of green ZnO NPs at 1000 ppm (₹ 56,876) followed by foliar spray of bulk ZnO @ 500 ppm (₹ 49,544) and least net returns of sorghum crop per hectare was registered with foliar spray of chemical ZnO NPs @ 1500 ppm (₹ -1,31,637) due to the increase in cost of cultivation. Similar negative net returns were obtained by nano multi micronutrient fertilizer application (Kailas et al 2017).

CONCLUSION

Nanotechnology has the potential to revolutionize the fertilizer use in agriculture. Application of nano fertilizers by foliar spray has a greater role in enhancing nutrient uptake, efficiency of fertilizers and yield of crop and there will be reduction of cost of fertilizers and pollution hazards. Foliar spray of green ZnO NPs @ 1000 ppm recorded higher growth and yield attributes found to be on par with foliar spray of chemical ZnO NPs @ 1000 ppm. The cost of cultivation was much higher with foliar spray of chemical ZnO NPs @ 1500 ppm. However, the higher gross returns, net returns and B: C was found to be superior with the foliar spray of green ZnO NPs @ 1000 ppm.

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Water Use Efficiency and Economics of Indian Mustard (*Brassica juncea* L.) Influenced by Drip Irrigation and Micronutrient Application Methods

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Abstract: A field experiment was conducted in split plot design with drip irrigation levels (0.4, 0.6 and 0.8 IW/CPE ratios) in main plot and micronutrient application methods (control, soil, foliar and fertigation) in sub plot during *Rabi* season 2018 at S.K.N. College of Agriculture, Jobner (Rajasthan). The scheduling of drip irrigation at 0.8 IW/CPE ratio recorded significantly higher plant height, dry matter accumulation, siliquae per plant, seeds per siliqua, test weight and seed yield over 0.4 IW/CPE ratio, however remaining statistically at par with 0.6 IW/CPE ratio. Drip irrigation at 0.8 IW/CPE ratio recorded higher net return. Among micronutrient application methods, fertigation significantly increased plant height at 80 days after sowing and at harvest, dry matter accumulation at all growth stages, siliquae per plant, seeds per siliqua and seed yield over all other application methods. Significantly higher net return and B: C ratio was also recorded under fertigation method of micronutrient application.

Keywords: Mustard, IW/CPE, Micronutrient, Drip irrigation and fertigation

India is a key player in the global oilseeds scenario with 12-15 per cent of oilseeds area, 6-7 per cent of vegetable oils production, 9-11 per cent of the total edible oils consumption and 14 per cent of vegetable oil imports. Despite of being the largest cultivator of oilseeds at the global level, India was an exporter of oil till fifties and now become a major importer of edible oil. Nutrient and irrigation management are the most important agronomic factors that affect the yield of Indian mustard (*Brassica juncea* L.). Drip irrigation is one of the most efficient methods of irrigation and it is viewed as a promising technology for its ability to support farmers in raising incomes (IWMI). A number of benefits have been ascribed to the use of drip irrigation. In addition to saving of water these include increased yield and productivity of crops, labour cost savings, electricity savings, lesser pumping hours and hence easier irrigation, better crop growth and also better soil health. In IW/CPE approach, known amount of irrigation water is applied when cumulative pan evaporation reaches predetermined level. For practical purpose irrigation should be started when allowable depletion of available moisture in the root zone reaches. The available water is soil moisture which lies between field capacity and permanent wilting point. Thus irrigation scheduling provides information to the managers to develop irrigation strategies for each plot of field on the farm.

Multiple micronutrient deficiencies are emerging at a faster rate in intensively cultivated high production areas due to greater removal of soil micronutrients through annual biomass harvest of 15-20 tonnes ha^{-1}. The deficiency range of micronutrients especially Zn and B in oilseed growing soils emphasizes the need to focus immediate attention on balanced nutrient management practices. The production of mustard in the region, state and in country often suffers from a higher degree of variation in the annual production owing to their predominant cultivation under low and uncertain rainfall situations and further handicapped by input starved conditions with poor crop management. There is limited scope for expansion of area under mustard and also the irrigation. Increasing the vertical growth in productivity is the feasible option. Fertigation is a modern agro technique, combining water and fertilizer application through irrigation provides an excellent opportunity to both maximize yield and minimize environmental pollution. It localizes the water supply and this triggers the development of a restricted root system that requires frequent replenishment of the nutrients. Applying nutrients in the irrigation water may satisfy this requirement. In a fertigation system, the timing, amounts, concentrations and ratios of the nutrients are easily controlled. Due to this improved control, crop yields are greater than those produced by a simple fertilizer application and irrigation system. Therefore, as a result of the shift from surface irrigation to drip method of irrigation, fertigation becomes the most common fertilisation in the irrigated agriculture. The use of soluble and compatible fertilisers, good quality irrigation water and application of actual crop water need are the prerequisite of the successful fertigation system.

MATERIAL AND METHODS

The experiment was conducted at S.K.N. college of agriculture, Jobner, Rajasthan(Lat 26.971873^0 long 75.377156^0). The region fall under semi-arid eastern plains agroclimatic zone of Rajasthan. The experimental soil was loamy sand in texture, alkaline in reaction (8.1), poor in organic matter (0.18), low in available nitrogen (129.50 kg/ha), medium in phosphorus (17.10 kg/ha) and potassium content (181.20 kg/ha). Field capacity and PWP of soil was 10.85 and 4.32 per cent, respectively. The experiment consisting of 12 treatment combinations with three levels of drip irrigation in main plot (drip at 0.4, 0.6 and 0.8 IW/CPE ratio) and four levels of micronutrient application method in sub plots (control, soil application, foliar application and fertigation) was conducted in split plot design and replicated four times. The seeds of mustard variety Laxmi @ 5 kg/ha was used for sowing in the experiment. Mustard seeds were sown at a spacing of 30 x 10 cm^2 apart. Two hoeing-cum-weedings were done manually at 30 and 40 days after sowing. To maintain uniform plant stand at 10 cm for mustard, extra plants were thinned out. The experimental mustard crop was fertilized uniformly with 60:40 kg/ha of N and P respectively. Half of the nitrogen along with full amount of phosphorous was applied at the time of sowing as basal. Five plants for each treatment were taken for recording the various data. Data on yield attributes and yield were recorded as per standard process at harvest. Various indices were used to assess the effectiveness of water management practices *viz.,* consumptive use of water by Dastane (1972) and Water-use-efficiency by Viets (1961). The economics of treatments was computed on the basis of prevailing market price of input and outputs for each treatment. Net returns and B: C ratio was calculated by following formulas.

$$\text{B: C ratio} = \frac{\text{Net return (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

All data were subjected to statistical analysis using the F–test, as per the procedure given by Gomez and Gomez (1984).

RESULT AND DISCUSSION

Effects of Drip Irrigation

Growth parameters: Scheduling of drip irrigation at 0.8 IW/CPE ratio, recorded significantly higher plant height (150.49 and 196.00 cm) as compared to 0.4 IW/CPE ratio at 80 days after sowing and at harvest, while it remained statistically at par with 0.6 IW/CPE ratio (143.59 and 193.70 cm, respectively) (Table 1). The drip irrigation level at 0.8 IW/CPE ratio, recorded significantly maximum dry matter accumulation (40.65, 114.99 and 196.00 g) as compared to 0.4 IW/CPE ratio at 40, 80 days after sowing and at harvest, while it remained statistically at par with 0.6 IW/CPE ratio (34.54, 100.95 and 155.16 g, respectively). The crop plants are able to maintain higher water potential with increasing IW/CPE ratio under drip irrigation which improves physiological and biochemical activities. This leads to improved growth of plant. Beside it, reduced water supply causes closure of stomata which raises the plant temperatures consequently increases respiration leading to higher break down of assimilates and ultimately poor growth and reduced dry matter accumulation. Similar results have

Table 1. Effect of drip irrigation level and micronutrient application method on plant height and dry matter accumulation of mustard

Treatment	Plant height (cm)			Dry matter accumulation per meter row length		
	40 DAS	80 DAS	At harvest	40 DAS	80 DAS	At harvest
Drip irrigation levels						
0.4 IW/CPE	70.90	129.29	177.30	34.54	100.95	155.16
0.6 IW/CPE	71.99	143.59	193.70	38.98	110.60	175.39
0.8 IW/CPE	72.49	150.49	196.00	40.65	114.99	185.13
CD (P=0.05)	NS	10.99	14.72	2.95	8.44	13.37
Micronutrient application methods						
Control	66.30	123.55	173.30	32.20	97.39	154.70
Soil application	70.80	137.15	185.90	37.08	105.96	168.45
Foliar application	74.60	147.55	197.30	40.90	113.76	178.95
Fertigation	75.48	156.25	199.50	42.05	118.27	185.46
CD (P=0.05)	3.91	7.91	10.52	2.14	6.07	9.67

NS=non-significant

also been reported by Bhunia et al (2004) and Choudhary et al (2005).

Yield attributes and yield: The different drip irrigation level affected the yield attributing characters of mustard significantly (Table 2). Among the different drip irrigation levels, the drip irrigation at 0.8 IW/CPE ratio recorded significantly higher no. of siliquae/plant (288.80), no. of seed/siliqua (15.64), test weight (3.86g), seed (18.06 q/ha), straw (69.66 q/ha) and biological yield (88.26 q/ha) over 0.4 IW/CPE ratio remain at par on 0.6 IW/CPE ratio (281.90, 14.95, 3.66, 18.06, 66.31 and 88.26, respectively) at all the growth stages. This increase in seed yield might be due to maintenance of sufficient moisture in root zone during critical stages of the crop growth, resulting in higher yields. The, higher seed yield with increasing IW/CPE ratio could be the resultant of cumulative beneficial effects of irrigation schedules first on vegetative growth and later on better partitioning of photosynthates towards the sink. These findings are in close conformity with those of Solanki et al (2014) and Kunapara et al (2017).

Economics: The higher net returns and B: C ratio of (Rs. 42639/ha and 1.87, respectively) at 0.8 IW/CPE ratio were significantly higher over 0.4 IW/CPE ratio (30413/ha and 1.65, respectively) and it remained statistical at par with 0.6 IW/CPE ratio (Table 3). The significantly higher net returns obtained under 0.8 IW/CPE ratio was due to higher seed and straw yields along with higher price of mustard. The total cost of production increased slightly with an increase in IW/CPE ratio for scheduling irrigation, because the irrigation charges were insignificant as compared with other expenses. The cost involved under this treatment was comparatively lower than its additional income, which led to more returns under

Table 2. Effect of drip irrigation level and micronutrient application method on yield attributes and yield of mustard

Treatment	No. of siliquae/ plant	No. of seed/ siliqua	Test weight (g)	Seed yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)
Drip irrigation level						
0.4 IW/CPE	257.90	13.32	3.20	15.78	57.63	73.41
0.6 IW/CPE	281.90	14.95	3.66	18.06	66.31	84.37
0.8 IW/CPE	288.80	15.64	3.86	18.60	69.66	88.26
CD (P=0.05)	21.56	1.14	0.28	1.38	4.17	5.30
Micronutrient application method						
Control	240.50	12.27	3.13	14.17	56.39	70.56
Soil application	267.90	14.45	3.46	17.37	62.90	80.27
Foliar application	289.80	15.5	3.74	18.65	68.18	86.83
Fertigation	306.60	16.34	3.97	19.73	70.66	90.39
CD (P=0.05)	15.42	0.83	0.20	1.00	3.65	4.65

Table 3. Effect of drip irrigation level and micronutrient application method on net returns, B: C ratio, consumptive use of water and water use efficiency in mustard

Treatment	Net return (Rs/ha)	B:C ratio	Consumptive use of water (mm)	Water use efficiency (kg/ha-mm)
Drip irrigation level				
0.4 IW/CPE	30413	1.65	191.1	8.26
0.6 IW/CPE	40784	1.85	264.3	6.83
0.8 IW/CPE	42639	1.87	334.6	5.56
CD (P=0.05)	2555	0.12	20.06	0.53
Micronutrient application method				
Control	30382	1.77	263.33	5.58
Soil application	34271	1.67	263.33	6.84
Foliar application	41215	1.82	263.33	7.34
Fertigation	45914	1.9	263.33	7.77
CD (P=0.05)	2250	0.10	15.57	0.35

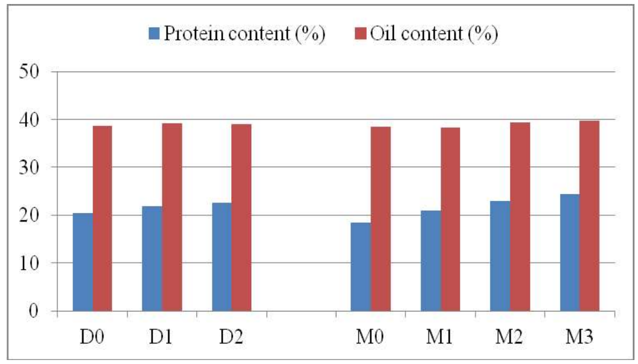
this treatment. These findings are in accordance with the results reported by, Mahalakshmi et al (2011) and Rajiv (2012).

Effects of Micronutrient Application Method

Growth parameters: Among micronutrients application method, fertigation recorded significantly higher plant height at 40, 80 days after sowing and at harvest (75.48, 156.25 and 199.50 cm, respectively) however, it remained at par with foliar application method, over control and soil application. The fertigation recorded maximum dry matter accumulation at 40, 80 days after sowing and harvest (42.05, 118.27 and 185.46 g, respectively) however, it remained at par with foliar application method, compared to control and soil application. Among the methods of nutrient application, foliar application is recognized as an important method of fertilization, since foliar spray usually penetrate the leaf cuticle or stomata and enters the cells facilitating easy and rapid utilization of nutrients. This leads to efficient utilization of micronutrients. The observed improvement in overall vegetative growth of the crop with the application method of micronutrient in the present investigation is in conformity with those of *Sintupachee* et al *(2010)* and Moosavi and Ronaghi (2011).

Yield attributes and yield: Micronutrient application method of fertigation recorded significant improvement in yield attributes and yield of mustard (Table 2). The fertigation recorded highest number of siliquae/plant, number of seed/siliqua and test weight (g) (306.60, 16.34 and 3.97, respectively) followed by foliar application (289.80, 15.50 and 3.74, respectively) over control at all the growth stages. Same trend was also observed in yield i.e. fertigation recorded highest seed, straw and biological yield (q/ha) (19.73, 70.66 and 90.39, respectively) followed by foliar application (18.65, 68.18 and 86.83, respectively) over control at all the growth stages. The combined application of micronutrients provided fertigation greater availability of nutrients for the development of reproductive structures and increase in the number of grains and grain weight. Since boron and combination of all micronutrients were responsible for the translocation of food materials in plants therefore it played a vital role in grain setting as well as higher number of grain. These results are in close conformity with the findings of Singh and choudhari (2001).

Oil and protein content (%): The micronutrient application by all methods significantly increased the oil and protein content in mustard seed. Further data showed that fertigation (39.83 and 22.88 %), being at par with foliar application (39.30 and 22.88 %), recorded significantly highest protein content in mustard seed over control and soil application (Fig. 1). The oil content and protein in seed of mustard was recorded significantly highest in fertigation of micronutrient.



D0-0.4 IW/CPE, D1-0.6 IW/CPE, D2-0.8 IW/CPE, M0- Control, M1- Soil application, M2- Foliar application and M3- Fertigation

Fig. 1. Effect of drip irrigation level and micronutrient application method on protein and oil content (%)

Higher nitrogen in seed is directly responsible for higher protein because it is a primary component of amino acids which constitute the basis of protein. These results are in close conformity with the findings of Mona et al (2015).

Economics: Significantly highest net returns (Rs. 45914/ha) and B:C ratio (1.90) were recorded under fertigation over control, soil and foliar application (Table 3). The highest income obtained in fertigation due to more yield. Similar findings were also observed by Jabran et al (2011) and Shankar et al (2017).

Water use Parameters

Consumptive use of water: The higher consumptive use of water obtained in 0.8 IW/CPE ratio as compared to 0.4 IW/CPE ratios. The 0.6 IW/CPE ratio statistically at par with 0.8 IW/CPE ratio. Water application with 0.8 IW/CPE provide higher water to crop, which leads to more available water and consumptive use by crop.

Water use efficiency (kg/ha-mm): The higher water use efficiency (kg/ha-mm) recorded in 0.4 IW/CPE ratio (8.26) followed by 0.6 IW/CPE ratio (6.83). Among different micronutrient application method, fertigation recorded higher water use efficiency (kg/ha-mm) (7.77) statically at par on foliar application (7.34).

CONCLUSION

The application of irrigation water through drip irrigation in mustard at 0.6 IW/CPE ratio provided higher plant growth parameter, yield attributes, yield, net return and quality. Similarly application of micronutrients through fertigation gave significantly higher growth, yield, net return, quality and water use efficiency.

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Effect of Seed Priming and Plant Geometry on Yield and Economics of Wheat in Modified System of Wheat Intensification under Sub-Tropical Conditions of Jammu

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***Abstract*:** A field experiment was conducted during the *Rabi* seasons of 2018–19 at the Research Farm, Division of Agronomy, SKUAST-Jammu to evaluate the effect of seed priming and plant geometry on yield and economics of wheat crop in modified system of wheat intensification under sub-tropical conditions of Jammu. The treatments comprised of different combinations of primed and un-primed wheat seed sown at 4 different plant geometries viz. 20 cm × 5 cm, 20 cm × 10 cm, 20 cm × 15 cm and 20 cm × 20 cm along with conventional sown wheat. The primed seed sown at plant geometry of 20 cm × 5 cm recoded significantly higher grain yield and straw yield which was statistically at par with the primed wheat seed sown at plant geometry of 20 cm × 10 cm and conventional sowing of primed seed. The grain yield of wheat was significantly higher with primed seeds as compared with un-primed seed. Further, conventional sowing of primed seed recorded highest net returns and B:C ratio which was closely followed by conventional unprimed sowing. However, with respect to grain yield, the primed sown at plant geometry of 20 cm × 5 cm registered highest of 23.87 % increment in grain yield over conventional sowing of wheat crop.

***Keywords*:** Modified system of wheat intensification (MSWI), Plant geometry, Seed priming, Yield and economics

Wheat is one of the most important cereal food grain crops and plays a pivotal role in India's food security after rice. In India, wheat is grown on an area of about of 29.58 million hectares with production and productivity of about 99.70 million tonnes and 3371 kg/ha, respectively (Anonymous 2020). Traditionally, wheat is grown by broadcasting and continuously sowing of seeds in lines without maintaining any specific plant geometry which have served well for long tracts but the limitations and constraints like non-uniformity in crop stand led to dilution effects of inputs and reflects in crop stand. System of Wheat Intensification (SWI) is a technique of wheat production which is based on manipulation of soil environment with minimum external inputs and less seed rate. SWI is based on the principles of root development and intensive care which demand to maintain optimum plant population, allowing sufficient aeration, moisture, sunlight and nutrient availability leading to proper root system development for early stage of crop growth. Modified System of Wheat Intensification (MSWI) is a synergistic management technique involving component of wheat farming such as sowing of a smaller number of seeds with wider spacing and seed treatment with specific formulations like vermi-compost, water, cow-urine and jaggery. The management practices under MSWI provides better conditions for the growth of wheat crop due to greater proliferation of root hairs and root length than those grown under traditional wheat cultivation. Besides this, seed priming also plays an important role in early germination of seedling in SWI. SWI along with seed priming enhance the grain yield to the tune of about 54 % over that of conventional sowing without priming (Uphoff et al (2011). Khadka and Raut (2011) reported the positive response of seed priming and line sown wheat crop over conventional practice. Keeping the above under consideration the study was planned to investigate the techniques of seed priming in conjunction with plant geometry on yield and economics in modified system of wheat intensification in wheat.

MATERIAL AND METHODS

A field experiment was conducted during *Rabi* season of 2018-19 at Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. The experimental site is located situated at 32°40´ N latitude and 74°82´ E longitude at an elevation of 293 m above mean sea level falling in the sub-tropical foot hill lands of Shiwaliks in Jammu and Kashmir. The climate of this place is bestowed with hot and dry early summers followed by hot and humid monsoon season and cold winters. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen but medium in available phosphorus and potassium with electrical conductivity in the safer range (Table 1).

The experiment was conducted in randomized block design with 10 treatments and three replications (Table 2). The wheat crop variety HD-3086 was sown in November using seed rate of 100 kg/ha in conventional sowing, 38, 19,13 and 10 kg/ha for 20 cm × 5 cm, 20 cm × 10 cm, 20 cm × 15 cm and 20 cm × 20 cm. Furrows were opened with the help of liner at a specified row to row distance of 20 cm between the rows and seeds were sown in furrows by *kera* method in case of conventional sown wheat. The intra row spacing's of 5, 10, 15 and 20 cm sowing was done by dibbling method using a rope tagged with signs indicating required plant spacing. Wheat crop was fertilized with 100:50:25 kg N: P_20_5: K_20 /ha respectively. Entire quantity of phosphorus, potassium and one half of the total nitrogen was applied as basal dose at the time of sowing. Remaining half dose of nitrogen was applied in two equal splits at crown root imitation stage and just before ear initiation stage in all treatments. The crop was grown under assured irrigation without any water stress during crop growth period and was managed as per regional recommendations of SKUAST-Jammu.

Seed priming formulation comprised of vermi-compost, water, cow-urine and jaggery in the ratio of 1.0: 1.0: 0.5: 0.1 to treat the seeds before sowing. 5 kg of wheat seed, 5 litres of water, 5 kg of vermi-compost, 2.5 litre of cow-urine and 500 g of jaggery was taken in a bucket and was kept overnight. The primed material was stirred during preparation period. Thereafter, the material was sieved using cotton cloth and the resultant solution so obtained was used to treat the seeds. The treated seeds were first immersed in water to remove the chaffy seeds which were found floating on the surface of water. The seeds which settled on the surface of the tub were then removed and immersed in the priming solution for eight hours. The seeds were taken out of the primed solution and dried in shade. Seeds were then treated with *Trichoderma viride* @ 4g/kg of seed, then again dried in shade for about an hour and thereafter sown directly in the field. *Trichoderma viride* @ 4g/kg of seed was used uniformly to treat the seeds irrespective of the conditions whether the seed used was primed or un-primed. Data pertaining to yield was obtained at harvest. For grain and straw yield, from the individual plot, net plot was harvested and subsequently, the grain and straw yield thus obtained were weighed. Among economic parameters, net return per ha was calculated by deducting cultivation cost from gross returns. Benefit cost (B:C) ratio was calculated by dividing net returns with total cost of cultivation to evaluate the economic viability of treatments. The analysis of variance was conducted using OP-Stat developed by CCSHAU, Hisar for all observations

RESULTS AND DISCUSSION

Grain yield: Crop yield is the resultant of better growth and development of the plant, higher rate of photosynthesis, better translocation of photosynthates and better source sink association. The grain yield of wheat was significantly influenced by seed priming under different plant geometries in modified system of wheat intensification (Table 2). Primed seed sown at plant geometry of 20 cm × 5 cm recorded significantly higher grain yield of 5,095 kg/ha which was statistically at par with primed seed sown at plant geometry of 20 cm × 10 cm with grain yield of4,714 kg/ha and conventional sowing of primed seed with grain yield of 4,662 kg/ha. Primed seed sown at plant geometry of 20 cm × 5 cm was in turn significantly superior in recording grain yield over all the rest of the treatments. The per cent enhancement in grain yield in primed seed sown at plant geometry of 20 cm × 5 cm over that of conventional sowing was to the tune of 23.99 per cent and un-primed seed sown at plant geometry of 20 cm × 20 cm, recorded lowest grain yield of 3,378 kg/ha. Wider spacing permitted better performance per hill than narrow spacing due to decreased competition between plant for nutrient, water, space and light but decreased overall grain yield. The wider spacing's of more than 20 cm x 10 cm could not compensate the drastic reduction in plant population and productive tillers per unit area and thus resulted in severe decrease in yield of wheat. The findings were in conformity with the findings of earlier researches (Thakur et al 2010, Kumar et al 2015, Zheng et al 2013). Seed priming also imparted a positive influence on grain yield of wheat as compared to un-primed seed. The increase in grain yield of wheat under seed priming might be due to its positive effect on growth parameters *viz*.; crop emergence, complete crop emergence, both above and below ground plant growth and yield attributes over un-primed seeding in modified system of wheat intensification. Sarlach et al (2013) also reported similar effect of seed priming on the grain yield of wheat.

Straw yield: The straw yield of wheat was also significantly influenced by seed priming at different plant geometries in modified system of wheat intensification. Further, similar statistical trends like that of grain yield were also observed in straw yield among all the treatments. Primed seed sown at plant geometry of 20cm x 5 cm recorded significantly higher straw yield of 6,339kg/ha which was statistically at par with Primed seed sown at plant geometry of 20cm x 10 cm (5,984 kg/ha) and conventional sowing of primed seed (5,815 kg/ha). Un-primed seed sown at plant geometry of 20cm x 20cm, recorded lowest straw yield of 4,436 kg/ha. The per cent enhancement in straw yield in primed seed sown at plant geometry of 20cm × 5 cm over that of conventional sowing was to 20.44%.The reduction in straw yield at wider spacings were mainly be ascribed to the decrease in overall number of plants per unit area rather than number of tillers per hill at wider spacings. Wider spacing better ulitlised the nutrient, water, space and light that are required for plant growth but decreased overall straw yield might be due to lesser plant biomass production at wider spacings. The results corroborate with the finding of Jayawardena and Abeysekera (2011). Damodaran et al (2012) and Hussain et al (2012) also claimed that wider spacing retained unfilled space between plants and thus reduced the yield. Further, primed seed enhanced the straw yield as compared with un-primed seed. Khadka and Raut (2011) have also reported that seed priming improves emergence, stand establishment, tillering and straw yields.

Harvest index (per cent): The harvest index of wheat crop was not significantly influenced by the effect of seed priming at different plant geometries in modified system of wheat intensification. Primed seed sown at plant geometry of 20cm x5 cm recorded highest harvest index (44.56 per cent), whereas minimum harvest index of 43.27 per cent was in un-primed seed sown at plant geometry of 20cm x 10cm. Maximum harvest index was recorded with primed seed as compared to un-primed seed at similar plant geometry. Jayawardena and Abeysekera (2001), Farooq et al (2008) and Bhargava et al (2016) also reported the increasing trend in harvest index with the increase in spacing. Seed priming with cow urine recorded higher harvest index than un-primed seed of wheat. These results are in conformity with the finding of Solemanzadeh (2013).

Relative economics: The highest cost of cultivation was in primed treatments as compared to un-primed treatments sown at similar plant geometries (Table 2). This is due to the extra expenditure incurred on the purchase of priming material and labour engaged in treating the seed in these treatments. Further seeding done at narrow plant geometry (20 cm × 5 cm) recorded higher cost of cultivation and a reduction in the cost of cultivation is recorded with the increase in crop geometry. This has happened to due to more man days involved in dibbling the seed in the treatments of narrow spacing to that of wider spacing. Highest gross return of Rs.1,19,097/ha was realized in primed seed sown at plant geometry of 20 cm x 5 cm and it was followed in the descending order by primed seed sown at plant geometry of

Table 1. Properties of soil

Soil type	Ph	EC (dS/m)	O.C. (g/kg)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Sandy clay loam	7.68	0.14	4.73	213.20	19.76	152.8

Table 2. Effect of seed priming at different plant geometries on grain yield, straw yield and relative economics in modified system of wheat intensification

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (Per cent)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C Ratio
Conventional sowing (Check)	4,109	5,263	43.88	24,344	96,656	72,312	2.97
Un-primed seed sown at 20 cm × 5 cm	4,416	5,645	43.93	40,791	1,03,827	63,036	1.54
Un-primed seed sown at 20 cm × 10 cm	4,112	5,338	43.57	37,135	97,009	59,873	1.61
Un-primed seed sown at 20 cm × 15 cm	3,772	4,798	44.04	33,793	88,605	54,812	1.62
Un-primed seed sown at 20 cm ×20 cm	3,378	4,436	43.27	30,530	79,904	49,374	1.61
Conventional sowing of primed seed	4,662	5,815	44.42	25,704	1,09,045	83,342	3.24
Primed seed sown at 20 cm × 5 cm	5,095	6,339	44.56	41,406	1,19,097	77,691	1.87
Primed seed sown at 20 cm × 10 cm	4,714	5,984	44.02	37,442	1,10,678	73,236	1.95
Primed seed sown at 20 cm ×15 cm	4,228	5,375	44.00	34,025	99,300	65,275	1.91
Primed seed sown at 20 cm × 20 cm	3,714	4,781	43.71	30,724	87,456	56,732	1.84
CD (p=0.05)	527.27	682.77	N.S	-	-	-	-

20 cm x 10 cm, conventional sowing of primed seed. It is because of highest yield both of grains and straw realized in this treatment as compared to the rest of the treatments. Highest net return of Rs. 83,342/ha and B: C ratio of 3.24 were recorded in conventionally sown primed seed as compared with Conventional sowing (Check) with net return of Rs. 72,312/ha and B: C ratio of 2.97. This is because of the fact that the increase in economic yield due to seed priming is proportionately far more than the expenditure made on the priming material as well as its application to the seeds, and thus has fetched higher net returns and B: C ratio. The results corroborate with the findings of Suryawanshi et al (2013). Conventional primed sowing was found to be more economical than modified system of wheat intensification (MSWI) at narrow plant geometry, this is because of far less cost of cost of cultivation involved in the conventionally sown primed seed as manual labour engaged for sowing under MSWI was much higher which might have neutralized the impact of its higher economic yield. The results corroborated the finding of Kumar et al (2015).

CONCLUSION

The primed seed sown at plant geometry of 20 cm × 5 cm recorded higher grain and straw yield and was statistically at par with primed seed sown at a plant geometry of 20 cm × 10 cm and conventional sowing of primed seed, except for the B: C ratio which was higher in the conventional sowing of primed seed and conventional sowing. Thus, modified system of wheat intensification is best suitable option for resource poor farmers for getting optimum wheat production in irrigated sub tropics of Jammu.

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Yield and Nutrient Budgeting as Influenced by Organic Sources of Nutrients and Weed Management in Rice-Potato-Frenchbean Cropping System

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***Abstract*:** A field experiment was conducted during 2015-16 and 2016-17 under different organic sources of nutrients and weed management in rice (*Oryza sativa* L.) - potato (*Solanum tuberosum* L.)-frenchbean (*Phaseolus vulgaris*) cropping system with six sources of nutrients as main-plot treatments and four weed management practices as sub-plot treatments. Among the organic sources of nutrients, application of 100% organics (100% recommended N through different organic sources each equivalent to 1/3 of recommended N i.e. FYM+ vermicompost + non-edible oil cake) + VAM recorded significantly maximum individual crop yield and rice equivalent yield (REY). The highest apparent balance of nitrogen and phosphorus was recorded with the application of 100 % recommended NPK + secondary and micronutrients based on soil test through inorganic fertilizer and 50 % recommended N through vermicompost + biofertilizers for N + rock phosphate to substitute the P requirement + PSB. Whereas, the balance of available potassium in soil was negative with the application of different sources of nutrients. Application of mustard seed meal @ 5 t/ha registered significantly higher yield of crops, REYand apparent balance of nitrogen. However, the balance of available phosphorous and potassium in soil was recorded highest with the application of rice bran @ 4 t/ha.

Keywords: Cropping system, Mustard seed meal, Nutrient budgeting, Organic sources of nutrients, Rice bran and Rice equivalent yield

In the Indian subcontinent, rice–wheat and rice–rice are the major rice-based cropping systems. However, the production potential of these systems has become fatigued and is plateauing and income has started to show a declining trend (Ray et al 2012). Because of high productivity, stability and less risk factor, the wide adoption of this system will still has to play a major role in future planning to sustain self-sufficiency of food grains in the years to come (Singh et al 2012). But now the productivity of both the crops has stagnated and factor productivity is declining year after year. The farmers realize much of their food security from this cropping system but its declining productivity needs urgent attention, which jeopardizes the farmer's economic security to a considerable extent. To strengthen the economic security, it is imperative to intensify and diversify the existing rice-wheat system with some other high value crops *viz.* potato and frenchbean having greater economic worth using organic agriculture as a practice towards crop production. In present context, general the rice-wheat crop is largely grown by applying high input using inorganic fertilizer. It can be ascertained by the fact that as far fertilizer consumption is concerned India ranks second next to China (Sharma and Thaker 2011). This practice of high input agriculture no doubt has led to self-sufficiency in food-grains but it has posed several new challenges. The productivity of most of the crops is declining. With wide application of chemical fertilizers, pesticides and herbicides, large-scale utilization of water resources and implementation of genetic engineering, the global per capita food production has been increased significantly. However, these efforts have also resulted in some negative impacts on environment and biodiversity and thus present potential threat to the sustainability. Balancing productivity, profitability and environmental health is a key challenge for agricultural sustainability facing today. Therefore, the use of locally available agro-inputs in agriculture by avoiding or minimizing the use of synthetically compounded agro-chemicals appears to be one of the probable options to sustain the agricultural productivity. Keeping this in view, a field experiment was undertaken to study the effect of different sources of organic nutrients and weed management on crop yield and nutrient budgeting in rice-potato-frenchbean cropping system.

MATERIAL AND METHODS

A field experiment was conducted during 2015-16 and 2016-17 on organic sources of nutrient and weed management in rice-potato-frenchbean system under irrigated condition at Sher-e-Kashmir University of

Agricultural Sciences and Technology of Jammu. The soil of the experimental site was clay loam in texture having *p*H 8.04, organic carbon 0.55%, available N, P and K of 220.40, 13.25 and 118 kg/ha, respectively. The experiment was laid out in split plot design replicated thrice with six sources of nutrients in main-plot and four weed management treatments in sub-plot (Table 1). In case of organic nutrient management, all manures were applied before final land preparation for transplanting of rice and at planting of potato and frenchbean in furrows. The inorganic sources used were urea, single super phosphate and muriate of potash to supply N, P and K, respectively. The recommended doses of fertilizers for rice, potato and frenchbean were 30:20:10; 120:60:60 and 50:100:50 NPK (kg/ha), respectively. In case of inorganic nutrient management, full quantity of P and K were applied as basal in all the crops and N was applied in split doses. In rice, 25% of N was applied as basal, 50% top dressed at tillering and rest 25% was applied at panicle initiation stage. In potato and frenchbean 50% of N was applied as basal and rest N was applied in 2 equal splits at 25 and 45 days after planting. The test varieties for rice, potato and frenchbean were 'Pusa 1121', 'Kufri Sindhuri' and 'Contender', respectively. In case of weed management, mustard seed meal and rice bran were applied as pre-plant incorporation (PPI) ten days before transplanting/planting of rice, potato and frenchbean. Standard agronomic management practices were followed for all crops. Crop yields were recorded at the end of each season and rice equivalent yield (REY) was computed at the end of each cropping cycle. Treatment wise apparent balances of nitrogen, phosphorus and potassium was worked out by calculating the levels of nutrients (nitrogen, phosphorus and potassium) present in the soil before transplanting/planting/sowing and after harvesting of the crops, and the amount of nutrients added through fertilizers and removed by the crop and weeds. Apparent balance of nutrients was calculated individually as per the standard formula given by Yadav et al (2002). Least significant difference (LSD) values at a 5% level of significance were used to determine the significance of differences between treatment means by using OPSTAT software.

RESULTS AND DISCUSSION

Yield: The yield of individual crop (rice, potato and frenchbean) and system yield in terms of REY during the both cropping cycle were the highest with the 100% organics (100% recommended N through different organic sources each equivalent to 1/3 of recommended N i.e. FYM+ vermicompost + non-edible oil cake + VAM which was statistically at par with 100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean and 100% recommended N through different organic sources each equivalent to 1/3 of recommended N i.e. FYM+ vermicompost + non-edible oil cake (Table 1). Combined application of FYM, vermicompost and neem cake increased the adsorptive power of soil for cations and anions particularly phosphates, nitrates and other micronutrients and their slow release during entire crop growth period led to better translocation of photosynthates to the sink reflected by higher crop yield. Favourable soil conditions and availability of micro and major nutrients through the integrated use of different organic sources led to increased leaf surface area resulting in more photosynthesis, dry matter accumulation and ultimately biomass yield (Verma et al 2011, Sharma and Subehia 2014). Rice equivalent yield was directly associated with the yield of respective crops in the sequence and so the application of 100% organics (100% recommended N through different organic sources each equivalent to 1/3 of recommended N i.e. FYM+ vermicompost + non-edible oil cake + VAM enhanced the yield potential of crops which ultimately increased the rice equivalent yield of the sequence. Among the weed management treatments, application of mustard seed meal @ 5 t/ha recorded significantly highest yield of rice, potato and frenchbean which was statistically at par with the application of rice bran @ 4 t/ha and weed free treatment. Enhancement in the growth parameters under congenial environment provided by substantial reduction in inter-generic competition due to weed suppression and better translocation of carbohydrates for higher sink realization in these treatments. Higher nutrient content of mustard seed meal led to enhanced N, P and K uptake also resulted in improvement in yield (Haramoto and Gallandt 2004, Ullah et al 2008). Increase in the yield of respective crops (potato and frenchbean) in sequence with the application of mustard seed meal which ultimately increased the rice equivalent yield.

Nutrient budgeting: Among the different sources of nutrients, the percent increase in apparent balance of nitrogen with the application of 100 % recommended NPK + secondary and micronutrients based on soil test through inorganic fertilizer was recorded to be 79.19% and 87.60% over the application of 50 % recommended N through vermicompost + biofertilizers for N + rock phosphate to substitute the P requirement + PSB after the completion of both crop cycles (Table 2 and Table 3). The highest apparent balance of nitrogen was recorded with the application of 100 % recommended NPK + secondary and micronutrients based on soil test through inorganic fertilizer which was due to less removal of nitrogen by different crops. The lowest apparent balance of nitrogen was observed with the application of 50 % recommended N through vermicompost +

Table 1. Effect of organic sources of nutrients and weed management on crop yield (t/ha) in rice–potato–frenchbean cropping system

Treatment	Yield (t/ha)						Rice equivalent yield (t/ha)	
	Rice		Potato		French bean			
	2015	2016	2015-16	2016-17	2016	2017	2015-16	2016-17
Sources of Nutrients								
T_1-50% recommended NPK through fertilizer + 50% N through FYM + inorganic source of micronutrients as per soil test	3.61	3.75	12.66	12.81	3.77	3.86	13.05	11.29
T_2-100% organics (100% recommended N through different organic sources each equivalent to 1/3 of recommended N *i.e.* FYM+ vermicompost + non-edible oil cake)	3.81	3.96	12.87	13.02	4.00	4.09	13.58	11.76
T_3-100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for French bean	3.88	4.03	12.97	13.12	4.05	4.14	13.75	11.91
T_4-50% recommended N through vermicompost + biofertilizers for N + rock phosphate to substitute the P requirement + PSB	3.34	3.47	12.43	12.57	3.50	3.58	12.39	10.70
T_5-100% organics+ VAM	3.94	4.10	13.03	13.18	4.11	4.20	13.89	12.04
T_6-100% recommended NPK + secondary and micronutrients based on soil test through inorganic fertilizer	3.37	3.50	12.45	12.60	3.53	3.61	12.46	10.77
CD (p=0.05)	0.15	0.17	0.19	0.20	0.16	0.16	0.39	0.37
Weed management								
W_0-Weed free	3.82	3.97	13.73	13.94	4.06	4.19	14.03	12.17
W_1-Mustard seed meal @ 5 t/ha	3.92	4.09	13.83	14.06	4.19	4.33	14.30	12.43
W_2-Rice bran @ 4 t/ha	3.86	4.02	13.75	13.97	4.11	4.25	14.12	12.26
W_3-Weedy check	3.03	3.13	9.64	9.55	2.93	2.88	10.30	8.77
CD (p=0.05)	0.11	0.13	0.14	0.15	0.14	0.15	0.30	0.28
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Apparent balance of nutrients after rice-potato-frenchbean system (2015-16) as influenced by different sources of nutrients and weed management

Treatment	N (kg/ha)				P (kg/ha)				K (kg/ha)			
	Addition	Removal	Actual change in soil after crop cycle	Apparent Balance	Addition	Removal	Actual change in soil after crop cycle	Apparent Balance	Addition	Removal	Actual change in soil after crop cycle	Apparent Balance
Sources of nutrients												
T_1	461.30	349.23	10.85	101.22	272.77	147.90	0.15	124.72	258.77	270.89	3.17	-15.29
T_2	461.30	391.34	14.66	55.30	225.81	178.05	0.19	47.58	244.62	328.66	5.96	-90.00
T_3	461.30	393.91	18.15	49.24	225.81	179.12	0.17	46.52	244.62	332.62	6.47	-94.47
T_4	361.30	321.13	13.39	26.79	324.65	130.58	0.12	193.95	170.69	232.00	3.49	-64.80
T_5	461.30	403.36	22.84	35.10	225.81	184.78	0.13	40.90	244.62	343.92	5.32	-104.62
T_6	461.30	327.36	5.20	128.74	324.65	134.34	0.13	190.19	217.3	243.05	-2.51	-23.24
CD (p=0.05)		14.31	14.66			9.78				16.64		
Weed management												
W_0	183.33	359.10	12.08	-187.85	121.93	133.17	0.02	-11.25	132.80	271.65	2.51	-141.36
W_1	883.33	403.86	17.34	462.13	390.93	176.84	0.34	213.76	326.80	330.99	5.35	-9.55
W_2	528.53	396.89	14.86	116.78	431.53	173.03	0.19	258.31	328.00	322.11	4.02	1.88
W_3	183.33	297.69	12.44	-126.80	121.93	153.47	0.04	-31.58	132.80	242.67	2.71	-112.58
CD (p=0.05)		12.69				9.24				14.59		

See table 1 for treatment details

Table 3. Apparent balance of nutrients after rice-potato-frenchbean system as influenced by different sources of nutrients and weed management (2016-17)

Treatment	N (kg/ha)				P (kg/ha)				K (kg/ha)			
	Addition	Removal	Actual change in soil after crop cycle	Apparent Balance	Addition	Removal	Actual change in soil after crop cycle	Apparent Balance	Addition	Removal	Actual change in soil after crop cycle	Apparent Balance
Sources of nutrients												
T_1	457.30	356.57	18.12	82.61	279.3	151.36	0.28	127.66	262.64	233.32	15.33	13.99
T_2	457.30	399.14	30.60	27.56	230.61	181.29	0.32	49.00	252.95	283.28	15.96	-46.30
T_3	457.30	404.20	31.36	21.74	230.61	183.05	1.30	46.26	252.95	286.73	16.00	-49.78
T_4	357.30	326.75	16.66	13.90	326.25	131.15	0.46	194.64	170.30	199.24	16.23	-45.16
T_5	457.30	412.93	35.50	8.88	230.61	190.01	1.08	39.52	252.95	296.64	16.27	-59.96
T_6	457.30	333.66	11.47	112.17	326.25	136.45	0.66	189.14	222.52	208.74	13.23	0.56
CD (p=0.05)		15.33				10.06				14.88		
Weed management												
W_0	183.33	370.59	21.85	-209.11	124.36	138.40	0.55	-14.60	133.19	235.61	14.35	-116.77
W_1	869.33	413.33	27.11	428.89	385.36	179.15	0.87	205.33	335.69	282.89	17.25	35.55
W_2	526.53	403.96	24.63	97.94	448.36	172.83	0.72	274.80	340.79	273.83	15.86	51.11
W_3	183.33	300.94	22.21	-139.82	124.36	158.49	0.58	-34.71	133.19	212.97	14.55	-94.32
CD (p=0.05)		12.82				9.64				13.27		

See table 1 for treatment details

biofertilizers for N + rock phosphate to substitute the P requirement + PSB was ascribed to the lowest addition of nitrogen under this treatment. The percent increase in apparent balance of nitrogen with the application of 50 % recommended N through vermicompost + biofertilizers for N + rock phosphate to substitute the P requirement + PSB over the application of 100% organics + VAM was recorded to be 78.91%and 79.69% after the completion of both crop cycles (2015-16 and 2016-17).The balance of available phosphorous in soil was recorded highest with the application of 50 % recommended N through vermicompost + biofertilizers for N + rock phosphate to substitute the P requirement + PSB followed by 100 % recommended NPK + secondary and micronutrients based on soil test through inorganic fertilizer which could be attributed to highest addition of phosphorus. The balance of available potassium in soil was negative with the application of different sources of nutrients. However, the highest negative balance of potassium was recorded with the application of 100% organics + VAM after the completion of first crop cycle (2015-16) which was due to the highest removal of potassium under this treatment. After the completion of second crop cycle (2016-17), the highest apparent balance of potassium was recorded with the application of 50% recommended NPK through fertilizer + 50% N through FYM + inorganic source of micronutrients as per soil test and the percent increase in the apparent balance of potassium was about 95.99% over the application of 100 % recommended NPK + secondary and micronutrients based on soil test through inorganic fertilizer which was due to the highest addition of potassium with the application of 50% recommended NPK through fertilizer + 50% N through FYM + inorganic source of micronutrients as per soil test. Among the weed management treatments, highest apparent balance of nitrogen was observed with the application of mustard seed meal @ 5 t/ha which was due to the highest addition of nitrogen by the application of mustard seed meal. The balance of available phosphorous in soil was recorded highest with the application of rice bran @ 4 t/ha followed by mustard seed meal @ 5 t/ha which might be due to highest addition of phosphorus with the application of rice bran. The apparent balance of available potassium in soil was higher with the application of rice bran @ 4 t/ha owing to highest addition of potassium with the application of rice bran.

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CONCLUSION

The application of 100% recommended N through different organic sources each equivalent to 1/3 of recommended N i.e. FYM+ vermicompost + non-edible oil cake+ VAM application of mustard seed meal @ 5 t/ha (organic weed management) produced significantly higher system productivity and REY besides showed improvement in apparent balance of nutrients (NPK) to considerable and sustainable levels coupled with organically weed management practice i.e. application of mustard seed meal rice bran in rice-potato-frenchbean cropping system.

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Resource Use and Technical Efficiency in Coriander Production in Jhalawar District of Rajasthan

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Abstract: This study examines the efficiency of resource use, technical efficiency and constraints in coriander production in Jhalawar district of Rajasthan. The results indicated that fertilizer, plant protection chemicals and irrigation water resources were being used at sub-optimal level, and increase in use of these resources will provide better return. The mean technical efficiency of farms was 85.40 percent, and more than 66 percent farms were operating at above 80 percent efficiency level. Lack of disease resistant seed varieties and lack of awareness about seed treatment were the major production constraints, whereas lack of proper market information and lack of ingredient estimation facilities for seed spices were the major marketing constraints faced by the farmers. Government interventions are needed for awareness creation, information dissemination, establishment of ingredient estimation facility, facilities for storage, processing and transportation.

Keywords: Coriander, Resources use efficiency, Stochastic frontier analysis, Technical efficiency

India is popularly known as the 'spices bowl' of the world from ancient times. This land of spices is ranked first in the production, consumption, and export of spices in the world. India fulfils around 50-60 per cent of the world's demand for seed spices with an annual export of about 15 per cent of its production (Lal 2018). The vast geographical area and diversified climate of India are favourable for the cultivation of a variety of spices. Rajasthan is the second largest spice-producing state of India with a 10.41 percent share after Madhya Pradesh. Coriander or Dhaniya (*Coriandrum sativum*) is one among the most popular seed spices along with cumin, fenugreek and fennel. It is an annual herbaceous plant of Apiaceae family characterized by the presence of a slender hollow stem. Young coriander leaves are used as an important ingredient of curries, chutneys, and soups. Seeds are used in the making of curry powders and seasonings of bakery products. It also has medicinal properties and is used as a natural diuretic, aphrodisiac, carminative, diabetic, antioxidant, anti-cancer, and cardioprotective. The area and production under coriander cultivation in India is 528970 ha and 700815 tonnes (2019-20). Rajasthan is the third largest producer of coriander after Madhya Pradesh and Gujarat. Major coriander growing districts of Rajasthan are Jhalawar, Baran, Kota, Bundi, and Alwar region. Coriander occupies an area of 60039 ha (5.88 per cent share of total spice area of Rajasthan) with a production of 89341 tonnes (8.44 per cent share of total spice production) in Rajasthan, in 2019-20. Rajasthan is a leading producer of coriander, and a number of farmers are depending on this spice crop for their livelihood. Hence it is important to understand the efficiency level of coriander production in Rajasthan. In this backdrop, this study looks into the efficiency of resource use, technical efficiency and constraints in the production and marketing of coriander in a major producing district of Rajasthan.

MATERIAL AND METHODS

The present study is based on primary data regarding inputs and output, and the constraints in production which were collected from the respondent farmers through personal interview method with a standardized schedule. Multi-stage sampling was used for the selection of the area of the study. Rajasthan was selected being the third largest producer of coriander, and Jhalawar district was selected as it was having highest area under coriander cultivation in the state. Jhalrapatan tehsil was selected for the same reason, and two villages (Samrai & Jhoomki) were selected randomly from Jhalrapatan tehsil. Fifteen farmers were randomly selected from each of these villages, thus making a sample of 30 farmers for the study.

Resource use efficiency: To estimate resource productivity and allocative efficiency, following Suresh and Reddy (2006) and Guleria et al (2022), Cobb-Douglas form of production function was fitted to the data by taking gross income as a dependent variable. Inputs used were the independent variables for regression.

The model used was:

$$Y = aX_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5}$$

This functional form was estimated using ordinary least square (OLS) method after converting into loglinear form.

$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5$

Where, Y = Gross return per hectare (₹), a = Constant representing intercept of the production function, X_1 = cost incurred in labour use per hectare (₹), X_2 = cost incurred in machine use per hectare (₹), X_3 = cost incurred in fertilizer use per hectare (₹), X_4 = cost incurred in plant protection chemicals used per hectare (₹), X_5 = cost incurred in irrigation per hectare (₹), b_1, b_2, b_3, b_4 and b_5 are the regression co-efficients of the respective resource variables.

Statistical significance of the coefficients was tested with the help of 't' test.

To examine the efficiency of resource use, the ratio of marginal value product (MVP) to the marginal factor cost (MFC) for every significant input was computed. When MVP > MFC, the ratio will be greater than 1. This indicates efficient utilization of that resource, and there is further scope for allocating more units of that particular resource. Conversely, if MVP < MFC, the ratio will come less than 1, indicating over-utilization of that resource.

RUE = MVP/MFC

$MVP = MPP_i \times P_y$

$MPP_i = b_i Y/X_i$

Where, MVP = marginal value product, MFC = marginal factor cost, MPP_i = marginal physical product of the i^{th} input, P_y = price of output, b_i = elasticity coefficient of the independent variable, Y = geometric mean of the output, and X_i = geometric mean of the i^{th} input.

Technical efficiency: Following Jacob and Ambily (2021) and Dev et al. (2021), Stochastic Frontier Analysis (SFA) was used to study technical efficiency in coriander production.

The stochastic model can be represented as: $Y_i = f(X_i, \beta) \exp(V_i - U_i)$

Where, Y_i is Production of i^{th} farm, $f(X_i, \beta)$ is a function of X_i, of the inputs for the i^{th} farm and β is the vector of unknown parameters, V_i is symmetric component of the error term and U_i is random error.

The model used in the study is:

$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + V_i - U_i$

Where, Y = Gross return per hectare (₹), a = Constant representing intercept of the production function, X_1 = cost incurred in labour use per hectare (₹), X_2 = cost incurred in machine use per hectare (₹), X_3 = cost incurred in fertilizer use per hectare (₹), X_4 = cost incurred in plant protection chemicals used per hectare (₹), X_5 = cost incurred in irrigation per hectare (₹), b_1, b_2, b_3, b_4 and b_5 are parameters to be estimated.

Constraints in production and marketing: Garrett's (1969) ranking technique was used to rank the farmers' responses on constraints in coriander production and marketing. Following formula was used to convert the ranks given by each respondent into percent position. These percent positions were further converted into scores using Garrett's table.

$$\text{Percent position} = \frac{100 \text{ X } (Rij - 0.5)}{N_i}$$

Where, R_{ij} is the rank given to i^{th} constraint by the j^{th} individual, and N_j is the number of constraints ranked by the j^{th} individual.

RESULTS AND DISCUSSION

Resource use efficiency: The coefficient of multiple determinations (R^2) was 0.7605 which indicate 76.05 per cent variation in gross return was explained by the independent variables included in the model (human labour, machine labour, fertilizers, plant protection measures and irrigation charges (Table 1). The regression coefficients of inputs like fertilizer, plant protection chemicals and Irrigation water were positive and significant. The increase in use of these inputs will increase the gross return. One percent increase of fertilizer, plant protection chemicals and irrigation from the existing mean levels, would increase the return by 0.27 percent, 0.52 percent and 0.22 percent, respectively.

The efficiency of resource use was computed with the help of the ratio of marginal value product (MVP) to their marginal factor cost for the significant resources included in the regression model (Table 2). The input variables such as fertilizer, plant protection chemicals and irrigation water showed their MVP/MFC ratios as greater than unity. This

Table 1. Regression coefficients of variables in coriander in Jhalawar district

Variables	Regression coefficients (bi)	Std. Error
Human labour	0.084	0.195
Machine labour	-0.174	0.178
Fertilizer	0.268*	0.135
Plant protection chemicals	0.518*	0.254
Irrigation	0.218**	0.104
R^2	0.761	

Note: *Significant at 10 per cent level, **Significant at 5 per cent level

Table 2. Resource use efficiency in Coriander production in Jhalawar district

Variables	MVP	MFC	MVP/MFC
Fertilizer	14.14	1	14.14
Plant protection chemicals	36.12	1	36.12
Irrigation	5.61	1	5.61

indicates that these variables are underutilized and additional returns of ₹ 14.14, ₹ 36.12 and ₹ 5.61 will be achieved by spending of every additional rupee on fertilizer, plant protection chemicals and Irrigation water, respectively.

Technical efficiency: Producing at technically inefficient levels leads to reduction in farmers income and profit. Understanding on estimates of technical efficiency can help farmers to understand whether they are producing at technically efficient level or not, subject to the available resources. This will ensure better use of inputs and thus improvement in efficiency in production (Dev et al 2021). High value of the estimated variance parameter of the model shows that differences between observed and maximum value of output was mostly due to farmers practices rather than random utility. Further, the results (Table 3) showed that estimated value of coefficient of irrigation was positive and highly significant. This indicates the potential of irrigation in increasing the crop output.

There was wide variation in technical efficiency among the sample farms- ranging from 66.1 to 98.5 percent (Table 4). The mean technical efficiency was 85.4 percent. This indicates that on an average, the sample farmers tend to realize around 85.4 percent of their technical capabilities. Thus, on an average, there is potential to realize 14.6 percent more of technical efficiency by following efficient crop management practices.

Table 3. MLE Estimates of stochastic frontier production function

Variables	Coefficient	Std. Error
Constant	7.748869	1.655552
Human labour	0.044372	0.204228
Machine labour	-0.1628	0.159555
Fertilizer	0.174697	0.108762
Plant protection chemicals	0.21338	0.339143
Irrigation	0.225264***	0.052939
sigma-squared	0.0402***	0.015268
gamma	0.999***	0.010983
log likelihood function	26.66595	
LR test	1.820197	

Table 4. Distribution of sample farmers under different levels of technical efficiency

Technical efficiency (%)	Number of farms	Percentage to total
60.01-70	2	6.67
70.01-80	7	23.33
80.01-90	10	33.33
> 90	11	36.67
Total	30	100
Mean TE (%)	85.40	

Majority of the farms (36.7 percent) were operating close to the frontier with technical efficiency of more than 90 percent. This was followed by 33.3 percent farms whose efficiency levels ranged between 80.01 to 90 percent and 23.3 percent farmers with efficiency range of 70.01 to 80 percent. The analysis revealed that more than 66 percent of the farms were operating at technical efficiency levels greater than 80 percent.

Constraints in production and marketing: Lack of resistant varieties to major diseases was a prime production constraint. Leaf blight, bacterial blight, powdery mildew and anthracnose were the major diseases of coriander. Varieties resistant to these diseases can help to improve productivity as well as the quality of produce. Lack of awareness about seed treatment was the second most ranked constraint by the respondents and illiteracy is a big issue behind this. Lack of availability of verified, improved seeds, lack of better machineries and lack of awareness about control measures for major diseases, lack of availability of fertilizers, and its high cost, lack of availability of labour, capital, poor texture of soil, issue of weeds and lack of electricity were the other major constraints in production (Table 5).

Table 5. Constraints in production and marketing of coriander crop

Constraints	Mean score	Rank
Production constraints		
Lack of resistant variety to major diseases	67.13	I
Lack of awareness about seed treatment	64.16	II
Lack of improved seed (Govt verified)	60.2	III
Lack of improved machineries for cultivation	59.66	IV
Lack of awareness about control measures for major diseases	55.56	V
Lack of timely availability of fertilizers	55.3	VI
High cost of fertilizers	48.06	VII
Non-availability of timely labour	47.73	VIII
Poor economic condition (Lack of capital)	40.43	IX
Poor texture of soil	40.33	X
Lack of effective weedicides for coriander	37.36	XI
Less availability of electricity for irrigation	35.9	XII
Marketing Constraints		
Lack of proper market information	62.86	I
Lack of ingredient estimations facility in seeds	59.36	II
Lack of declaration of Minimum support prices	57.46	III
Lack of proper storage structures	56.96	IV
Lack of transportation facility	56.5	V
Lack of regulated market	56.1	VI
Lack of processing units	33.83	VII

Among the major constraints in marketing of coriander, lack of proper market information was the major issue faced by farmers in the study area. Farmers mostly depend on the information provided by local trader only. Lack of ingredient estimations facility in seeds was the second important marketing constraint faced by the coriander growers. A proper ingredient estimation facility can provide better pricing for a good quality product. As there are no support measures like MSP, farmers were facing difficulty to get reasonable price for their produce. Lack of proper storage and transportation facilities were other major issues. Because of this, farmers were not able to take benefit of price movements over time and space. The lack of regulated markets and processing facilities also were creating hurdles to farmers in marketing their produce and to fetch better returns.

CONCLUSIONS

A number of variables such as fertilizers, plant protection chemicals and irrigation water were underutilized by the farmers. Further use of these resources can significantly contribute to farm yield and income. Also, from the analysis of technical efficiency, it was found that the major share in deviation of farm income from the maximum was mostly due to farmers practices rather than random factors. Thus, farmers can resolve this and improve the efficiency levels. Most of the farms were found functioning in efficiency levels not much far from the frontier. A number of constraints related to both production and marketing were found creating difficulties to coriander farmers in the area. There is need for awareness creation programmes, mechanisms for dissemination of accurate market information, establishment of ingredient estimation facilities, and government interventions for regulated markets and better storage, processing and transportation facilities.

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Growth and Yield of Rice (*Oryza sativa* L.) Varieties as Influenced by Nutrient Management Practices under Irrigated-Aerobic Condition

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Abstract: A Field experiments were carried out during *kharif* 2019 and 2020 at Agricultural Research Station, Binjhagiri , Faculty of Agricultural Sciences, IAS, SOADU, Bhubaneswar, Odisha to study the growth and yield of rice (*Oryza sativa* L.) varieties as influenced by nutrient management practices under irrigated-aerobic condition. The experiment was laid out in split plot design and consisted of three varieties (CR Dhan-205, Naveen and- Nirmal-150) in main plot and five practices of nutrient management (F_1 - Control, F_2 – 40-20-20 N-P_2O_5-K_2O kg ha^{-1}, F_3 -80-40-40 N-P_2O_5-K_2O kg ha^{-1}, F_4– 120-60-60 N-P_2O_5.K_2O $kgha^{-1}$and F_5- 160-80-80 N-P_2O_5-K_2O kg ha^{-1}) in subplot. CR Dhan 205, an aerobic rice variety, performed well and produced significantly the highest yield of grain (4.01 tha^{-1}) and straw (5.3 tha^{-1}).The increase in grain yield was associated with a significantly higher number of filled grains/panicle (107.7), Ear bearing tillers/ m^2(288.6), and test weight(23g). Among the nutrient management practices, F_4 -120-60-60 N-P_2O_5-K_2O $kgha^{-1}$recorded highest grain (4.36 tha^{-1}) and straw (5.86 tha^{-1}) yield and it was at par with F_3 -80-40-40 N-P_2O_5-K_2O kg ha^{-1}. The variety Naveen closely followed with CR Dhan 205.

Keywords: Nutrient management practices, Aerobic condition, Rice varieties, Grain yield

The word “food grains or cereals” usually indicates rice in many parts of the world. Owing to its ability of adaptability to a wide range of geo-hydrological situations, rice holds a distinctive place among the field crops. The rice production area in India as of the year 2019-20 is 43.78 million hectares with a production of 118.4 million tonnes (Anonymous 2021). West Bengal ranks first among the different rice growing states of the country having acreage of about 5.46 M ha with total production of 15.57 MT of rice (Anonymous 2021). Rice is the single biggest user of freshwater. Although, the maximum proportion of rice yield is obtained from lowland the cost of ample use of water for transplanting and puddling operations includes maintenance of 5-10 cm of standing water throughout its growing period. India leads the world in total water withdrawal for irrigation, where irrigation withdrawals represent 80 to 90% of all water use in India. With these facts and predictions, the future of our most important staple food crop can be easily presumed. Therefore, to cope up with this water scarcity situation, scientists are now taking on the challenging task of developing rice production systems that require economic water-use. In this scenario, the aerobic rice production technology is a good alternative of the conventional puddling system and is effective with limited water resources. Aerobic rice reported 51% lower total water use (by reducing water use during land preparation, seepage, percolation and evaporation) and 32-88% higher water productivity, expressed as gram of grain per kilogram of water, than flooded rice (Bouman et al 2005). As this system devoid of the practices like nursery preparation, transplanting and puddling, so the labour requirement is also lower than the conventional method of rice establishment. In another perspective, aerobic rice production system can be considered as eco-friendly and environmentally safe since rice is grown here under non-saturated condition and thus reduces the methane gas emission to the atmosphere, whereas lowland conventional rice cultivation is the major source of methane gas (CH_4) emissions, contributing 48% of the total greenhouse gases emitted by agricultural sources. It will be convincing for the farmers if they find the performance of available and popular varieties (mostly suitable for the conventional system) well under this irrigated-aerobic condition. This will reduce their cultivation cost and will encourage adopting this technique. The research-based information on the effect of nutrient management on different varieties (besides aerobic rice variety) grown under irrigated-aerobic system is meagre. In this context, the present research has been framed to evaluate the effect of nutrient management practices on growth and yield of different rice varieties under irrigated-aerobic condition.

MATERIAL AND METHODS

A field experiment was conducted to study the “growth and yield of rice (*Oryza sativa* L.) varieties as influenced by nutrient management practices under irrigated- aerobic condition" at Agricultural Research Station, Binjhagiri, Institute of Agricultural Sciences, SOADU, Odisha, India. The experiment field is situated between 20°26' N latitude and 85°67' E longitude at an altitude of 45 meters above mean sea level. The soil of the experimental plot was sandy loam in texture with acidic in reaction (pH 5.80) and low in organic carbon (0.43%) and available nitrogen (205.24 kg ha^{-1}), high in phosphorous (32.15 kg ha^{-1}) and medium in potassium (142 kg ha^{-1}) content. The experiment was laid out in split plot design with three replications comprising fifteen treatment combinations. Treatments consisted of three varieties (in main plot and five nutrient management practices (Table 1). The rice varieties were transplanted at 21 DAS on dd/mm/year.One third quantity of nitrogen and full amount of phosphorus and potassium were applied in each plot as basal during the final land preparation. Rest two third quantity of N was applied in two splits as top dressing *i.e.* one third of nitrogen was top dressed at active tillering stage and rest one third of nitrogen was top dressed at panicle-initiation stage. The recommended agronomic practices and plant protection measures were adopted to raise the crop. Grain and straw yields along with associated characters such as ear bearing tillers, dry matter accumulation, leaf area index, panicle length, panicle weight and fertile grains per panicle.

RESULTS AND DISCUSSION

Significant variations in plant height observed at harvest during both the years (2019 and 2020). At harvest, the highest plant height (96.9 cm) was recorded with the variety Naveen followed by CR Dhan 205 (90.2 cm) and shortest plant (81.8 cm) was with the variety Nirmal-150 (Table 1). Mahajan et al (2010) reported heights differ due to their genetic makeup and response to different climatic components. Praveen *et al* (2014) observed that the ultimate plant height is highly influenced by the variety and favourable weather. Among the nutrient management practices highest plant height (106.45 cm) was with the application of 160-80-80 N-P_2O_5-K_2O kg ha^{-1} at harvest followed by application of 120-60-60 N- P_2O_5- K_2O kg ha^{-1} (Table 1). The plant heights of treatment F_4 and F_3 were at par with each. Upland rice variety CR Dhan 205 registered significantly highest value of dry matter production m^{-2} and number of tillershill^{-1} at harvest and it was at par with variety Naveen. CR Dhan 205 recorded 7.76% higher number of tillers per hill compared to hybrid variety Nirmal 150 .Ndaeyo et al (2008) reported that significant differences in the number of tillers can be attributed to differences due to their ability to utilize the fertilizer as well as partitioning of dry matter. Among the nutrient management practices, highest number of tillers/hill and dry matter production per/$m^2$was recorded in F_4 at harvest and was closely followed by treatment F_3. Lowest no of tillers per hill and dry matter production per m^2 was recorded under control plot at harvest (Table 1). Shekara et al (2010) revealed that application of 125 kg N ha^{-1} recorded significantly higher plant height, a greater number of tillers $hill^{-1}$ and dry matter accumulation over its lower levels.

Yield attributes and yield: Upland rice variety CR Dhan 205 recorded the maximum panicle length, ear bearing tillers/ m^2, panicle weight, thousand grain weights, number of fertile grains $panicle^{-1}$ than other varieties and it was at par with variety Naveen. Hybrid variety Nirmal 150 recorded 11.07 and 9.50% lower number of Ear bearing tillers m^{-2} than variety CR Dhan 205 and Naveen respectively. The number of fertile grains per panicle increased by 22.72% with upland variety CR Dhan 205 in compared to hybrid variety Nirmal 150 (Table 2). Medium duration lowland high yielding variety Naveen

Table 1. Effect of rice varieties and nutrient management practices on growth attributing characters(pooled data of two years)

Variety	Plant height (cm)	Number of tillers per hill	Dry matter production (g m^{-2})
V_1 CR Dhan -205	90.2	11.1	743.68
V_2 Naveen	96.9	10.9	709.01
V_3 Nirmal-150	81.8	10.3	684.68
CD(p= 0.05)	5.16	0.54	39.90
Nutrient management practices			
F_1=Control	68.59	5.93	553.22
F_2=40:20:20 N:P_2O_5:K_2O kg/ha	80.29	9.57	648.74
F_3=80:40:40 N:P_2O_5:K_2O kg/ha	93.95	12.98	798.67
F_4=120:60:60 N:P_2O_5:K_2Okg/ha	98.79	13.38	830.56
F_5=160:80:80 N:P_2O5:K_2O kg/ha	106.45	12.08	730.00
CD (p=0.05)	6.98	1.09	57.07

recorded 18.18% higher number of fertile grains panicle^{-1} than hybrid variety Nirmal in irrigated upland condition. Among the nutrient management practices, panicle length, ear bearing tillers/ m^2,panicle weight, thousand grain weights, number of fertile grains per panicle were recorded in treatment F_4 (120-60-60 N-P_2O_5-K_2O kgha^{-1}) at harvest and it was closely followed by treatment F_3 (80-40-40 N-P_2O_5-K_2O kgha^{-1}) at harvest .Similar findings have been reported by Prakash et al (2014)

An insight into the data clearly highlighted marked effect of all the variables on yield of grain and straw. Among the varieties aerobic rice CR Dhan 205 recorded significantly higher grain and straw yields (4.03 and 5.3 tha^{-1}, respectively) but it was statistically at par with variety Naveen (3.90 and 5.20 tha^{-1}), a medium duration lowland high yielding variety (Table 3). Both of these varieties were recorded significantly 17.61and 14.87% higher grain yield , respectively over the

Table 2. Effect of rice varieties and nutrient management practices on yield attributing characters (pooled data of two years)

Variety	Panicle length (cm)	Panicle weight (g)	EBT per m^2	1000 grain weight (g)	Fertile grains per panicle	Sterile grains per panicle	Sterile (%)
V_1 CR Dhan -205	24.6	2.59	289	23.0	108	27	20.28
V_2 Naveen	23.6	2.46	284	22.1	104	26	20.29
V_3 Nirmal-150	22.4	2.2	257	19.1	88	33	28.0
CD (p= 0.05)	1.53	0.22	22.52	1.31	7.84	3.01	
Nutrient management practices							
F_1=Control	19.11	1.84	170	17.34	63	31	32.67
F_2=40:20:20 N:P_2O_5:K_2O kg/ha	21.91	2.21	226	20.01	76	34	30.68
F_3=80:40:40 N:P_2O_5:K_2O kg/ha	26.07	2.71	333	23.39	123	23	15.99
F_4=120:60:60 N:P_2O_5:K_2Okg/ha	27.16	2.80	353	24.11	128	23	15.19
F_5=160:80:80 N:P_2O5:K_2O kg/ha	23.47	2.44	301	22.14	109	34	23.56
CD (p=0.05)	2.01	0.10	25.22	1.19	5.22	2.04	
Interaction	NS	S	NS	NS	S	NS	
	CD (p=0.05)	CD (p=0.05)	CD (p=0.05)	CD (p=0.05)	CD (p=0.05)	CD (p=0.05)	
V X F	-	0.17	-	-	9.42	-	
F X V	-	0.22	-	-	9.97	-	

Table 3. Effect of rice varieties and nutrient management practices on grain yield, straw yield and harvest Index (pooled data of two years)

Variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index(%)
V_1-CR Dhan -205	4.03	5.3	43.1
V_2-Naveen	3.90	5.2	42.8
V_3-Nirmal-150	3.32	4.7	41.5
CD (p= 0.05)	0.27	0.22	NS
Nutrient management practices			
F_1=Control	2.85	3.94	42.04
F_2=40:20:20 N:P2O5:K2O kg/ha	3.30	4.51	42.14
F_3=80:40:40 N:P2O5:K2O kg/ha	4.26	5.73	42.58
F_4=120:60:60 N:P2O5:K2O kg/ha	4.38	5.85	42.70
F_5=160:80:80 N:P2O:K2O kg/ha	3.96	5.25	42.93
CD (p= 0.05)	0.18	0.13	NS
Interaction	S	S	NS
	CD	CD	CD
V X F	0.31	0.23	NS
F X V	0.34	0.26	NS

Table 4. Interaction effect of varieties with nutrient management practices on grain yield (t/ha) (pooled data of two years)

Variety	Nutrient management practices Grain yield (t ha^{-1})					
	F_1	F_2	F_3	F_4	F_5	Mean
V_1	3.04	3.56	4.60	4.70	4.25	4.03
V_2	2.85	3.35	4.53	4.63	4.15	3.90
V_3	2.67	3.00	3.64	3.80	3.48	3.32
Mean	2.85	3.30	4.26	4.38	3.96	
	Variety (V)		Nutrient management practices(F)		V XF	FX V
CD (p=0.05)	0.27		0.18		0.31	0.34

variety Nirmal 150, a new hybrid variety that produced 3.32 tha^{-1} of grain yield. Present investigation indicated that hybrid variety could not perform well under aerobic condition. Grain and straw yield varied significantly with different nutrient management practices. Among the nutrient management practices, the treatment F_4 (120-60-60 N-P_2O_5-K_2O kg ha^{-1}) produced the highest grain and straw yield (4.38 and 5.85 t ha^{-1}) followed by treatments F_3 (80-40-40 N-P_2O_5-K_2O $kgha^{-1}$),F_5 (160-80-80 N-P_2O_5-K_2O $kgha^{-1}$) and F_2 (40-20-20 N-P_2O_5-K_2O $kgha^{-1}$). Treatments F_4 and F_3 did not differ among themselves and were at par. Treatment F_4 (120-60-60 N-P_2O_5-K_2O $kgha^{-1}$) recorded 53.68% higher grain yield over control plot. The least value of grain and straw yield (2.85 and 3.94 t ha^{-1}) were recorded under control treatment. Two factors Interaction effect were found significant (Table 4). Variety CR Dhan 205 with application of treatment F_4 recorded the highest grain yield (4.70 tha^{-1}) as against the grain yield of variety Naveen (4.63 t/ha) and Nirmal 150 (3.80 t ha^{-1}) under same management practices. No significant difference in values of harvest index with respect to varieties and nutrient management practices were evident (Table 3). Among the varieties, CR Dhan recorded the highest harvest index (43.10%) followed by Naveen (42.80%) and Nirmal 150 (41.50%). Among different nutrient management practices, F_5 (160-80-80 N- P_2O_5-K_2O kg ha^{-1})recorded highest harvest index (42.93%) followed by treatments F_4(42.70%), F_3(42.58%) and F_2(42.14%).The least value of harvest index was found in control plot (42.04%).

CONCLUSION

The rice variety CR Dhan 205, performed well under aerobic condition. However, the existing high yielding variety Naveen performed equally well. Naveen can be used both as lowland and aerobic rice depending on situation. Hybrid variety Nirmal 150 does not perform well under aerobic condition. Application of 120-60-60 N- P_2O_5- K_2O $kgha^{-1}$was superior in respect to growth, yield attributes character and yield of rice under aerobic condition and it was closely observed by 80-40-40 N-P_2O_5-K_2O kg ha^{-1} in all the crop growth stage.

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Effect of Agrochemicals and Irrigation Levels on Growth and Yield of Barley (*Hordeum vulgare* L.)

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***Abstract*:** A field experiment was conducted at RRS, Bawal, CCSHAU, Hisar during *Rabi*, 2019-2020 to study the growth and development of barley under various irrigation levels as affected by agrochemicals. The experiment was conducted in split plot design with three irrigation levels in main plot and six agrochemical levels in subplot. The main plot treatments included- no irrigation, one irrigation and two irrigation. The subplot treatments were- control, seed treatment with *Tragacanth katira* @ 100 g kg^{-1} seed, soil application with *Tragacanth katira* @ 5 kg ha^{-1}, foliar application of salicylic acid @ 200 ppm, soil application with *Tragacanth katira* @ 2.5 kg ha^{-1} + foliar spray with salicylic acid @ 200 ppm and foliar application with potassium nitrate @ 1%. Number of days taken to physiological maturity, plant height, shoot dry matter accumulation at harvest and grain yield was significantly higher with two irrigation and soil application of *Tragacanth katira* + foliar spray of salicylic acid among irrigation levels and agrochemicals, respectively. Days to 50% flowering were significantly lower with no irrigation compared to one and two irrigation with no significant difference among various agrochemicals.

Keywords: Barley, *Tragacanth katira,* Irrigation levels, Potassium nitrate, Salicylic acid

Barley (*Hordeum vulgare* L.), the fourth major cereal grain crop of the world is the hardiest crop when it comes to stress (drought, heat or salinity) tolerance. Water shortage combined with higher temperature is considered as the crucial yield declining factors in arid and semi-arid areas. The major barley producing states are Rajasthan (40-50%), U.P. (25-30%), Haryana, Punjab, Madhya Pradesh and Uttarakhand. In Haryana conditions, barley generally needs two irrigations for higher productivity but due to limiting irrigation facilities in south west zone of Haryana, it is grown as either rainfed or with one irrigation at critical stage. Rainfall behaviour in these areas is highly unpredictable and the factor which affect crop growth most is the long dry spells in between rains. Barley plants cope with minor stress conditions by reducing transpiration rates without affecting photosynthesis. But, as the stress level increases, the photosynthetic pathway is adversely affected and the vegetative growth and development of the plant stops. Stress at heading and grain formation is considered as more detrimental than stress at vegetative stages (Mahalingam and Bregitzer 2019). However, stress at earlier stages also cause significant yield loss.

The availability of proper moisture during the growth period of the crop leads to healthy and succulent plants. Water is better known to improve cell division and cell enlargement by increasing the turgor pressure inside cell. The other important role it plays in lush growth of plants is the nutrient absorption capacity by behaving like an ideal solvent for dissolving nutrients. To make the crop plants cope up with the water stress, one should either increase the availability of water by using hydrogels which have the property to absorb moisture by 350-400 times its weight and 80-180 times by its volume (Kalhapure et al 2016). Since hydrogel polymers are quite expensive and cultivators in India are mostly marginal farmers, its applicability is greatly reduced. An alternative to hydrogel polymers are natural hydrogels such as *Tragacanth katira* which are cost effective as well as easy to apply. *Tragacanth katira* commonly also known as *Gond-Katira*. The other way to protect crop plants from stress is to modify the physiology of crop plants with agrochemicals such as KNO_3, salicylic acid, ascorbic acid and humic acid etc. Salicylic acid (SA) alleviates the effect of stress condition by increasing the plant height and dry matter (El- Nasharty et al 2019). SA protects plant from stress by shortening the crop cycle evidenced by reduction in no. of days taken to 50% flowering in black gram (Narayanan et al 2015). KNO_3 helped plants in overcoming stress by maintaining turgor balance and improving plant height as well as dry matter accumulation. Considering the above points, the present study was planned to study the effect of agrochemicals on growth, development and yield of barley crop under different irrigation levels.

MATERIAL AND METHODS

The field experiment was conducted in *Rabi,* 2019-2020 at Regional Research Station, Bawal, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (India) located at 28° 6' N latitude and 76° 30' E longitude at an elevation of 266 metres above mean sea level. The mean weekly meteorological data recorded during the crop season is given in Figure 1. A total of nine rainy days with 105.3 mm of total rainfall were recorded during crop growth period. The investigation was carried out on BH-393 variety of barley grown in split plot design with three replications and 18 treatment combinations. Three irrigation levels *viz*. no irrigation- control (I_0), one irrigation at 40-45 DAS (I_1) and two irrigation at 40-45 and 80-85 DAS (I_2) were taken as main plot factors and six agrochemicals in subplots *viz.* control (T_1), seed treatment with *Tragacanth katira* @ 100 g kg^{-1} seed (T_2), soil application of *Tragacanth katira* @ 5 kg ha^{-1} (T_3), foliar spray of SA @ 200 ppm at booting and grain formation stage (T_4), combination of *Tragacanth katira* @ 2.5 kg ha^{-1} + foliar spray of SA @ 200 ppm at booting and grain formation stage (T_5) and; foliar spray of KNO_3 @ 1% at booting and grain formation stage (T_6). Seed treatment was done by hydro-priming the seeds followed by air drying for 12 hrs to attain moisture near to initial level and then treating them with jaggery solution and *Tragacanth katira* powder. Soil application of *Tragacanth katira* was done by line sowing the dry hydrogel powder followed by planking. Cultural practices were followed as per the recommendation of CCSHAU, Hisar. Half dose of nitrogen (30 kg ha^{-1}), full dose of phosphorus (30 kg ha^{-1}) and potash (15 kg ha^{-1}) were incorporated into soil through urea, DAP and muriate of potash, respectively. Remaining half dose of nitrogen (30 kg ha^{-1}) was broadcasted after first irrigation. Plant height and dry matter accumulation (shoot) was recorded at 30, 60, 90, 120 DAS and at harvest. Plant height was recorded in centimetres from base of the main shoot to the highest tip of the plant. Days to 50 per cent flowering were recorded when flowering was observed in 50 per cent of the plants in a plot and days to maturity when plants attained physiological maturity. Absolute growth rate (AGR) and Relative growth rate (RGR) were calculated with methods by Radford (1967) and Blackman (1919) for the shoot dry matter accumulation during the interval 30-60, 60-90 and 90-120 DAS, respectively:

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

$$RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

where, w_1 and w_2 are dry weights of plant at time t_1 and t_2, respectively.

AGR was expressed as mg day^{-1} and RGR was expressed as mg g^{-1} day^{-1}. Grain yield was recorded at harvest after sun-drying the grains to reduce the moisture content to 14 per cent. Recorded data was subjected to statistical analysis using STAR software at 5 per cent level of significance and F variance test was used to evaluate the significance of different treatment effects.

RESULTS AND DISCUSSION

Growth parameters: The plant height indicated no significant difference at 30 DAS among irrigation levels (Table 1). At 60 and 90 DAS, I_1 and I_2 were observed at par and significantly increased plant height compared over I_0. At 120 DAS and at harvest, all three treatments differed significantly with maximum height recorded with I_2 followed by I_1 and I_0. The improved plant height with irrigation might be due to the higher nutrient uptake and increased rate of cell elongation and cell division with increase in turgor pressure by virtue of high moisture uptake (Jai et al 2015). Among

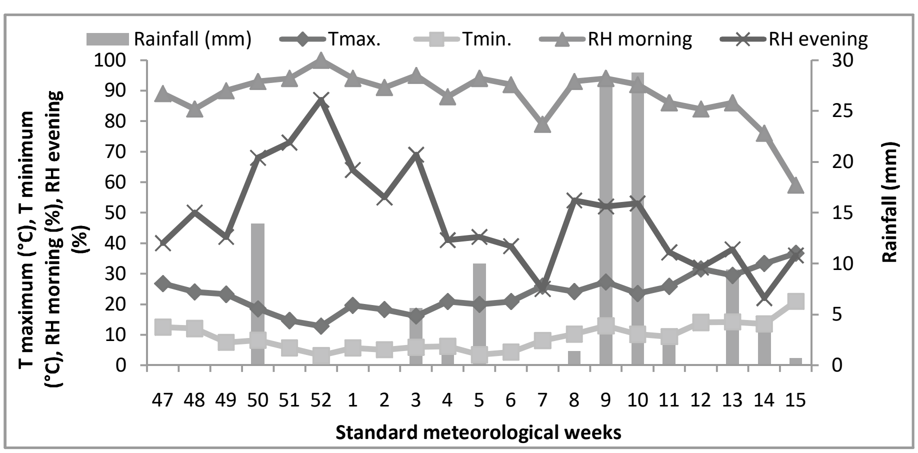

Fig. 1. Weekly meteorological data of crop season

agrochemicals, no significant difference in plant height was recorded upto 60 DAS. T_4, T_5 and T_6 were observed significant over control at 90 DAS and over control, T_1 and T_2 at 120 DAS and at harvest. The effect of *Tragacanth katira* on plant height at 30, 60, 90 and 120 DAS is consistent with the findings of Kumar et al (2019) and at harvest, with Lather (2019) and Kumar and Singh (2020). The increased plant height with SA might be accrued to their role as a phenolic phytohormone and signaling molecule in plant system, which induces specific changes in leaf anatomy and enhances ion uptake improving plant growth (Pandey et al 2020). In case of T_6, the increased plant height might be due to additional supply and faster absorbance of nutrients with application of KNO_3 supported by the findings of Hellal et al (2020).

I_2 was significantly more productive and increased shoot weight (at harvest) by 31.1 per cent over I_0 (Table 2). This may be attributed to the high photosynthesis rates and increased cell division and elongation with high moisture availability and similar findings were also reported by Shirazi et al (2014). Among agrochemicals, higher shoot dry matter accumulation in barley varied significantly with maximum under treatments with *Tragacanth katira* (T_2 and T_3) at 30 and 60 DAS. It might be due to water holding capacity of *Tragacanth katira* and more availability of water in the root zone when plant needs it. At 90 and 120 DAS as well as at harvest, combination of *Tragacanth katira* and SA (T_5) resulted in 54.6, 64.0 and 58.5 per cent higher shoot dry weight as compared to control. Foliar spray of SA (T_4) and KNO_3 (T_6) recorded statistically at par results as were observed with combination of *Tragacanth katira* and SA (T_5). The findings were supported by the

Table 1. Effect of irrigation levels and agrochemicals on plant height (cm)

Treatment	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Irrigation levels					
I_0	26.75a	53.44b	83.44b	87.33c	87.72c
I_1	26.65a	57.92a	87.90a	94.66b	95.04b
I_2	26.01a	58.48a	91.50a	98.48a	98.81a
Agrochemicals					
T_1	50.22a	25.67a	56.18a	84.78c	90.74b
T_2	57.00a	27.35a	57.50a	85.67bc	91.08b
T_3	53.11a	26.98a	56.89a	85.44bc	90.86b
T_4	48.22a	26.04a	56.22a	89.44ab	95.40a
T_5	53.44a	26.93a	56.61a	90.47a	97.48a
T_6	52.11a	25.83a	56.27a	89.89a	95.38a

Means with same letters are not significantly different

Table 2. Effect of irrigation levels and agrochemicals on shoot dry matter accumulation (g plant^{-1})

Treatment	Shoot dry matter accumulation (g plant^{-1})				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Irrigation levels					
I_0	0.14a	2.38b	9.35b	12.06c	13.07c
I_1	0.14a	2.82a	11.23a	14.69b	15.70b
I_2	0.14a	2.80a	12.01a	16.12a	17.13a
Agrochemicals					
T_1	0.13b	2.37b	8.21c	10.34d	11.34c
T_2	0.15a	3.01a	10.60b	13.76c	14.77b
T_3	0.16a	3.09a	10.79b	14.04bc	15.05b
T_4	0.13b	2.54b	11.38ab	15.16bc	16.18ab
T_5	0.13b	2.66ab	12.68a	16.96a	17.98a
T_6	0.13b	2.49b	11.61a	15.49ab	16.51a

Means with same letters are not significantly different observations of Azmat et al (2020) by virtue of the improved osmotic balance, enhanced nutrient uptake and enhanced metabolism of plants.

Higher growth rate indicate plant is healthy, photosynthesizes properly and efficiently deposits the photosynthates in sink organs. Among irrigation levels, I_1 and I_2 treatments produced similar effects on AGR and RGR during all developmental phases, except during 60-90 DAS, where AGR was significantly higher with I_2 compared to both I_1 and I_0 (Fig. 2). Among agrochemicals, during 30-60 DAS, AGR was maximum with *Tragacanth katira*, while, RGR was not significantly affected (Fig. 3). During 60-90 and 90-120 DAS, T_5 improved AGR and RGR and was at par with T_4 and T_6. It is obviously due to increased metabolic activities of the plant with two foliar sprays of SA at 65 and 85 DAS and higher moisture availability due to good amount of rainfall (59.4 mm) during 90-120 DAS. Similar findings were also reported by Nagaraju (2014). Likewise, two sprays of KNO_3 enhanced supply of nitrogen and potassium which might have resulted in higher growth rate.

Developmental parameters: I_1 and I_2 delayed days to 50 per cent flowering by 2 to 3 days compared to I_0 and; delayed days also to physiological maturity by 3 to 7 days, respectively (Table 3). This may be attributed to the fact that vegetative as well as reproductive phase of plant is enhanced with adequate moisture availability. Stress at any stage of crop growth shortened the life cycle of plant by few days as they tend to complete it at earliest to avoid or escape unfavorable conditions of stress. Similar results were also reported by Hussen et al (2019) in mung bean and Muleke et al (2022) in wheat. No significant effect of agrochemicals was observed on days to 50 per cent flowering while, days to physiological maturity was delayed by 4 to 5 days under T_5. It showed the role of SA on stomatal conductance and water uptake. T_4 and T_6 also delayed days to physiological maturity and were found at par with T_5. Rehman and Khalil (2018) also reported similar results.

Grain yield: Significantly higher grain yield was observed in I_2 followed by I_1 and I_0 (Table 3) obviously due to higher dry matter accumulation and partitioning as supported by the findings of Kumar et al (2019), Singh and Meena (2020). Among agrochemicals, all treatments yielded significantly higher over control with T_4, T_5 and T_6 significant over T_2 and T_3 also. Higher grain yield with SA and KNO_3 was observed in line with findings of Suryavanshi and Buttar (2016), Abdelaal

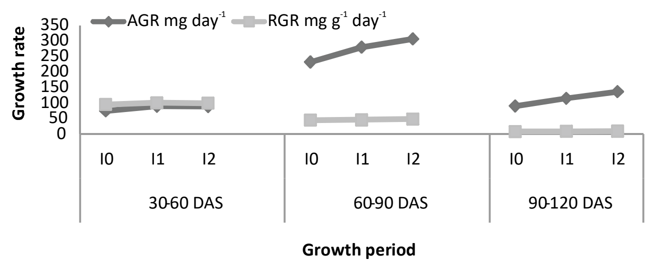

Fig. 2. Effect of irrigation levels on AGR and RGR at various crop growth stages

Table 3. Effect of irrigation levels and agrochemicals on grain yield and developmental parameters

Treatments	Days to 50% flowering	Days to physiological maturity	Grain yield (kg ha^{-1})
Irrigation levels			
I_0	71.11b	117.06c	4025c
I_1	73.72a	120.50b	4538b
I_2	73.61a	124.33a	4712a
Agrochemicals			
T_1	72.78a	117.06c	3912d
T_2	72.89a	120.39b	4261c
T_3	72.78a	120.28b	4334c
T_4	72.67a	121.61ab	4620b
T_5	72.89a	122.39a	4765a
T_6	72.89a	122.06a	4657ab

Means with same letters are not significantly different

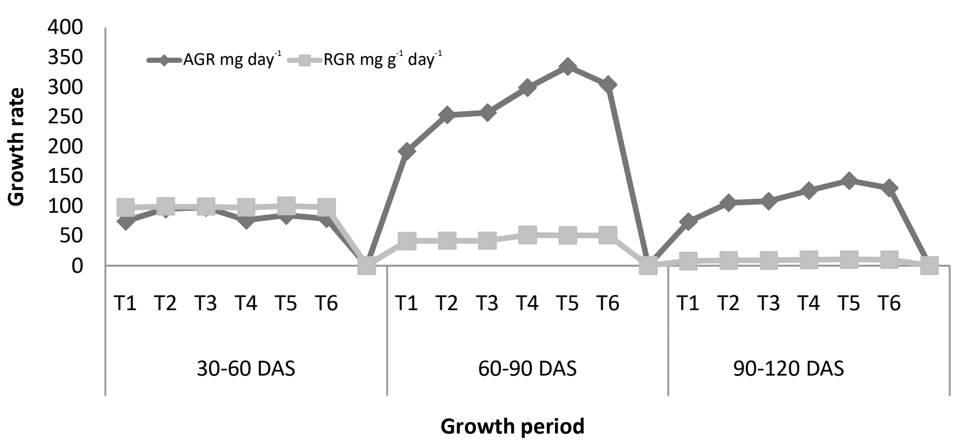

Fig. 3. Effect of agrochemicals on AGR and RGR at various growth stages

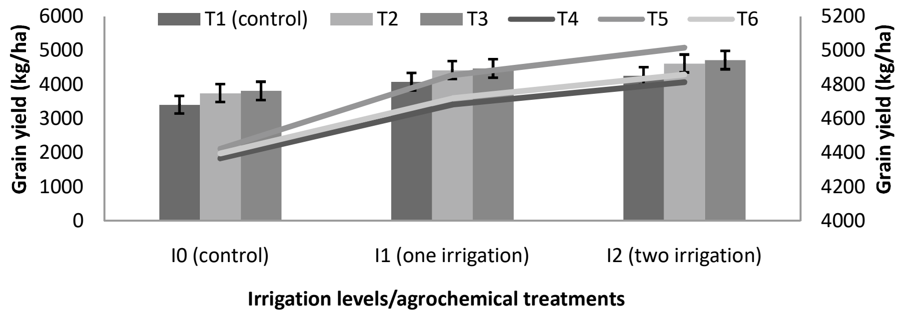

Fig. 4. Interaction effect of irrigation levels and agrochemicals on grain yield (kg ha^{-1})

et al (2020) and Meena et al (2020). Significant interaction was also observed among irrigation levels and agrochemicals for grain yield (Fig. 4).

CONCLUSIONS

The study concluded that with different irrigation levels, all agrochemical treatments were productive over control, however combination of soil application of *Tragacanth katira* @ 2.5 kg ha^{-1} with two foliar sprays of SA @ 200 ppm at booting and grain formation stage (T_5) was observed most beneficial. Farmers can adopt any of the agrochemical treatment depending on the availability of moisture and the economic resources available to them.

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Economic Perspective of Integrated Nitrogen Management under Teak (*Tectona grandis* L.f.) - Okra (*Abelmoschus esculentus* L.) based Silvi-Horticulture System

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Abstract: Aim of present study to assess the profitable agroforestry model and economically best INM treatments under Teak based silvi-horticulture system for Okra. A field experiment was conducted during the year 2019 and 2020 in *summer* season. Okra (*Abelmoschus esculentus* L.) cv. GAO- 5 was sown in the inter spaces of 23-years old plantation of *Tectona grandis* planted at a spacing of 3m x 2m and applied the different integrated nitrogen management (INM) treatments under the teak and in open condition. The trial was framed with eleven treatments under teak plantation and open condition in Randomized Block Design (RBD) consisting of three replications. From the calculation of economics of experiment the result emerged that when only sole okra crop yield considered in economic estimation the highest net realization (₹2,17,022 ha^{-1}) was recorded in T_{11}: 75% RDN through Neem coated urea + 25% RDN through Vermicompost in open field while benefit cost ratio was recorded highest in $T_{10:}$ 100% RDF in open condition (2.61). Whereas, the lower net realization and BCR of okra were registered under teak-okra based silvi-horticulture system as compared to sole crop. However, if we considered the yield of both okra as intercrop with teak the highest net realization and BCR (₹ 5,05,797 and 6.95, respectively) were recorded in T_5: 75% RDN through Neem coated urea + 25% RDN through Vermicompost under teak-okra based silvi-horticulture system.

Keywords: Economic, Okra, Silvi-horticulture system, Teak, Integrated nitrogen management

Agroforestry systems have multifunctional roles in enhancing agronomic productivity, co-production of diversity of food and non-food products and provision of ecosystem services (Lehmann et al 2020). One of the goals of agroforestry in economical aspect is to ensure improvement in the availability, diversification and sustainability of food (Magcale-Macandog et al 2010). Agroforestry plays a very important role in Indian economy by providing tangible and intangible benefits (Divya et al 2014). In agroforestry, many crops are grown traditionally or tested in improved systems are economically viable (Thakur et al 2014, Panchal et al 2017). Conventionally, vegetable crops are promoted as compatible understory crops, many of the best vegetables to grow in shade (Pleasant 2012). Commercially important vegetable crop have been effectively intercropped under tree and generated additional income (Patel et al 2018, Bhusara et al 2018). Okra is one of the commercially important vegetable crops with many medicinal properties. It requires large quantities of both macro and micro nutrients for economic yields but in market chemical fertilizer has high price and its deterioration of soil health (Solangi et al 2015). While, combination of organic manures and synthetic fertilizers has the advantage of restoring soil fertility and sustaining productivity (Mevada et al 2021). On the other hand, Teak is one of the valuable timber producing perennial crop and generating the most important income (Miassi et al 2021). New tree-crop combinations are evolving with time due to changes in industrial demand and nature of products needed. Such new agroforestry techniques need to be analyzed on economic parameters. Therefore, keeping in view the above facts and economic importance of the vegetable crops and teak the aim of present study to analyzes the economics of cultivation of integrated nitrogen management in Okra under Teak (*Tectona grandis* L.f.) - (*Abelmoschus esculentus* L.) based silvi-horticulture system.

MATERIAL AND METHODS

The present field experiment was conducted during summer season of 2019 and 2020, at Navsari Agricultural University, Navsari, Gujarat, India. Geographically it's located at 20.95° N latitude and 72.93° E longitude with an elevation of 9m MSL. This area is typically characterized by humid and warm monsoon with rainfall of about 1500 mm, moderately cold winter, and fairly hot and humid summer.

The average annual temperature is 27.1 °C. Okra (*Abelmoschus esculentus* L.) cv. GAO- 5 was sown in the inter spaces of 23-year-old plantation of *Tectona grandis* planted at a spacing of 3 x 2m. Experiment was designed in Randomized Block Design with eleven treatment combinations *viz*. Under Teak; T_1: 100% RDF through Chemical Fertilizer (150:50:50 @ NPK kg ha^{-1}), T_2: 75% RDN through Neem coated urea + 25% RDN through Neem cake, T_3: 50% RDN through Neem coated urea + 50% RDN through Neem cake, T_4: 25% RDN through Neem coated urea + 75% RDN through Neem cake, T_5: 75% RDN through Neem coated urea + 25% RDN through Vermicompost, T_6: 50% RDN through Neem coated urea + 50% RDN through Vermicompost, T_7: 25% RDN through Neem coated urea + 75% RDN through Vermicompost, T_8: 100% RDN through Vermicompost, T_9: 100% RDN through Neem cake, In open condition T_{10}: 100% RDF through Chemical Fertilizer and T_{11}: 75% RDN through Neem coated urea + 25% RDN through Vermicompost. Recommended dose of nitrogen, phosphorus and potassium @150-50-50 kg ha^{-1} applied to okra form the vermicompost, neem cake, urea, single super phosphate and muriate of potash under Teak and in open condition. Cultivation practice and cultural operations carried out in okra (Kumar and Choudhary 2014). Teak wood volume was estimated using quarter girth formula. The individual tree volume (average of 9 trees under each land-use system) was converted to per hectare basis in each system considering 10% mortality (Table 3). The economic analysis of Teak

Table 1. Economic of okra crop as affected by different INM treatments under teak based horti-silviculture system and in open condition

Treatments	Marketable yield (t ha^{-1})	Okra				Teak		Total gross realization (₹ha^{-1})	Total cost of cultivation (₹ha^{-1})	Without teak		With teak	
		Fixed cost (₹ha^{-1})	Variable cost (₹ha^{-1})	Total cost (₹ha^{-1})	Gross realization (₹ha^{-1})	Total cost (₹ha^{-1})	Gross realization (₹ha^{-1})			Net realization (₹ha^{-1})	BCR (with teak)	Net realization (₹ha^{-1})	BCR
Under teak													
T_1	3.70	41663	5673	47336	111000	19969	401356	512356	67305	63664	1.34	445050	6.61
T_2	3.94	41663	14652	56316	118200	19969	425321	543521	76285	61884	1.10	467236	6.12
T_3	3.68	41663	23049	64712	110400	19969	386572	496972	84682	45688	0.71	412290	4.87
T_4	3.27	41663	31380	73043	98100	19969	479481	577581	93012	25057	0.34	484569	5.21
T_5	4.18	41663	11129	52792	125400	19969	453158	578558	72762	72608	1.38	505797	6.95
T_6	3.73	41663	15584	57247	111900	19969	418038	529938	77217	54653	0.95	452721	5.86
T_7	3.40	41663	20116	61779	102000	19969	435996	537996	81749	40221	0.65	456248	5.58
T_8	3.10	41663	24714	66377	93000	19969	457630	550630	86347	26623	0.40	464283	5.38
T_9	3.04	41663	39809	81472	91200	19969	424193	515393	101442	9728	0.12	413951	4.08
In open condition													
T_{10}	9.60	67301	12517	79818	288000	-	-	288000	79818	208182	2.61	-	-
T_{11}	10.07	67301	17777	85078	302100	-	-	302100	85078	217022	2.55	-	-

Table 2. Cultivation cost of teak (₹ha^{-1})

Operations	Rate (₹)	Total cost (₹ha^{-1})
Cost of planting (Planting material, preparation of pits, planting)	@ ₹8.75 Tree^{-1}	14583
	i.e. ₹ ha^{-1} Year^{-1}	634
FYM (2 kg plant^{-1})	@ ₹1.6 Tree^{-1}	116
Urea (50 g after six month and 75 g after 2 year)	@ ₹0.75 Tree^{-1}	54
SSP (30 g after six month and 60 g after 2 year)	@ ₹0.81 Tree^{-1}	59
Weeding and cleaning (20 labours 3 times per year)	@ ₹178 labour^{-1} day^{-1}	10680
Pruning (20 labours 2 times per year)	@ ₹178 labour^{-1} day^{-1}	7120
Total		18663
Interest on working capital @ 7 %		1306
Gross total (₹)		19969

(*Tectona grandis* L.f.) - Okra (*Abelmoschus esculentus* L.) based silvi-horticulture system was worked out by gross and net realization from okra fruits and timber volume production on the basis of prevailing market rates. The benefit-cost ratio (BCR) on account of yield of okra marketable fruits and timber volume were estimated.

RESULTS AND DISCUSSION

Economics without teak: The okra crop grown in open condition recorded highest net realization and BCR as compared to integrated nitrogen management under teak based silvi-horticulture systems (Table 1). The highest net realization (₹ 2,17,022.00 ha^{-1}) was in T_{11}: 75% RDN through Neem coated urea + 25% RDN through Vermicompost in open field condition. The benefit cost ratio (BCR) was maximum in $T_{10:}$ 100% RDF in open condition (1: 2.61). Moreover, in case of teak based silvi-horticulture system, the highest net realization and BCR was in T_5: 75% RDN through

Table 3. Estimation of volume (quarter girth formula) and income of teak

Treatments	Tree height (m)	GBH (cm)	GBH (m)	Volume (m^3) (Girth/4)^2 * h	Gross return tree^{-1} (₹)	Gross return ha^{-1} up to 23 year (₹)	Gross return ha^{-1} year^{-1} (₹)	Total cost ha^{-1} year^{-1} (₹)	Net return ha^{-1} year^{-1} (₹)
T_1	19.73	59.71	0.60	0.44	6154	9231183	401356	19969	381386
T_2	18.91	62.78	0.63	0.47	6522	9782387	425321	19969	405352
T_3	19.64	58.73	0.59	0.42	5927	8891157	386572	19969	366603
T_4	19.64	65.41	0.65	0.53	7352	11028072	479481	19969	459512
T_5	20.66	61.99	0.62	0.50	6948	10422637	453158	19969	433189
T_6	20.39	59.95	0.60	0.46	6410	9614875	418038	19969	398069
T_7	18.64	64.02	0.64	0.48	6685	10027914	435996	19969	416021
T_8	17.96	66.83	0.67	0.50	7017	10525494	457630	19969	437661
T_9	18.99	62.57	0.63	0.46	6504	9756437	424193	19969	404223

Note: Selling price of teak wood: ₹14000 m^{-3}, Trees ha^{-1}: 1600, Mortality 10% calculated from total trees

Table 4. Variable cost of various integrated nitrogen management treatments

Treatment	Total yield (t ha^{-1})	Quantity required (kg)			Cost (₹)					Total cost (₹ha^{-1})
		NCU	VC	NC	NCU	VC	NC	Harvesting	Transport	
Under Teak (cost calculation on the basis of 6000 m^2 area)										
T_1: 100% RDF (100:50:50 NPK kg/ha)	4.09	196	-	-	1174	-	-	4090	409	5673
T_2: 75% NCU + 25% NC	4.32	147	-	501	880	-	9020	4320	432	14652
T_3 : 50% NCU + 50% NC	4.02	98	-	1002	587	-	18040	4020	402	23049
T_4 : 25% NCU + 75% NC	3.66	49	-	1503	294	-	27060	3660	366	31380
T_5: 75% NCU + 25% VC	4.56	147	1047	-	880	5233	-	4560	456	11129
T_6 : 50% NCU + 50% VC	4.12	98	2093	-	587	10465	-	4120	412	15584
T_7 : 25% NCU + 75% VC	3.75	49	3140	-	293	15698	-	3750	375	20116
T_8 : 100 % VC	3.44	-	4186	-	-	20930	-	3440	344	24714
T_9 : 100 % NC	3.39	-	-	2005	-	-	36080	3390	339	39809
In open condition (cost calculation on the basis of 1 ha area)										
T_{10}: 100% RDF	9.6	326	-	-	1957	-	-	9600	960	12517
T_{11} : 75% NCU+ 25% VC	10.07	245	1047	-	1467	5233	-	10070	1007	17777

Price of various organic and inorganic

NCU (Neem coated Urea) (46% N)	₹6 / kg
NC (Neem cake) (4.49% N)	₹18 /kg
VC (Vermicompost) (2.15% N)	₹5 /kg
Harvest okra cost	₹1 /kg
Transportation cost	₹100 /t
Fresh Okra price	₹30/kg

Neem coated urea + 25% RDN through Vermicompost that is ₹ 72,608 ha^{-1} and 1:1.38, respectively and lowest net realization and benefit cost ratio was in $T_{9:}$ 100 % RDN through Neem cake (₹ 9,728 ha^{-1} and 1:0.12, respectively).

Economics with teak: The benefit cost ratio was maximum in teak based silvi-horticulture system as compared to open condition. The highest net realization and BCR (₹ 5,05,797 and 1: 6.95, respectively) were in T_5: 75% RDN through Neem

Table 5. Cost of cultivation okra (₹ha^{-1}) in under teak (on the basis of cultivation of 6000 m^2 area) and in open condition

Description	Rate	Cost **(₹)** under teak	Cost **(₹)** in open condition
Preparatory tillage			
Ploughing by tractor with (1time) M.B. plough	@ ₹400/ hr for 8 hours	1920	3200
Ploughing by tractor with (2 times) cultivator	@ ₹300/ hr for 6 hours	2160	3600
Ploughing by tractor with (1 times) Rotavator with planking	@ ₹650/ hr for 4 hours	1560	2600
Total		5640	9400
Lay out and Transplanting			
Layout, Preparation of channel, beds and earthing up	@ ₹178/ /labour/day	2136	2136
Seed requires (GAO-5)	@ ₹850/kg	4335	7225
Sowing	@ ₹178/ /labour/day	1602	2670
Gap filling	@ ₹178/ /labour/day	534	890
Total		8607	12921
Manures			
FYM	@ ₹800/t	7200	12000
SSP	@ ₹9/ kg	1687.5	2813
MOP	@ ₹15/kg	750	1249
Expenditure on manures application	@ ₹200/ t of FYM	1800	3000
Expenditure on fertilizer application	@ ₹178/ labour/day	712	1068
Total		12149.5	20130
Intercultural operations			
Weeding	@ ₹178/ /labour/day	2136	3560
Total		2136	3560
Irrigation application			
Irrigations (@ 12hr for 1 ha.)	@ ₹30 per hour	2880	6600
Labour charges	@ ₹178/ /labour/day	2848	3916
Total		5728	10516
Plant protection			
Labour for spraying (2 men per spray)	@ ₹178 /labour/day	2136	2136
Chloropayriphos 1 spray	@ ₹475/lit	285	475
Thimethoczam 2 spray	@ ₹895/kg	429.6	716
Imedachlor 2 spray	@ ₹1340/lit	482.4	804
Profenophos 1 spray	@ ₹460/lit	276	460
Total		3609	4591
Harvesting			
Uprooting the plants	@ ₹178/ /labour/day	1068	1780
Total		1068	1780
Grand Total		38938	62898
Interest on working capital @ 7 %		2726	4402
Gross total		41663	67301

coated urea + 25% RDN through Vermicompost under teak-based silvi-horticulture system. Among intercrop the lowest net realization and BCR were registered in T_9: 100% RDN through Neem cake (₹ 4,13,951 and 1: 4.08, respectively). The net realization and benefit cost ratio of okra crop was higher when they were grown in open condition as compared to under teak based silvi-horticulture system. The highest net realization was registered when okra was grown in open with the application of T_{11}: 75% RDN through chemical fertilizer with 25% RDN from Vermicompost while highest BCR registered with T_{10}: 100% RDF through chemical fertilizer. The probable reason for highest net realization due to increase of growth and yield parameters in open condition as compared to under teak-based silvi-horticulture system (Table 1). The BCR ratio was maximum in T_{11}: 100% RDF from inorganic fertilizer it might be due to high cost of Vermicompost then chemical fertilizer. In case of teak based silvi-horticulture system highest net realization and BCR were in T_5: 75% RDN through inorganic fertilizer with 25% RDN from Vermicompost as compared to other treatments under teak and okra grown alone. These results are in line with earlier findings Hanif et al (2010) in okra under *Litchi chinensis*, Panwar and Wani (2014) in *Ipomoea batatas* under *Populus deltoides*, Yadav et al (2014) in *Triticum aestivum* under *Populus deltoides*, Kumar et al (2016) in *Ocimum spp*. under *Tectona grandis*, Rajalingam et al (2016) in vegetable crops under *Ailanthus excelsa*, Kazi et al (2017) in colocasia under *Borassus flabellifer*, Bhusara et al (2018) in okra under *Melia composita*, Patel et al (2018) in cucurbitaceous vegetable crops under *Tectona grandis* and Jilariya et al (2019) in *Aloe vera* under *Melia dubia*.

CONCLUSION

The application of 75% RDN through Neem coated urea + 25% RDN through Vermicompost to okra under teak based silvi-horticulture system to generate maximum net realization and BCR as compared to sole okra crop. Thus, Teak-Okra based silvi-horticulture system is much profitable and more sustainable than sole cropping.

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Assessing Performance of Maize (*Zea mays* L.) Hybrids under Different Regimes of Irrigation and Organic Manure in Semi-Arid Region of Haryana

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Abstract: A field investigation was conducted in a sandy loam during the spring 2020 at CCS Haryana Agricultural University Hisar, Haryana to study the effect of irrigation source and organic manure source's on performance of maize (*Zea mays* L.) hybrids. The treatments consisted of two single cross hybrids (HQPM-1 and HQPM-5) and two irrigation sources [Canal water and treated sewage water] in main plots and four organic manure sources [No manure, 100% recommended dose of nitrogen (RDN) through FYM, 100% RDN through vermicompost and 50% of RDN through FYM + 50% of RDN through vermicompost] in sub-plot. The higher growth parameters and yield of maize were recorded in HQPM-1 as compared to HQPM-5. Treated sewage water performed statistically at par in different growth parameters and significantly higher in yield of maize, in comparison to canal water. Application of 100% RDN through vermicompost resulted in significantly higher plant height, dry matter accumulation per plant, yield (grain, straw and biological) of maize as compared to rest of the treatments. This study concluded that treated sewage water can be a replacement to the conventional water sources under use and application of 100% RDN through vermicompost can improve the growth and yield of maize.

Keywords: FYM, Growth, Maize, Organic manure, RDN, Vermicompost, Yield

Maize is one of the most important cereal crops of the world as well as India. It is cultivated under diverse conditions of soil and climate. In India, it is the third most important crop, after rice and wheat. In 2019-20, maize was cultivated on an area, of 9.57 Million hectare with a production of 28.77 Million tonnes and productivity of 3.00 t/ha respectively, in India. In Haryana (2019-20), the area, production and average productivity of maize in *kharif* was 6,000 ha, 17,000 tonnes and 2.83 t/ha respectively (DES 2021). Maize is highly sensitive to water stress as well as excess irrigation. Cities generate a huge amount of domestic wastewater. Pollution of soil, groundwater and air results from indiscriminate disposal of such water. Because of rising population and progressive industrial development, the resources are depleting on a daily basis throughout the world, which encouraged people to reuse, recycle and adopt strategies to reduce the existing load on resources rather than polluting them through discharging in environment. The reuse of wastewater for irrigation in agricultural crop can reduce the amount of water that is extracted from water resources. Such wastewater contains the high nutrient load and can possibly be utilised to irrigate crops, which can in turn will lead to increase in agricultural yield and planting. Addition of organic material to the soil aids in the preservation of soil fertility and productivity. Organic manures improve soil organic carbon, which is important for maintaining soil physical quality as well as plant nutrients. Farmyard manure (FYM) and vermicompost (VC) are particularly important for use in maize in this context. It helps in nutrient recycling, transformation and availability to the crop by boosting soil microbiological activity. It also improves physical properties such as soil's water holding capacity, porosity and structure, as well as reducing compaction, crusting and salt accumulation in root zone. The present studies aimed at finding the appropriate irrigation source and organic manure source by assessing the growth and yield of maize single cross hybrids.

MATERIAL AND METHODS

The field experiment was conducted at CCS Haryana Agricultural University Hisar during spring 2020 ($29^0$10' N and $75^0$46' E, of 215.2 meter above mean sea level). The soil was sandy loam, having a pH 8.01 and EC 0.39 dS/m. The soil initially contained organic carbon (0.34 %), available nitrogen (105 kg/ha), available phosphorous (15.4 kg/ha) and available potassium (302 kg/ha). The experiment was laid down in split plot design with three replications. The treatments comprised of 2 single cross hybrids (SCH) ['HQPM-1' (A_1) and 'HQPM-5' (A_2)] and 2 irrigation sources [canal water (B1) and treated sewage water (B2)] as main plots and 4 organic manure sources [No manure (C_1) = No manure or fertilizer, 100% FYM (C_2) = 100 % recommended dose of nitrogen (RDN) though FYM, 100% VC (C_3) = 100 % RDN though vermicompost and 50% FYM + 50% VC (C_4) = 50% of RDN through FYM and 50% of RDN through vermicompost] in sub-plot. Each experimental units consisted of 6.0 m × 5.0 m plots. The FYM contains 0.62-0.20-0.50 % and vermicompost contains 2.5-1.0-1.5 % N-P-K respectively. The maize crop was sown on 26 February 2020 at recommended spacing of 60 cm × 20 cm. The nutrients were applied according to the treatments at the time of field preparation for the crop. Other practices were carried out as per package of practices of CCS HAU Hisar (Anonymous, 2020). The plant population was counted from five randomly selected central rows of two meter row length and then average out to get number of plants per square meter. The plant height was measured from the base of plant to the tip of fully opened top leaf. Five plants were randomly selected from each plot and carefully uprooted to take dry matter accumulation. These samples were firstly sun dried and then oven dried at 70^0C to achieve constant weight and then averaged to get dry matter accumulation per plant. The data of plant height (cm), dry matter (g/plant) were taken from each plot at 30, 60, 90 days after sowing (DAS) and at maturity. The crop was harvested manually, at maturity. The harvested cobs were then threshed to estimate grain yield. Grain and straw yield (kg/ha) were determined from each plot and converted to tonnes per hectare (t/ha). The following formula was used to work out biological yield:

Biological yield = Grain yield + Straw yield

Harvest index (%) was calculated by the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

All the data recorded were analysed as per the standard statistical technique as described by Panse and Sukhatme (1978). The significance of difference were compared by using critical difference (C.D.) at 5 % level of probability using OPSTAT software.

RESULTS AND DISCUSSION

Growth Parameters

Plant height: Plant height varied significantly due to different SCH at all crop growth stages except at 30 DAS. HQPM-1 produced significantly taller plants, *viz*. 135.95, 165.12 and 166.29 cm at 60, 90 DAS and at maturity, respectively as compared to HQPM-5 (Table 1). Taller plant were recorded with HQPM-1, plant height is strongly influenced by considerable varietal variation in this characteristics and environmental conditions during stem elongation and growth of plants. These results are in conformity with Kumar (2016) and Gaile (2012). Irrigation source had no significant effect on plant height at all crop growth stages except at 60 DAS. Treated sewage water had higher plant height at all crop growth stages than canal water. This could be due to treated sewage water causing higher nutrient inputs, accumulation

Table 1. Effect of sewage water and organic manure on plant height and dry matter accumulation per plant of maize hybrids at different crop growth stages

Treatments	30 DAS		60 DAS		90 DAS		At maturity	
	Plant height (cm)	Dry matter (g/plant)	Plant height (cm)	Dry matter (g/plant)	Plant height (cm)	Dry matter (g/plant)	Plant height (cm)	Dry matter (g/plant)
A. Single cross hybrid								
A_1: HQPM-1	40.61	14.87	135.95	53.21	165.12	98.50	166.29	138.51
A_2: HQPM-5	40.22	14.32	130.80	51.18	161.38	93.29	163.76	125.44
C.D. (p=0.05)	NS	NS	2.61	1.36	3.35	2.63	1.91	4.249
B. Irrigation source								
B_1: Canal water	40.27	14.48	131.91	51.79	162.44	94.97	164.13	130.82
B_2: Treated sewage water	40.56	14.71	134.84	52.60	164.06	96.81	165.92	133.12
C.D. (p=0.05)	NS	NS	2.61	NS	NS	NS	NS	NS
C. Organic manure source								
C_1: No manure	35.10	11.39	107.30	39.85	130.40	70.20	131.10	87.50
C_2: 100% FYM	41.16	14.20	140.90	50.92	172.90	93.55	174.60	130.20
C_3: 100% VC	43.40	17.60	143.70	63.28	175.80	118.33	178.40	167.02
C_4: 50% FYM + 50% VC	42.00	15.20	141.60	54.73	173.90	101.49	176.00	143.16
C.D. (p=0.05)	1.71	1.05	3.25	6.41	4.00	16.97	3.78	46.46

and uptake of nutrients. Similar results were reported by earlier researchers (Chandrikapure et al 2017, Mousavi and Shahsavari 2014). Organic manure significantly improved plant height at all crop growth stages and application of 100% VC recorded significantly taller plant at all the crop growth stages which was statistically at par with 50% FYM + 50% VC and 100% FYM than control except at 30 DAS whereas 100% VC was statistically at par with 50% FYM + 50% VC. Increased plant height might be due to quick and higher availability of nutrients especially nitrogen under vermicompost treated plots. These results are in close conformity with Prasad et al (2018) and Gunjal and Chitodkar (2017).

Dry matter production: Dry matter production was significantly affected due to different SCH treatment at all crop growth stages except at 30 DAS (Table 1). HQPM-1 had higher dry matter accumulation per plant (53.21, 98.50 and 138.51 g) at 60, 90 DAS and at maturity, respectively as compared to HQPM-5. These results are in agreement with Kumar (2016) and Gul et al (2015). Irrigation source failed to bring any significant variation in dry matter accumulation per plant at all crop growth stages. However, treated sewage water had numerically higher dry matter accumulation per plant than canal water at all crop growth stages. Organic manure had significant effect on dry matter accumulation at all crop growth stages. Maximum dry matter accumulation was found under 100% VC (17.60 and 63.28 g/plant), which was significantly higher than rest of treatments at 30 and 60 DAS, respectively; while it was statistically at par with 50% FYM + 50% VC at 90 DAS and significantly higher than no manure (C_1) and 100% FYM (C_2). At maturity, 100% VC recorded highest dry matter accumulation per plant, which was statistically at par with 50% FYM + 50% VC and 100% FYM while significantly higher than no manure (C_1). This might be due to slow release of nutrients over time with using organic manure and improved physio-chemical properties, which ked to better growth. The increment in plant height by use of organic manure consequently increase the dry matter. These results are in close conformity with Prasad (2019) and Raman and Suganya (2018).

Yield

Plant population: The number of plants per square meter at maturity was non-significantly affected by different SCH, irrigation source and organic manure treatments (Table 2).

Harvest index: Different SCH, irrigation source and organic manure treatments had non-significant effect on harvest index of maize (Table 2).

Grain, straw and biological yield: The significantly higher yield of grain, straw and biological (5.808, 8.375 and 14.183 t/ha) of maize was obtained with HQPM-1 than HQPM-5 (Table 2). Treated sewage water recorded significantly higher grain, straw and biological yield (5.726, 8.260 and 13.986 t/ha) than canal water. This might be due to increased nutrient inputs in treated sewage water plots, higher dry

Table 2. Effect of sewage water and organic manure on number of plants per square meter, grain yield, straw yield, biological yield and harvest index of maize hybrids

Treatments	At maturity				
	No. of plants/m^2	Yield (t/ha)			Harvest index (%)
		Grain	Straw	Biological	
A. Single cross hybrid					
A_1: HQPM-1	8.259	5.808	8.375	14.183	40.85
A_2: HQPM-5	8.231	5.523	7.989	13.512	40.79
C.D. (p=0.05)	NS	0.120	0.153	0.214	NS
B. Irrigation source					
B_1: Canal water	8.245	5.605	8.103	13.708	40.79
B_2: Treated sewage water	8.245	5.726	8.260	13.986	40.85
C.D. (p=0.05)	NS	0.120	0.153	0.214	NS
C. Organic manure source					
C_1: No manure	8.217	1.414	2.084	3.499	40.44
C_2: 100% FYM	8.245	6.921	10.028	16.950	40.86
C_3: 100% VC	8.273	7.288	10.449	17.737	41.08
C_4: 50% FYM + 50% VC	8.245	7.038	10.165	17.203	40.91
C.D. (p=0.05)	NS	0.389	0.573	0.921	NS

matter, plant height and yield attributes. The interaction between SCH and irrigation source had significant effect on grain yield of maize. Higher grain yield was recorded in HQPM-1 with treated sewage water. These results are in close conformity with Chandrikapure et al (2017), Nahhal et al (2013) and Galavi et al (2009).

Organic manure had significant effect on grain, straw and biological yield of maize. Highest grain, straw and biological yield (7.288, 10.449 and 17.737 t/ha, respectively) was recorded under 100% VC which was statistically at par with 50% FYM + 50% VC and 100% FYM, but was significantly higher than no manure (C_1). This might be due to more supply of nutrients through organic manure, higher number of plants, dry matter. Application of organic manure might have improved the soil physical, chemical and biological properties resulting in increased nutrient uptake causing higher yield. The interaction was significant between SCH and organic manure source. Highest grain yield was obtained in HQPM-1 with 100% VC. These results are in close conformity with Gunjal and Chitodkar (2017) and Prasad (2019).

CONCLUSIONS

The application of 100% recommended dose of nitrogen through vermicompost, the single cross hybrid HQPM-1 produced higher growth parameters (plant height, dry matter accumulation) and yield (grain, straw and biological) of maize (*Zea mays* L.) as compared to HQPM-5 irrespective of irrigation source. Hence, treated sewage water can be successfully used for replacement of conventional irrigation water.

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Effect of Induced Salt Stress on Growth of *Lygeum spartum* L.

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***Abstract*:** The esparto (*Lygeum spartum* L.) is a perennial poaceae which is of significant ecological interest in the fight against the advance of the desert and desertification because of developed root system and a salinity-tolerant species. The present study aimed at to study some parameters of biological adaptation to salinity in *Lygeum spartum* Land to observe the effect of salinity by adding increasing concentrations of NaCl (0, 50, 100 mM). The results obtained show the negative effect of NaCl on the growth and development of the plant, salt stress led to a decrease in the growth of the plant, decrease in the concentration of flavonoids and antioxidant activity which indicate increase in the rate of inhibition of 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and an increase in the rate of malondialdehyde (MDA). These results confirm that esparto is a model plant that has an adaptive and salinity-tolerant capacity.

***Keywords*:** Salt stress, *Lygeum spartum*, Growth, Oxidative stress, Flavonoids

Soil salinity is one of the environmental factor affecting vegetation cover and land. Salinity leads to soil degradation and erosion (Ferreira et al 2021). Numerous studies confirmed the deleterious effects of salinity on soil properties, microflora, seed germination, plant growth, and soil-dwelling organisms (Sahab et al 2021). In addition salinity stress causes osmotic stress, nutrient imbalance, ion toxicity, increased reactive oxygen species (ROS) production, decreased photosynthesis and reduced plant productivity (Kordrostami and Rabiei 2019). Salinity-induced oxidative stress in the form of ROS adversely affects plant growth and productivity (Kumar et al 2018). Plants trigger an antioxidant defense system through non-enzymatic compounds, such as ascorbic acid, glutathione, α-tocopherol, carotenoids and flavonoids (Caparos et al 2019) and is identified salt-tolerant species. The level of tolerance is important to fight abiotic stress. Tolerant and hardy grass species have been (Kumar et al 2016, Liu et al 2022).Among these is *Lygeum spartum* L. species is of interest because of its tolerance to environmental in combating the advance of the desert and desertification due to its developed root system. *L. spartum* L. is a perennial poaceae serves as a natural barrier against advancing sand and desertification in the Algerian high plateaus. Nedjimi (2009) showed that salt tolerance strategies of *L. spartum* L. is achieved by appropriate osmotic adjustment involving accumulation of ions and glycine betaine. Physiological behavior of *L. spartum* L. in a salty environment shows an osmotic adjustment in this species which is associated with a significant accumulation of sodium (Na^+) and chlorine (Cl^-), while the accumulation of soluble sugars contributes partially to osmo-regulation (Nedjimi 2013). But until there is no study which has been carried of biological adaptation defense system to fight the effect of salinity on growth of *Lygeum spartum* L.

The objective of this study is to demonstrate the influence of a salt stress on certain physiological and morphological parameters of the plant by the induction of salt stress by different concentrations of NaCl and to measure of some plant growth parameters, flavonoids, antioxidant activity and lipid peroxidation.

MATERIAL AND METHODS

Plant material: The seeds of *Lygeum spartum* L. harvested in the region of El Bayedh (El_Kheiter) in June 2021 and were disinfected with 2% sodium hypochlorite for 3 minutes, then rinsed with sterile distilled water and then placed in plastic petri dishes 10 cm in diameter and 1.3 cm thick. The seeds were germinated in an oven at 30°C. Afterwards were placed in pots; containing the soil taken from the El_Kheiter station. The pots are placed in the greenhouse then watered daily with a nutrient solution consisting of K_2HPO_4 (0.5 mM), $MgSO_4$ (0.5 mM), H_3BO_3 (25 mM), $MnSO_4$ (2 mM), $ZnSO_4$ (2 mM), $CuSO_4$ (0.5 mM) for 7 days at a rate of 5ml per pot.

Induction of salt stress: After 7 days, the pots of *L. spartum* L. seedlings were divided into 3 batches, each batch containing 60 seedlings. The first batch was watered with the nutrient solution for 7 days at the rate of 5 ml per pot, 3 times per week for 60 days and kept as control. The second batch was sprayed with a 50 mM NaCl solution for 60 days, 3 times a week. The third batch was sprayed with a 100 mM NaCl solution for 60 days, 3 times a week.

Measurement of the aerial part and the underground part: After 60 days of growth, the lengths were measured. For the measurement of the fresh mass, the seedlings were dug up. The fresh weight of the seedlings was weighed. For dry weight, the seedlings were dried in the open air, and placed in an oven at 30°C, from the 5th day the dry weight was estimated after stabilization of the dry weight.

Estimation of flavonoids: The extraction of flavonoids was made after crushing the seedlings of *Lygeum spartum* L. 10 g of plant powder were extracted using 100 ml of 80% methanol for 2 h at room temperature. Then centrifugation was carried out for 5 minutes at 3500 rpm. The quantification of flavonoids was carried out by a colorimetric method adapted by Dirar et al (2019) with slight modification. The method is based on the complexing of flavonoids with aluminum trichloride. A standard range is produced with catechin (Sigma-aldrich) (5-10-15 and 25 µg/ml). The results are expressed in mg of catechin equivalents per gram of extract (mg EC/g of extract).

Estimation of antioxidant activity: The estimation of the antioxidant activity was carried out by the chemical compound 2, 2-diphenyl-1-picrylhydrazyl (DPPH) test. DPPH is a free radical used to study the structure-antioxidant activity relationship of phenolic compounds (Aree and Jongrungruangchok 2018). Fifty µL of different concentrations of the extracts were added to 1950 µL of DPPH solution (0.025 g/L) dissolved in methanol. After 30 min incubation at room temperature, absorbance is read at 515 nm against a blank containing all reagents except test compound. Ascorbic acid was used as a positive control. Each sample was measured in triplicate. The results were expressed as a percentage of trapping activity (I %).

$$I\% = [(\text{White Abs} - \text{Sample Abs}) / \text{White Abs}] \times 100.$$

Estimation of lipid peroxidation: Lipid peroxidation was estimated by measuring MDA (malondialdehyde) with the TBARS (thiobarbituric active species) (Burri et al 2019). MDA is one of the products of the decomposition of polyunsaturated fatty acids under the effect of free radicals released during stress. The assay is based on the formation in an acidic medium (pH 2 to 3) and hot (100°C) between one MDA molecule and two molecules of thiobarbituric acid (TBA) of a pigment colored pink, absorbing at 530 nm. Lipid peroxidation was estimated by measuring the MDA content. Fifty mg of sample was ground and homogenized in 2 mL of 1% w/v trichloroacetic acid (TCA). The homogenate was centrifuged at 15,000 rpm for 10 min at 4°C. 0.5 mL of the supernatant was mixed with 1.5 mL of thiobarbituric acid (TBA) prepared in 20% TCA and incubated at 90°C for 20 min. Absorbance was read at 532 nm. The MDA content was determined using the extinction coefficient at 155 mm/cm. All experiments were repeated 3 times.

RESULTS AND DISCUSSION

Seed germination and length of the aerial part and the underground part: The germination rate of Lygeum *spartum* L. seeds was 100%. The various saline treatments applied to the seeds after 60 days of growth influenced the growth and development of the seedlings, The elongation of the root axis and of the hypocotyl in the presence of NaCl, indicated that elongation of the aerial part and underground part of the plant was slowed down compared to the elongation in the control. The application of 50 mM of NaCl caused a slight reduction in root elongation, and reduction was more marked for the roots at 100 mM of NaCl. The hypocotyl showed significant reduction at 50 mM of NaCl compared to the control plant which stabilizes despite the increase in the doses of NaCl to 100 mM (Table 1). The result of application of high concentrations of NaCl from 50 mM to 100 mM, resulted in decrease of fresh weight of young seedlings obtained after 60 days of germination compared to the control plants. The results showed that 50 and at 100 mM, increased, dry weight of young seedlings obtained after 60 days of germination as compared to control (Table 1).

Flavonoids : The quantitative analysis of the extracts of the aerial parts of *L. spartum* L. was carried out by spectrophotometric determination of flavonoids (Fig. 1). The results are expressed in mg catechin equivalent/g DW. The flavonoid content obtained from a calibration curve (y=0.040 x +0.006; R2 = 0.998) established that with increasing

Table 1. Length of the aerial part and the underground part, fresh and dry weight of control and stressed plant (50, 100 mM NaCl)

	LAP	LUP	FW	DW
Control	25.85±0.70	26.81±1.05	0.72±0.48	0.15±0.006
50 mM NaCl	22.35±0.80	26.42±1.12	0.29±0.01	0.15±0.006
100 mM NaCl	21.34 ±0.87	24.98±0.98	0.3±0,01	0.19±0.009

concentrations of catechin .The flavonoid content in the control extract is higher (0.34 mg CA Eq/g DW) as compared to 50 mM extract (0.29 mg CA Eq/g DW (and 100 mM extract (0.012 mg CA Eq/g DW).

Antioxidant activity: The DPPH assay was used to estimate the antioxidant activity of the different extracts obtained from the different treatment (control, stressed at 50 Mm and 100 mM). The test is based on the capacity of the anti-radical substances present in the extracts to reduce the DPPH free radicals, ascorbic acid was used as a positive control to check the reactivity of the solution. The different treatment have variable anti-free radical activities towards the DPPH free radicals. The control extract shows a low anti free radical activity between 21.78 and 76.16 % compared to the 50 mM extract (45.97 and 85.14) and the 100 mM extract (95.12 %) at the concentration 6 mg/ml. all these extracts showed their possession of an antioxidant power (Fig. 2).

Lipid peroxidation: There was a variability in the accumulation of MDA in *Lygeum spartum*; in control batch there, accumulation of 1.09 µmol/g of MDA was observed. The plants stressed at 50 mM of NaCl have an accumulation of 1.1 µmol/g of MDA plants stressed with 100 mM of NaCl present 1.3 µmol /g of MDA (Fig. 3).

The results show after 60 days of growth a decrease in the length of the aerial and underground parts of the plant, however it is indicate that the aerial parts are more affected than the underground parts. Indeed, salt stress inhibits the growth of and development of plants (Lepengue et al 2010, Silva et al 2014).Similar results were observed in *Hordeum vulgare*, where salt stress reduces the growth of young leaves and roots (El Goumi et al 2014), Moreover, salinity negatively affects the growth of the vegetative apparatus, in *Pistacia vera,* (Benmahioul 2009). Khodarahmpour et al (2012) concluded that aerial parts were more affected than the roots in the presence of salt stress. Wang (2022) observed the reduction in the root, stem, and leaf dry weights exposed to salt stress. This decrease in biomass was also reported by earlier researchers (Benmahioul 2009, El Goumi et al 2014). The decrease in dry biomass can be caused by the increase in Cl- concentration in the tissue (Tavakkoli et al 2011). Shabala et al (2016) and El-Badri (2021) shows that soil salinity is a major abiotic stress factor who negatively affects crop yield by impairing germination, plant vigor and metabolic pathways. Saline condition in halophyte grasses leads to an increase in the content of antioxidants. Indeed saline condition in halophyte grasses leads to an increase in the content of antioxidants (Singh et al. 2015).In addition salinity enhanced the production of ROS, which are highly toxic to the cell, and they disturb cell redox homeostasis. Surplus ROS in the cells facilitates protein and enzyme degradation and lipid peroxidation (Li et al 2017). The flavonoids decrease when the NaCl concentration increases and slight decrease in flavonoids from the treatments at 50 mM NaCl, whereas when the concentration of NaCl doubles, significant decrease of content of flavonoids is observed. Lipid peroxidation were estimated by MDAs by the TBARS test, an indicator of damage caused by stress. There was

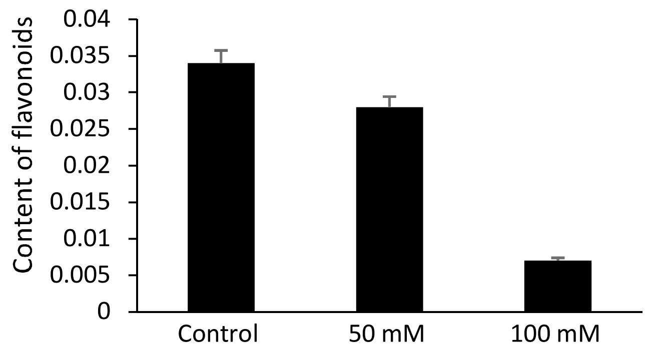

Fig. 1. Flavonoid content by spectrophotometric determination (results are expressed in mg catechin equivalent/g DW)

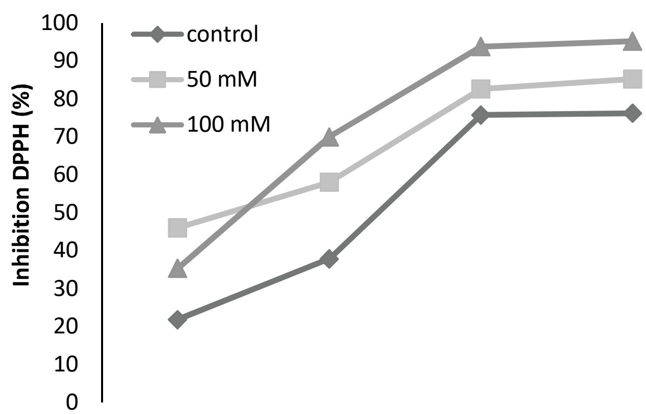

Fig. 2. Percentage of inhibition of DPPH according to the different concentrations of *Lygeum spartum* L

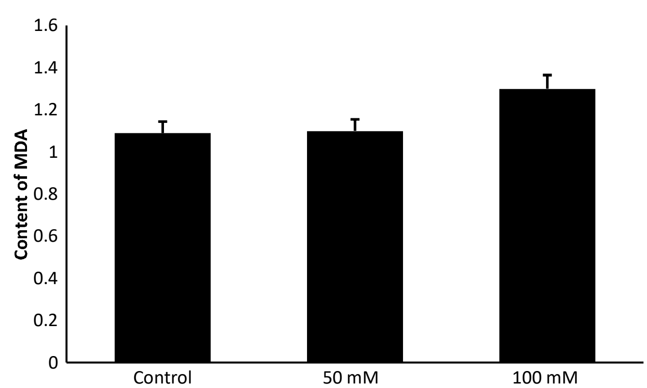

Fig. 3. Determination of content of MDA (results are expressed in µmol/g)

increase in MDA levels compared to controls. The results are similar with induced salt stress in maize, prolong salinity reduced leaf relative water content and leaf water potential and increased malondialdehyde (MDA) and hydrogen peroxide (H_2O_2) content (Abdelgawad et al 2016).

CONCLUSION

The induction of salt stress by sodium chloride shows that the development of the aerial and underground system of the plant is affected by the concentrations of sodium chloride, as well as the development of fresh matter, which is strongly affected by sodium chloride. Salinity is a limiting factor for the growth of *L. spartum* L. The effect of salt stress on the growth of *L. spartum* L at the root and leaf emergence stage is visible and the increase in salt concentration leads to a slowdown in growth. The salt stress generates oxidative stress, this results in an accumulation of hydrogen peroxide and lipid peroxidation indicating the instability. The production of reactive oxygen species disturbed the redox status of cells h triggered oxidative stress in *Lygeum spartum* L. The quantitative estimate of flavonoids indicate plant contains significant amount metabolites. Esparto is a model plant for adaptation and tolerance to salt stress.

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Effect of Micro-Irrigation and Nutrient Management on Yield and Quality of Potato in Acid Alfisol of Himachal Pradesh

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Abstract: Present study was carried out at the experimental farm of Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, to study the effect of micro-irrigation and nutrient management on yield and quality of potato in an acid Alfisol of Himachal Pradesh. The experiment consisted of three drip irrigation levels (0.4 PE, 0.6 PE and 0.8 PE), three fertigation levels (50% RDF, 75% RDF and 100% RDF) and Recommended practice. The results revealed that yield and quality parameters of potato were higher at drip irrigation level of 0.6 PE and fertigation level of 75% RDF. There was significant increase in the yield of potato with increase in fertigation levels. Fertigation level of 75% RDF recorded significantly higher marketable tuber yield which was 22 per cent higher than that obtained with 50% RDF. Drip irrigation and fertigation was better than the recommended practice as combination of irrigation level of 0.6 PE and 75% RDF recorded higher yield and better quality parameters, thereby saving 25 per cent of NPK.

Keywords: Potato, Drip irrigation, Fertigation, Yield, Quality

The water requirement of potato is quite high and depends upon soil type/texture, atmospheric conditions, duration of variety, length of growing period, cropping pattern and management practices. Drought at any stage can prove detrimental, however, the excess water is also equally harmful as it creates aeration problem and favours certain diseases and pests. The crop productivity and quality of the produce largely depend upon proper balance between soil air and soil water in the plant root zone. In the present day context, due to increasing water scarcity and recurring drought in many parts of the country, the use of drip and sprinkler irrigation methods have become extremely important. These methods not only improve efficiency of irrigation water and fertilizer nutrients, but also the hydro-thermal regimes and physical conditions of the soil by maintaining proper balance between soil air and soil water in the plant's root zone for better root growth and tuber development. The use of drip irrigation considerably decreases the amount of water used and maintains adequate moisture content in soil (Ghiyal et al 2016). In Himachal Pradesh, potato is mostly grown by applying flood irrigation at critical stages, leading to significant water as well as nutrient losses. Moreover, 80 per cent of the cultivated area in this state is rainfed where drip irrigation system may be used by making use of the harvested rain water. Recent emphasis on efficient utilization of water (per drop more crop) necessitates systematic studies for standardizing the frequency and amount of water to be used for growing potato through drip irrigation system (Mokh et al 2015). Fertigation is an attractive technology in modern agriculture, which can maintain optimal nutrient and moisture levels according to the specific needs of the crop in a particular soil type for enhancing nutrient use efficiency and productivity of the crops. However, this requires standardization of nutrient doses and fertigation schedule (Sharma et al 2016). There are number of factors that play a crucial role in deciding the growth and yield of potato, however, irrigation and fertilization are the most predominating among them. Improper irrigation and nutrient management practices not only waste the expensive and scarce water resources but also reduce the tuber yield and quality. Hence, it is possible to increase the production of potato by adopting well-scheduled irrigation and fertigation throughout the growing season.

MATERIAL AND METHODS

Location and site characteristics: The Present study was conducted at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during *rabi* 2016. The experimental farm is situated at 32° 6' N latitude and 76° 3' E longitude at an altitude of about 1290 m above mean sea level. The site lies in the Palam valley of Kangra district representing mid hill wet temperate zone (Zone 2.2) of Himachal Pradesh. Taxonomically, the soils of study area fall under order Alfisol and sub-group Typic Hapludalf. These soils have originated from rocks like slates, phyllites, quartzites, schists and gneisses.

Experimental details: The field experiment on potato (cv. Kufri Jyoti) was laid out in randomized block design (RBD) with ten treatments, each replicated three times. Ten treatments comprised three drip irrigation levels viz., 0.4 PE, 0.6 PE and 0.8 PE corresponding to 40, 60 and 80 per cent of cumulative pan evaporation, respectively, three fertigation levels viz., 50% RDF, 75% RDF and 100% RDF equivalent to 50, 75 and 100 per cent of recommended dose of NPK, respectively and RP i.e. recommended practice (recommended dose of fertilizers was applied through conventional methods and 6 flood irrigations of 50 mm each). The recommended dose of fertilizers (RDF) for potato was N, P_2O_5 and K_2O were 120, 80 and 60 kg/ha, respectively. The irrigations were applied through online drip system on alternate days for each treatment. Fertigation was done as per treatments using urea and water soluble fertilizers; 17:44:00 and 00:00:50 in calculated proportions. Fertigation was started after complete emergence of the crop. Fertigation with 17:44:00 and 00:00:50 was completed in 5 splits whereas, urea was applied in 10 splits. In the last treatment i.e. RP, recommended dose of fertilizers was applied through urea, single super phosphate and muriate of potash. Half of the nitrogen dose (60 kg/ha N) and full dose of phosphorus and potassium was applied in the RP treatment at the time of sowing. The remaining dose of nitrogen in this treatment was applied at the time of earthing up. Six irrigations @ 50 mm water per irrigation were applied during the crop period.

RESULTS AND DISCUSSION

Yield: Varying drip irrigation levels from 0.4 PE to 0.8 PE did not affect the marketable tuber, haulm and total yield of potato significantly (Table 1). The non-significant effect of irrigation levels on tuber haulm and total yield may be ascribed to the fact that soil moisture contents under these levels, though increased with irrigation level but no moisture stress was observed at any level during the crop growth as the soil moisture contents were nearby field capacity of the soil and there was ample availability of water for the crop growth. Therefore, the crop under varying levels of irrigation was able to utilize the nutrients properly for growth and development of tubers. Similar results have been reported by different workers for various crops under almost same set of conditions where irrigation levels did not influence the crop yield (Kapoor et al 2013 and Kapoor 2016).

Highest tuber yield (21.97 t/ha) and total yield (25.41 t/ha) were obtained with fertigation level of 75% RDF whereas, haulm yield was highest (3.67 t/ha) at 100% RDF. There was significant increase in the tuber, haulm and total yield of potato with increase in fertigation levels. The marketable tuber, haulm and total yield obtained at 50% RDF were 18.01, 3.27 and 21.27 t/ha, respectively which increased to 21.97, 3.44 and 25.41 t/ha, respectively at 75% RDF, the corresponding increases being about 22, 5.5 and 19 per cent, respectively. Further increase in fertigation level to 100% RDF significantly increased the marketable tuber, haulm and total yield over 50% RDF by about 16.7, 12.6 and 16.1 per cent, respectively. The data further revealed that fertigation level of 75% RDF was statistically at par with 100% RDF in respect of tuber and total yield. Similar results were reported by Patel et al (2012) where higher rate of NPK provided better growth, development and translocation of photosynthates to tubers which might have resulted into higher yield of tubers. Similar findings were reported by Bisht et al (2012), Kapoor et al (2013, 2016). No significant difference in tuber yield (17.37 t/ha) obtained between the recommended practice involving surface irrigation and recommended fertilization (RP) and overall mean of different drip irrigation and fertigation combinations termed as others (20. 33 t/ha). However, haulm yield (3.46 t/ha) and total yield (23.79 t/ha) were significantly higher in others in comparison to recommended practice. This established the benefit of drip irrigation coupled with fertigation over the recommended practice since similar tuber yield could be realized by consuming less water and nutrients.

Tuber grades: Tuber size is one of the important quality parameters of potato. Large to medium potatoes are liked by most of the consumers and fetch good prices to the farmers. The application of water at 0.8 PE, significantly increased the yield of large sized potato over 0.4 PE (Table 2). As regards

Table 1. Effect of drip irrigation and fertigation levels on tuber, haulm and total yield (t/ha)

Treatments	Tuber yield	Haulm yield	Total yield
Irrigation level			
0.4 PE	18.93	3.37	22.30
0.6 PE	20.93	3.47	24.40
0.8 PE	21.13	3.53	24.67
CD (p=0.05)	NS	NS	NS
Fertigation level			
50 % RDF	18.01	3.26	21.27
75 % RDF	21.97	3.44	25.41
100 % RDF	21.02	3.67	24.69
CD (p=0.05)	2.35	0.14	2.31
Recommended practices (RP) vs others			
RP	17.37	3.11	20.48
Others	20.33	3.46	23.79
CD (p=0.05)	NS	0.18	2.98

the yield of medium sized potato tubers, irrigation level of 0.6 PE recorded significantly higher yield of such potatoes over the other two levels. The proportion of large sized potatoes was highest under irrigation level of 0.8 PE (58.5%) followed by 0.6 PE (56 %) and minimum proportion of large potatoes was under 0.4 PE (53.3%). Higher proportion of large potatoes under higher irrigation levels may be due to comparatively higher moisture contents in soil since at bulking stage more of water is required for development of tubers. Highest yield of large potatoes (13.06 t/ha) was recorded at fertigation level of 100% RDF, however it was statistically at par with 75% RDF (12.07 t/ha). Significantly lower amount of these potatoes was observed under 50% RDF. This emphasizes the need for proper fertilization of the crop for harvesting good quality potatoes of large grade. Application of increasing levels of fertilizers through fertigation brought out marked increase in the proportion of large potatoes. About 61.8 per cent of the total yield accounted for large potatoes, 24.8 per cent towards medium and 13.4 per cent towards small potatoes at fertigation level of 100% RDF. Similarly at fertigation level of 50% RDF, 54.7 per cent of the total yield was from large potatoes, 28.7 per cent from medium and 16.7 per cent from small potatoes. However, at fertigation level of 50% RDF only 51.2 per cent of the total yield was from large potatoes and small potatoes were 19.5 per cent-the highest proportion of these among all the fertigation levels for this grade.

The comparison of overall mean of fertigation and irrigation combinations with recommended practice (RP) revealed that large, medium and small size potato were significantly higher in others (11.46, 5.56 and 3.32 t/ha, respectively) in comparison to RP (8.63, 5.08 and 3.65 t/ha, respectively). The proportion of large potatoes under others was 55.9 per cent in comparison to 49.7 per cent under recommended practice. The higher proportion of large potatoes with higher fertigation levels may be ascribed to increased supply of nutrients through fertigation which might have increased the leaf area index thus increasing assimilates for tubers to grow. Our findings are in line with the conclusions of many workers who have also reported the increase in size of potato tubers with increasing fertilizer levels (Badr et al 2012, Ghiyal and Bhatia (2018) and Kumar et al 2018). The higher proportion of large potatoes in 'others' in comparison to recommended practice (RP) may also be ascribed to better availability of nutrients to plants through fertigation in comparison to soil applied nutrients during the growth period.

Crude protein content: Crude protein content was significantly higher under 100% RDF (10.93 %) in comparison to 50% RDF (9.94 %) (Table 3). There was no significant difference between 75% RDF (10.75 %) and 100% RDF (10.93 %). The increase in protein content due to the synergetic effect of N and K in absorption and their role in protein synthesis, translocation of amino acids and their polymerization (Yusuf et al 2017). The comparison of overall mean of fertigation and irrigation combinations (others) with recommended practice (RP) revealed that crude protein content was significantly higher in others (10.54 %) in comparison to the RP (10.00 %).

Total soluble solids (TSS): The TSS content was significantly higher in 100% RDF (5.5 °brix) in comparison to 50% RDF (5.2 °brix) (Table 3). There was no significant difference between 75% RDF (5.4 °brix) and 100% RDF (5.5° brix). Overall mean of fertigation and irrigation levels (others) exhibited significantly higher TSS content (5.4° brix) in comparison to that recorded under the recommended practice (5.1 °brix).

Sugar and starch content: Sugar and starch content was significantly higher in 0.8 PE (0.880 mg/g and 63.4 %, respectively) in comparison to 0.4 PE (0.811 mg/g and 61.0 %, respectively) (Table 3). There was no significant difference between irrigation levels 0.6 PE and 0.8 PE. Among different fertigation levels, sugar and starch content was significantly higher in 100% RDF (0.869 mg/g and 63.8 %, respectively) in comparison to 50% RDF (0.829 mg/g and 60.5 %, respectively). However, 75% RDF (0.846 mg/g and 62.4 %, respectively) was significantly at par with 100% RDF (0.869 mg/gand 63.8 %, respectively). Potassium which was applied along with nitrogen played a greater role in translocation of sugars from leaves to tubers and synthesis of

Table 2. Effect of drip irrigation and fertigation levels on graded yield (t/ha) of potato

Treatments	Large (>75g)	Medium (50-75g)	Small (<50g)
Irrigation level			
0.4 PE	10.18 (53.3)	5.47 (29.2)	3.28 (17.5)
0.6 PE	11.75 (56.0)	5.77 (27.6)	3.41 (16.5)
0.8 PE	12.44 (58.5)	5.42 (25.9)	3.27 (15.6)
CD (p=0.05)	1.82	0.21	NS
Fertigation level			
50 % RDF	9.24 (51.2)	5.26 (29.2)	3.51 (19.5)
75 % RDF	12.07 (54.7)	6.24 (28.7)	3.66 (16.7)
100 % RDF	13.06 (61.8)	5.17 (24.8)	2.79 (13.4)
CD (p=0.05)	1.82	0.21	0.19
Recommended practices (RP) vs others			
RP	8.63 (49.7)	5.08 (29.3)	3.65 (21.0)
Others	11.46 (55.9)	5.56 (27.6)	3.32 (16.5)
CD (p=0.05)	2.35	NS	NS

Table 3. Effect of drip irrigation and fertigation levels on quality parameters of potato

Treatments	Crude protein content (%)	TSS (°brix)	Sugar content (mg/g)	Starch content (%)
Irrigation level				
0.4 PE	10.38	5.3	0.811	61.0
0.6 PE	10.56	5.3	0.853	62.4
0.8 PE	10.67	5.4	0.880	63.4
CD (P=0.05)	NS	NS	0.031	1.8
Fertigation level				
50 % RDF	9.94	5.2	0.829	60.5
75 % RDF	10.75	5.4	0.846	62.4
100 % RDF	10.93	5.5	0.869	63.8
CD (P=0.05)	0.35	0.2	0.031	1.8
Recommended practices (RP) vs others				
RP	10.00	5.1	0.850	62.2
Others	10.54	5.4	0.848	62.2
CD (P=0.05)	0.46	0.3	NS	NS

starch. The amount of starch accumulated is a function of the rate of photosynthesis, translocation of photosynthates from leaves to tubers and subsequent conversion to starch (Kandi et al 2011). There was no significant effect of overall mean of fertigation and irrigation levels (others) and recommended practices on sugar and starch content of potato.

CONCLUSIONS

Irrigation through drip and fertigation has been found to be better than the recommended practice as the yield and quality parameters recorded under overall mean of these treatments (0.6 PE irrigation level, 75 per cent recommended dose of fertilizer) were either statistically at par or better with the recommended practice. There was significant increase in the yield of potato with increase in fertigation levels. Fertigation with 75 per cent recommended dose of NPK has been found to be statistically at par with 100 per cent recommended dose of fertilizers for yield and quality parameters of potato.

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Resource Use Efficiency and Constraint Analysis of Mango Cultivation in Kangra District of Himachal Pradesh

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Abstract: The present study has been designed to investigate the resource use efficiency and problems of mango growers. A sample of 80 farmers cultivating mango was selected using multistage simple random sampling. Area under mango increased at a rate of 1 per cent per annum, but productivity has shown negative growth during this period (2003-04 to 2018-19), indicating poor management of mango orchards in the state. The cropping intensity was 126.59 per cent, which is low due to the greater area under mango plantation. The coefficient of determination (R^2) was 0.94 which indicated that 94.00 per cent variation in mango production. The ratio of MVP/MFC was greater than unity, which indicated that the resource is being under-utilized and increase the use of these inputs will increase the output. The study signifies that there is need to enhance usage for the maximization of profit. The major constraints were shortage of skilled labor, high wage rates, lack of storage facilities, transportation problem, problems in market intelligence. Provision of marketing facilities, fertilizers, pesticides, is made available at subsidized rates and availability of low cost technologies was the major suggestions of the respondents. The study also suggests that there is a need of adoption of improved technologies along with proper utilization of resources like manures and fertilizers, irrigation, and better management practices for improving both yield and net returns among the mango growers. The main reasons for the low productivity were imbalances in nutrient application, alternate bearing and inadequate fertilization.

Keywords: Mango and cropping pattern, Input use, Costs, Returns, Efficiency and problems

Agriculture, forestry, and fishery had a gross value added of Rs 19.48 lac crore (US$ 276.37 billion) in fiscal year 2020. In fiscal year (FY) 2020, agricultural and allied industries accounted for 17.80 per cent of India's gross value added (GVA) at current prices. In 2021, consumer spending in India could rise by up to 6.60 per cent. India's share of global agricultural exports increased to 2.10 per cent in 2019 from 1.71 per cent in 2010 (Ministry of Commerce 2021). Mangoes are now growing in more than 100 countries of which more than 65 countries produce each more than 1,000 MT a year (FAO 2020). Currently, mango ranks third among tropical fruits and has become one of the top five fruits in the world (Galan 2017). In recent years, mangoes have become well established as fresh fruit and processed products in the global market (Mitra 2016). World demand for mango is ascertained to be increasing particularly from temperate countries where mangoes are rapidly gaining popularity. The cultivated in area is 2,291 thousand hectares with a production of 20,444 million tons in India and contributing 40 per cent of total world production of mango (NHB 2020). India is the largest producer of mango in the world followed by Indonesia and China. Approximately, India produces 25 million metric tons of mangos every year contributing to more than 45% of the world's mango production (FAO 2020).

Mango is perishable in nature and should be marketed immediately after picking of the fruits. At present, there are large numbers of intermediaries in this trade between the producer's and the consumer's which has resulted in a wide gap in the producer and consumer price of these commodities. This needs to be normalized to enable farmers receive remunerative price of their produce and boost their production and consumption in the country (Kaur et al 2014). Himachal Pradesh is having the advantage of varied climate ranging from subtropical to dry temperate. The total fruit production in state is 624.48 thousand metric tons from an area of 234.77 thousand hectares. The area under mango cultivation in the state is 42.41 thousand hectares which accounts for 18.06 per cent of total area under fruits in H.P and producing 51.54 thousand metric tons which is 8.00 per cent of total fruit production of Himachal Pradesh (NHB 2020). Mango cultivation is concentrated in Kangra, Una, Bilaspur, Hamirpur and parts of Mandi district of Himachal Pradesh. The Kangra district is the major mango growing district covering an area of 21.28 thousand hectares which is 50.17 per cent of total area under mango cultivation in H.P and producing 24.90 thousand metric tons i.e. 48.31 per cent of total production of Himachal Pradesh (Directorate of Economics and Statistics 2020). The growers are facing a number of problems during production and marketing of mango. The more serious problems faced by the cultivators are fluctuations in mango yield due to changes in the rainfall and other weather conditions. But the main reason for the lower production of mango is the frequent climatic changes in the production areas and it also shows that mango grower's share in consumer's rupee is less in India because of its perishability and seasonality. Mango growers do not want any risk in marketing and so contract marketing system is popular prevalently. This study was carried out in order to determine resource utilization and also to analyze the cost and returns of mango cultivation and encouraging mango production among marginal and small farmers.

MATERIAL AND METHODS

Kangra district of Himachal Pradesh was purposively selected for the present study during 2018.Two blocks of Kangra District (Nurpur and Indora) were chosen based on the area under mango cultivation and a list of villages in the selected blocks was created, and eight villages from each block were carefully selected. From the list, 5 mango growers were selected from each village, thus, 80 mango growers were selected for collecting data. The Primary data were collected from the sampled growers by the survey method using well designed and pretested schedule.

Cropping intensity: Cropping intensity was estimated as

$$\text{Cropping intensity} = \frac{\text{Gross cropped area}}{\text{Net sown area}} \times 100$$

Net sown area (NSA) is the area which has been cultivated at least once during a reference year. Gross cropped area (GCA)is the total area under different crops cultivated during that year. Thus if a particular plot is cultivated twice during the year, the area of the plot will be counted twice in GCA but only once in NSA.

Compound growth rate (CGR): The compound growth rates were computed by fitting the exponential function of area, production and productivity total fruits and mango in Himachal Pradesh for the period 2003-04 to 2020-21 to measure the growth rates of area, production and productivity of total fruits and mango in Himachal Pradesh. Data were collected from official website National Horticulture Board from the year (2003-2018). The Compound growth rate (CGR) is calculated by Patil and Yeledhalli (2016). Secondary data were entered into MS Excel and the analysis was performed using SPSS (Statistical Package for Social Sciences). The ordinary least square method was used to fit the exponential function of the following form, which was converted into a log linear function using the logarithmic transformation as follows:

$$Y = ae^{bt}$$

$$\text{Ln}\, Y = \text{Ln}\, a + bt.$$

Where,

Y = Dependant variable (area, production and productivity)

t = Independent variable (time in year).

Compound growth rate (CGR) was calculated by using the following formula:

$$CGR = b \times 100$$

Standard error (SE) of CGR was calculated by using the following formula:

$$\text{SE of CGR} = 100 \times \text{SE (b)}$$

Test of significance

$$t_{cal} = \frac{\text{Compound growth rate (CGR)}}{\text{Standard error (CGR)}}$$

The t_{cal} values for CGR were compared with t_{table} values at error degree of freedom and at two levels of significance *viz;* 0.01 and 0.05. t_{cal} value greater than t_{table} values were marked as significant and single asrerix (*) were placed on those value which were significant at 1 per cent level of significance and double asrerix(**) were places on those values that were significant at 5 per cent level of significance. Compound growth rate (CGR) was calculated by using SPSS (statistical package for social sciences) statistical software.

Cobb-Douglas production function: The elasticity of inputs/factor used in the production of mango was worked out by fitting Cobb-Douglas production function given by Charles Cobb and Paul Douglas (1928). Cobb-Douglas production function was fitted on the basis of higher value of R^2, theoretical plausibility of sign and magnitude of parameter estimate and severity of multicollinearity. The following variables were used in order to determine the factors affecting the yields of hundred mango trees.

$$Y = aX_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} u_i$$

Log-log equations

$\text{Log}\, Y = \text{Log}\, a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + \log u_i$

Y = Yield (Qtl/ha.), X_1= Farm yard manure (Kg/ha.),

X_2= Fertilizer (Kg/ha.), (Kg/ha). X_4= Human labor expenditure (Man days)

u_i= Stochastic error term, a = Intercept, b_1 to b_4 are the elasticity coefficients

Adjusted coefficient of multiple determination: Adjusted R^2 is a modified version of R^2 that has been adjusted for the number of predictors in the model. Adjusted R^2 adjusts the statistic based on the number of independent variables in the model. That is the desired property of a goodness-of-fit statistic. The adjusted value of R^2 is calculated as follows (Gujarati et al 2012).

$$\overline{R}^2 = 1 - (1 - R^2)\frac{n-1}{n-k}$$

Where, R^2 = Coefficient of multiple determination, n = Number of sample observations

k = Number of parameters estimated, R^2 = Adjusted R^2

Test for overall significance of regression: 'F' test has been used to test the overall significance of explanatory variables whether they affect the dependant variable or not. The expression for the test is as under (Gujarati et al 2012).

$$F(k-1, n-k)df. = \frac{R^2}{1-R^2}\frac{n-k-1}{k}$$

Resource-use efficiency: To ensure maximum profit and efficiency of resources, a cashew farmer must utilize resources at the level where their marginal value product (MVP) is equal to their marginal factor cost (MFC) under perfect competition (Tambo and Gbemu, 2010). The efficiency of a resource would be determined by the ratio of MVP of inputs (based on the estimated regression coefficients) and the MFC.

where, $$r = \frac{MVP}{MFC}$$

$$MVP_{xi} = \left\{ \beta_i \frac{\bar{y}}{\bar{x}_1}(P_y) \right\}$$

Here,

MVPi = Marginal value product of the ith input,

y = Geometric mean of output

x_i = Geometric mean of input

β_i= Estimated coefficient (or) elasticity of the i^{th} input,

I = 1, 2, 3 …n

P_y= Price of mango (Rs/qtl.)

The relative percentage change in MVP of each resource was required to obtain optimal resource allocation estimated:

$$D = \left(1 - \frac{MFC}{MVP}\right) \times 100$$

Where, D is the absolute value of percentage change in MVP of each resource.

The decision rule for the efficiency analysis is if:r = 1; resource is been used efficiently

r >1; resource is under-utilization and increased utilization will increase output.

r <1; resource is over utilized and reduction in its usage would lead to maximization of profit.

Returns to scale are estimate by the sum of the elasticity of the various inputs. The decision rule for the return to scale is that if:

$\Sigma\beta_i$ = 1, implies constant returns to scale, $\Sigma\beta_i$< 1, implies decreasing returns to scale, $\Sigma\beta_i$> 1, implies increasing returns to scale

Significance of efficiency ratio

H_0 = resources are efficiently used, H_1 = resources are inefficiently used

t statistic was used to compare with significant t table value at 0.05 level of probability.

The various problems associated with the production and marketing of mango crop it is assumed that the extent of a particular problem varies from place to place and farmer to farmer.

Chi-square test: To test the significant difference for the problems among different farms, Chi-square test was used (Rana and Singhal 2015).

The detail of approximate Chi-square test is given as under:

$$\sum_{j=1}^{L}\sum_{i=1}^{K}\frac{(O-E)^2}{E} \sim \chi 2(L-1)(K-1)d.f.$$

Where, O= Observed values, E=Expected values, K= Number of problem, L = Number of farm size groups

The study is based on the data collected for one year only i.e. 2018-2019, which may not essentially hold true for other periods as well. The data were collected by survey method through personal interview with the sample farmers. Generally, the farmers were not maintaining the proper farm records and estimates were provided by the recall memory. However, sincere efforts have been made to elicit accurate and reliable information as far as possible by cross questioning. The degree of discrepancy, if any, would be negligible as the estimates presented are in averages.

RESULTS AND DISCUSSION

Status of mango production in India and Himachal Pradesh: The area under total fruits has increased from 182.44 thousand hectare to 230.85 thousand hectare during the period 2003-04 to 2018-19 (Table 1). The area of total fruits in Himachal Pradesh was increased at 1.60 per cent per annum, during last 15 years. The area under mango cultivation in the state is 42.41 thousand hectares which accounts for 18.19 per cent of total area under fruits in H.P and producing 37.62 thousand metric tons of mangos which is 8.79 per cent of total fruit production of Himachal Pradesh. Area under total fruits was increasing significantly, but production and productivity was not increasing significantly. In mango, area was increasing at the rate of 1.00 per cent per annum but productivity has shown negative growth during this period, which indicates the poor management of mango orchards in the state. Moreover the procurement price for the crop under market intervention scheme is also low with limited number of procurement centers and processing units in the mango growing areas. The maturity of the crop coincides with the onset of rainy season which results in the low yields. The yield has fluctuated over the years due to its alternate/irregular bearing habit. Mango productivity cannot be determined based on a single year's data and must be based on an average of at least five years. Furthermore, when compared to other tropical and subtropical fruits, mango yield is generally low.

Socio- economic characteristics of mango growers: The demographic profile is given in Table 2. The family labour-based occupation at the village level influenced the size and structure of the sampled farmers' families. The size and structure of the family among the sampled households has a significant impact on farm production. These factors determine the family's socioeconomic well-being, which is important in farm business and marketing activities. The average size of land holding per sampled households was found to be 2.26 hectare. The orchard and cultivated area occupied 24.70 per cent and 58.47 per cent, respectively. Net sown area was 1.88 ha out of which 1.18 ha area under mango cultivation i.e. mango is major fruit crop in the study area. The change in per cent share of area under different crops in the gross cropped area has revealed the extent of agriculture diversification on sample farms.The cropping intensity was 126.59 percent, indicating that farm efficiency could be improved lower cropping intensity is due to the maximum area under fruit crop, which accounted for more than 50 per cent of gross cropped area.

Production function and resource use efficiency: Production function merely provides general indication of overall productivity of mango orchards. Therefore, it tried to identify the factors affecting the mango production as a part of the study using high precision methods and measures of resource use with the help of production function analysis (Table 3). The Cobb- Douglas production function was used and the appropriate functional form was chosen based on the value of R^2, the theoretical plausibility of the sign and magnitude of parameter estimates, and the severity of multicollinearity. The farm yard manure, fertilizers and plant protection chemicals were identified as the main factors affecting the productivity and production of mango. It was hypothesized that farm yard manure, chemical fertilizers, and plant protection chemicals has positive impact on the productivity of mango crop

Wagale et al (2007), Sharma and Kumar (2019) also observed that FYM and fertilizer has positive impact on productivity of kinnow and mango crop R^2 was 0.94, indicating that the explanatory variable explained 94 per cent of the variation in the model. The sum of the elasticity coefficient (bi) was 1.01, indicating increasing returns to scale and cultivators are operating under sub optimal level, to increase the use of input level has to achieve the profit

Table 1. Trends in area, production and productivity of total fruits and mango in Himachal Pradesh

Year	Total fruits			Mango		
	Area (000'ha)	Production (000' MT)	Productivity (MT/ha)	Area (000'ha)	Production (000'MT)	Productivity (MT/ha)
2003-04	182.44	559.98	1.18	35.14	22.11	0.63
2004-05	186.90	692.01	2.61	36.21	59.73	1.65
2005-06	191.67	695.52	3.07	37.4	63.09	1.69
2006-07	197.45	369.10	3.70	38.37	40.15	1.05
2007-08	200.50	712.84	3.63	37.84	29.25	0.77
2008-09	204.63	628.08	1.87	38.44	38.75	1.01
2009-10	208.15	382.24	3.56	38.68	24.16	0.62
2010-11	211.30	1027.82	3.07	39.19	31.46	0.80
2011-12	214.57	372.82	1.84	39.56	28.97	0.73
2012-13	218.30	555.71	4.86	39.92	50	1.25
2013-14	220.71	866.34	1.74	40.29	25.4	0.63
2014-15	224.35	751.94	2.55	41.10	47.61	1.16
2015-16	226.80	928.83	3.93	41.52	37.62	0.91
2016-17	228.75	825.78	3.60	41.79	42.62	1.01
2017-18	230.85	565.30	2.44	41.98	31.35	0.74
2018-19	232.13	495.36	2.13	42.24	43.54	1.03
CGR (%)	1.60 (0.10)	1.10 (1.80)	1.20 (2.10)	1.10* (0.10)	0.10 (1.80)	-1.10 (1.70)

Source: National Horticulture Board, Note: *, ** significant at 1 and 5 per cent level, respectively maximization. Similar results showed by Singh et al (2018). FYM and plant protection chemical were positive and statistically significant and which was in line with Ali et al (2019). The fertilizer was also positively related with the output and was highly significant. Chand et al (2017) also mentioned similar result. The 1 per cent change in FYM and fertilizer; will change yield by 0.39 and 0.48 per cent, respectively. The elasticity coefficient for human labour showed that one per cent increase would result 0.16 per cent decrease in the yield. This indicated irrational use of this inputs by the mango growers. This may be due to the availability of sufficient farm labour and strong financial power to hire more labour and similar results showed by Ali et al (2019).

Table 2. Farm specific characteristics of sampled households

Particulars	Value
Number of the family	80
Joint family (%)	43.75
Nuclear family (%)	56.25
Average family size (No.)	5.28
Male (%)	52.60
Female (%)	47.40
Sex ratio	901.14
Literacy rate (%)	93.90
Literacy index	2.81
Agriculture (%)	74.61
Service (%)	16.89
Business (%)	8.50
Average No. of workers	4.26
Average No. of dependents (< 14yrs &>65)	1.02
Dependency ratio w.r.t family size	0.19
Average cultivated area (ha)	0.55
Average orchard area (ha)	1.33
Average area under mango (ha)	1.18
Gross cropped area	2.38
Net sown area	1.88
Total land holding (ha)	2.26
Cropping intensity (%)	126.59

Table 3. Estimated production function for mango cultivation

Particulars	Coefficients	Standard error
Intercept	0.47	0.08
FYM	0.39**	0.11
Fertilizer	0.48*	0.11
Plant protection	0.14**	0.06
Labour	-0.16	0.10
$\sum_i^b$	1.01	
R^2	0.94	
F	416.67	
Adjusted	0.93	

Note: * and ** significant at 1 and 5 per cent level

Resource use efficiency: Resource use efficiency determines the efficiency with which a resource is used as mandated by its economically optimal level. When efficiency ratio is less than one, the resource is over utilized; when the ratio is greater than one, the resource is underutilized.

The MVP to MFC ratio is greater than one which indicates that the farmers are underutilizing the resource (Table 4). The efficiency ratio for FYM was (2.08) followed by fertilizers (1.39) and plant protection chemical (1.07) being was positive and greater than unity which means under utilization of resources and in usage would lead to profit maximization. Wagaleet al (2007) and Sharma and Kumar (2019) also observed that FYM and fertilizers was greater than unity indicating that these inputs were under-utilized and is due to the absence of technical knowledge. Farmers don't have proper knowledge about the particular disease affecting the crop. Labour however had a negative coefficient (-1.46) Efficiency ratio for human labour (-1.46) was less than unity which indicates that there was a need to reduce the use of human labour to get the optimum level of output. Wongnaa and Ofori (2012) obtained similar results for human labour. The adjustment in the MVPs for optimal resource use indicates that for optimum allocation of resources more than 51. 92 per cent increase in FYM was required, while approximately 28.06 per cent increase in fertilizer was needed. Similarly, over 6.54 per cent increase in plant protection chemical was needed. Human labour was over utilized and required approximately 168.49 per cent reduction for optimal use in mango production. Eze et al (2010) obtained similar results for human labour.

Constraints faced by mango growers: Due to wide fluctuation in prices, high wage rates, lack of technical knowledge, non-arability of healthy plant material, spurious chemicals and lack of irrigation and storage facilities, growers faced many problems in production and marketing (Table 5). The problems were categorized in two subgroups viz; production related problems and marketing related problems. Shortage of skilled labour and lack of technical knowledge were also intimated by more than 31 per cent and 33 per cent, respectively, High rates of chemicals were considered as the main problems by 31.25 per cent of average sampled farmers and small farmers were worst hit by these problems than the medium farm farmers. Irrigation is one of the critical inputs which directly affect the productivity of mango. 33.75 per cent of the farmers reported lack of irrigation facilities in the study area. Majority of the growers reported that they remain unaware of exact information in respect of prices and supply available in different markets. The 53.75 per cent of the farmers in the study area reported the wide fluctuations in the price of mango as a major problem. The information regarding the market demand, arrival and prices prevailing in the market are very important as the same can affect the income of the growers. Mango produce being perishable, require immediate disposal. Due to lack of cool chain system, huge losses are borne by the participants of marketing process. The 43.75 per cent of the farmers face the problems of non-availability of storage facilities in the market. The producers got the inadequate and misleading in formations about the market prices spread showed by the market functionaries. Lack of proper transportation facility was significant in the study area as revealed by significant chi-Square value (6.06). These results are similar with those of Bharamappanavara et al (2013) and Sharma (2019).The Chi square test was also used to determine whether the problems identified by mango growers are farm category specific or farm category independent. Among these production problems, shortage of skilled labour and higher wages rates pointed out the mango growers differ significantly between the different farm categories. In case of marketing problems, lack of market information and harassment by middleman differs significantly in the farm categories. All other marketing

Table 4. Efficiency of resource use in mango cultivation

Particulars	Coefficients	APP	MPP	PY	MVP	MFC	r	Percent adjustment required
FYM	0.39	0.43	0.16	3500	584.50	280	2.08	51.92
Fertilizers	0.47	0.85	0.39	3500	1396.50	1000	1.39	28.06
Plant protection chemical	0.14	0.29	0.04	3500	140.00	130	1.07	6.54
Human labour	-0.16	0.92	-0.14	3500	-514.50	350	-1.46	-168.49

*APP= Average Physical Product, MPP= Marginal Physical Product, MVP=Marginal value product, MFC = Marginal Factor Cost

Table 5. Constraints faced by mango growers in the study area (Multiple response %)

Problems	Farm size				
	Marginal (35)	Small (24)	Medium (21)	Overall (80)	Chi square
Production constraints					
Shortage of skilled labour	17.14	33.33	52.38	31.25	11.78**
Higher wages rates	22.86	25.00	47.62	30.00	6.60**
Lack of technical knowledge	37.14	33.33	28.57	33.75	0.72
High Input cost	34.29	29.17	28.57	31.25	0.55
Desired brand not available	25.71	29.17	33.33	28.75	0.64
Non availability of healthy plant material	42.86	37.50	40.00	40.00	0.23
Lack of Irrigation facility not available	31.43	33.33	38.10	33.75	0.41
Diseases management	40.00	41.67	42.86	41.25	0.07
Marketing constraints					
Fluctuation in prices	62.86	58.33	33.33	53.75	5.54
Lack of storage facility	51.43	45.83	28.57	43.75	3.93
High commission charges	37.14	37.50	28.57	35.00	0.83
Lack of transportation facilities	44.29	35.42	19.05	35.00	6.06**
Lack of market information	34.29	37.50	38.10	36.25	0.19
Markets very far-off	31.43	29.17	23.81	28.75	0.65
Delay in payments	25.71	20.83	14.29	21.25	2.06
High dominance of market intermediaries	45.71	41.67	19.05	37.50	6.57**
Lack of market facility for processed products	37.14	33.33	19.05	31.25	3.50

Note: ** significant at 5 per cent level problems do not differ significantly between the farm categories.

CONCLUSIONS

The resource use efficiency of mango cultivation has been estimated by Cobb-Douglas production function. The study has shown that FYM, fertilizers and plant protection chemicals were significantly affecting the mango production. These resources were under-utilized thus there is need for proper utilization of the resources for optimum level of output. The balanced use of these inputs by the orchardists can boost the mango productivity. Also, it was observed that the most important difficulty faced by the mango growers were shortage of skilled labour after that high wage rate, lack of transportation facilities, high dominance of market intermediaries, fluctuation in prices, etc. Mango has specific problem of alternate bearing leading many times to low yields or no yield. Short term training programs should be organized in the mango producing areas regarding the diseases management, timely application of fertilizers and insecticides and scientific methods of cultivation in order to enhance the skill of producers to maximize the net profit. Government subsidies can also help reduce the marginal input cost and hence improve efficiency. Mango production is a profitable enterprise in Himachal Pradesh and is in its mature state as depicted by positive and increasing returns to scale.

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GIS approach on Determining Domestic Groundwater Quality in Villupuram District of Tamil Nadu

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***Abstract*:** An investigation was conducted using the secondary data to identify the domestic groundwater quality through Water Quality Index (WQI) method. Piper diagram for to understand groundwater chemistry indicates mixed type of water, with the relative order of $Cl^->HCO_3>SO_4^{2-}$ for anions and $Na^+/K^+>Mg^{2+}>Ca^{2+}$ for cations. Pearson Correlation Coefficient technique were adopted to find out the relationship between the water quality parameters were identified positive correlation between $HCO_3^- – F^-$ during pre-monsoon and with Na^+ - pH and K^+ - pH during the post-monsoon season at a significant level of 0.01. The WQI results revealed that 52 percent of samples during pre-monsoon and 40 percent in post-monsoon are under the excellent category during the study period. About 9 and 16 percent of samples fall under poor quality during the study period. The quality of groundwater for domestic purposes in the study area is slowly changing its original quality.

***Keywords*:** WQI, Correlation, Piper plot, Na, GIS

Groundwater quality is one of the important components that need to be a concern for domestic as well as agriculture. Surface and groundwater is the only source for drinking and other activities in arid and semi-arid regions of India (Sakram and Adimalla 2018). The quality of water is mainly distorted by geology and anthropogenic activities as well (Vinothkanna et al 2021a). Jalali (2011) reveals that the quality of water in many countries has getting deteriorated in past few years. In India, one of the hectic problem is groundwater pollution due to unintended drainage facilities, applying a large number of fertilizers in the agricultural field, over-exploitation of groundwater, *etc*. The quality of water once lost its original chemical composition is very difficult to restore to its original content (Vinothkanna et al 2020a) and can be identified using geochemical studies (Kumar et al 2016). Geochemistry of water determines the suitability of groundwater for domestic as well as irrigation purposes (Kumar et al 2014, Vinothkanna et al 2021b). Particularly, in the case of drinking water purpose, the quality of water should be at the standard level prescribed by the Bureau of Indian Standards (BIS) or World Health Organization (WHO) otherwise it leads to human health problems. Assessing water quality using the Water Quality Index (WQI) method is an efficient tool because it integrates multiple water quality parameters (Jamshidzadeh and Barzi 2018). Many studies in Tamil Nadu used WQI to determine the quality of water (Vinothkanna et al 2016 for Namakkal district; Karthikesan et al 2019 for Nagapattinam district). For the past few decades; there is a tremendous increase in population as well as urbanization (Adimalla et al 2018). So the demand for fresh water is increasing rapidly. Hence, quality studies getting important to understand the groundwater chemistry in any study area. Therefore an attempt has been made in this study to know the quality of groundwater in Villupuram district of Tamil Nadu. GIS (Geographic Information System) is a widely used tool for mapping and monitoring spatial data and it will act as a decision support system for fast management activities.

MATERIAL AND METHODS

Study area: Villupuram district extends between 11°30' to 12°35' north Latitude, and 78°37' to 80°00' east longitude (Fig. 1). The normal annual rainfall of the district is 1029.4 mm and the district receives maximum rainfall during the northeast monsoon season followed by the southwest monsoon season. The total geographical area of the district is 7190 sq/km and experiencing a semi-arid tropical climate.

Geologically the district is underlain by crystalline metamorphic complex and sedimentary tracks in the western and eastern sides respectively. The majority of the area is covered by metamorphic crystalline rocks. Red loam and clay loam are the dominant soil group and paddy is the major crop cultivated in the study area. As per the 2011 census, the total population of the district is 34, 58, 873 people with a population density of 481 people / sq.km.

Methods: The secondary data collected from State Ground and Surface Water Resource Data Centre, Tharamani, Chennai were used for drinking water quality analysis. Out of 107 sample wells, 97 common wells found in pre and post-monsoon season were identified and used for this analysis. To determine the groundwater quality, ten parameters were considered (Table 1). Weight has been given based on the importance of the quality parameter, and relative weight of respective parameters were computed using a weighted arithmetic index method.

The Pearson Correlation technique has been used to find out the relation between each water quality parameter using R. The values are attributed to GIS (Geographic Information System) tool and interpolation technique mainly IDW (Inverse Distance Weight) were used to show the map spatially. Finally, WQI (Water quality Index) is calculated based on BIS standards.

Table 1. BIS standards, weight and relative weight for each parameter

Chemical parameters	BIS standards	Weight (Wi)	Relative weight
pH	8.5	3	0.103
TDS	500	5	0.172
SO_4^{2-}	200	3	0.103
Cl^-	250	3	0.103
Na^+	200	3	0.103
K^+	12	1	0.034
Ca^{2+}	75	2	0.069
Mg^{2+}	30	2	0.069
F^-	1	5	0.172
		Σwi=27	ΣWi = 1.00

Water Quality Index (WQI) = Σqiwi

Where qi (water quality rating) = 100 X (Va-Vi) / (Vs-Vi), Va = actual value present in the water sample, Vi = ideal value (0 for all parameters except pH and DO which are 7.0 and 14.6 mg l^{-1} respectively). Vs = standard value. Wi (unit weight) = K/S_n

K (constant) =1

1/Vs1 + 1/Vs2 + 1/Vs3 + 1/Vs4…….. + 1/Vsn

S_n = 'n' number of standard values.

Mechanism controlling groundwater chemistry: Piper trilinear diagram for plotting water quality data is simple and easy to identify water types. The diamond shape indicates that the study area is dominated by the mixed type of water that is mixed Ca^{2+}-Mg^{2+}-Cl^- type followed by Ca^{2+}-HCO_3^- type. It generally denotes that no one cation-anion pair exceeds 50%.

Cations that constitute Mg^{2+}, Ca^{2+}, Na^+ and K^+ are on the left side and anions comprise Cl^-, SO_4^{2-}, CO^3 and HCO_3^- is on the right side of the triangle. The cations clearly define that no dominant type of water is present in the study area (Fig. 2). Na^+/ K^+ >Mg^{2+} > Ca^{2+} is the relative order for cations and for anions Cl^->HCO_3^->SO_4^{2-}. Anions clearly portray that chloride type of water is dominated followed by bicarbonate type in both monsoon seasons.

RESULTS AND DISCUSSION

pH and TDS: The pH is 7.80 and 7.85 during pre and post-monsoon respectively indicates pH value in the study area is under permissible limit and alkaline in nature. The 99 and 100 percent of samples are under the permissible limit in pre and post-monsoon season respectively. The concentration of TDS during pre-monsoon is varied from 115 to 2890 mg l^{-1} with a mean of 1502.5 mg l^{-1} and for the post-monsoon

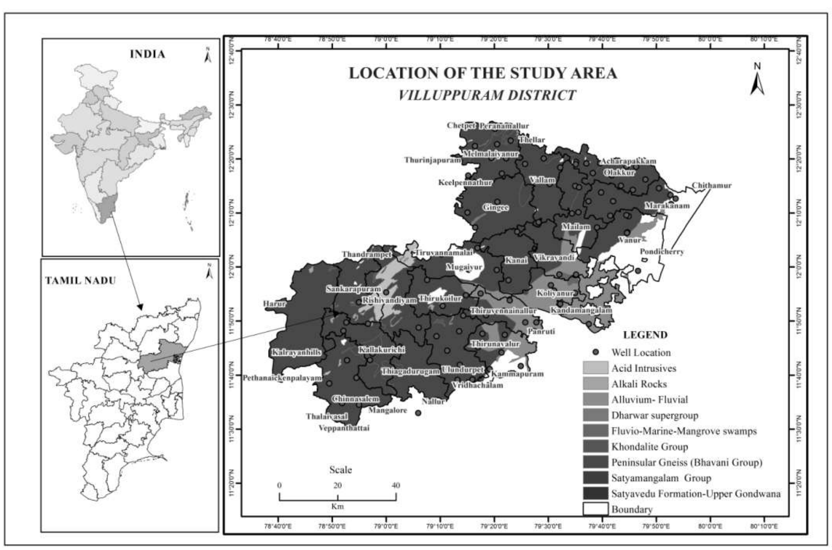


Fig. 1. Location of the study area

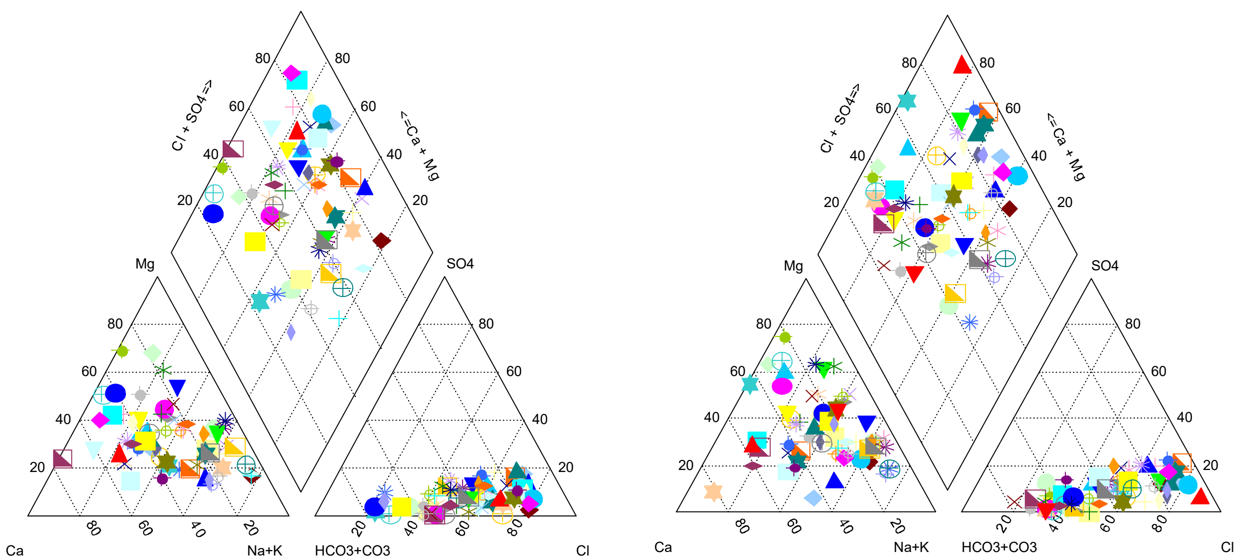
season, the value is varied from 88 to 3271 mg l^{-1} with a mean of 1679.5 mg l^{-1}. There are 27 samples (27 %) that are under the not permissible limit in both monsoon seasons.

Mg^{2+} and Ca^{2+}: The mean value of calcium is 224 and 148 mg l^{-1} in pre and post-monsoon season respectively. Generally, in natural surfaces both calcium and magnesium are found abundant (Prasanth et al 2012) which is mainly found in silicate rocks and dolomite deposits (Sharma et al 2016). The mean value of magnesium is 80.19 and 74.11 mg l^{-1} with 8 and 6 samples are not permissible during pre and post-monsoon season respectively.

Na^{+} and K^{+}: Sodium is varied from 2 - 761 mg l^{-1} and 1 - 812 mg l^{-1} with a mean of 381 and 406 mg l^{-1} having 26 and 19 percent of samples are not permissible in pre and post-monsoon seasons respectively. The mean potassium is 18 and 123 mg l^{-1} with 13 and 9 percent of samples are under not permissible limit during pre and post-monsoon season respectively.

Cl^{-} and SO_4^{2-}: The mean value of chloride is 569 and 728.5 mg l^{-1} with 60 and 57 percent of samples are under the desirable limit during pre and post-monsoon season respectively. With respect to Sulphate, 99 percent of pre-monsoon samples and 96 percent of post-monsoon samples are under the desirable limit as per BIS standards over the study area.

F^{-} and HCO_3^{-}: Fluoride and bi-carbonate in the study area are under the permissible limit in both monsoon seasons. The mean value is 0.79 and 0.85 mg l^{-1} for fluoride and 381 and 378 mg l^{-1} for bi-carbonate for pre and post-monsoon seasons respectively.



a) Pre Monsoon

b) Post Monsoon

Fig. 2. Piper diagram for pre and post-monsoon seasons

Table 2. Water quality parameters

Category	Parameters	Pre-monsoon			Post-monsoon		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
General	pH	7.2	8.4	7.8	7.1	8.6	7.8
	TDS	115	2890	1502.5	88	3271	1679.5
Anions	Mg^{2+}	2.4	157.9	80.1	4.8	143.3	74.1
	Ca^{2+}	16	432	224	16	280	148
	Na^{+}	2	761	381.5	1	812	406.5
	K^{+}	0.1	35	17.5	0.1	246	123.0
Cations	Cl^{-}	11	1127	569	25	1432	728.5
	SO_4^{2-}	1	270	135.5	1	266	133.5
	F^{-}	0.05	1.5	0.7	0.05	1.65	0.85
	HCO_3	61	701.5	381.2	24.9	732	378.4

The summary of water quality parameters such as minimum, maximum and mean values are shown in Table 2 and their classifications on BIS standards are shown in the Table 3. The spatial distribution of WQ parameters which are under not permissible limit are shown in Figure 3.

Correlation analysis: The physico-chemical parameters of waters are correlated using the Pearson correlation coefficient technique. A significant positive correlation was identified between HCO_3^- – F^- during pre-monsoon and with Na^+ - pH and K^+ - pH during the post-monsoon season. There is a significant negative correlation between pH - TDS, SO_4^{2-} - pH, F^- - Ca in the pre-monsoon season and there is no negative significant correlation during the post-monsoon season. The graphical diagram portrays the bivariate scatter plot with a fitted line in the bottom of the diagonal and values of correlation and its significance as a star in the upper diagonal (Figure 4 & 5).

Groundwater quality index: The quality of groundwater is classified into 5 categories based on the index value (Vinothkanna et al 2020b). During the study period, 52 percent of samples from pre-monsoon and 40 percent in post-monsoon are under the excellent category which is

Table 3. Water quality parameters based on BIS standards

Parameters	Classification on BIS standards	Water classes	Post-monsoon season		Pre-monsoon season	
			Total wells	%	Total wells	%
pH	< 8.5	Desirable	96	98.97	97	100.00
	>8.5	Permissible	1	1.03	Nil	---
TDS	<500	Desirable	29	29.90	30	30.93
	500-1000	Permissible	41	42.27	40	41.24
	>1000	Not Permissible	27	27.84	27	27.84
Mg^{2+}	<30	Desirable	17	17.53	19	19.59
	30-100	Permissible	72	74.23	72	74.23
	>100	Not Permissible	8	8.25	6	6.19
K^+	<20	Permissible	84	86.60	88	90.72
	>20	Not Permissible	13	13.40	9	9.28
Ca^{2+}	<75	Desirable	57	58.76	63	64.95
	>75	Permissible	40	41.24	34	35.05
Na^+	<200	Permissible	72	74.23	79	81.44
	>200	Not Permissible	25	25.77	18	18.56
SO_4^{2-}	<200	Desirable	96	98.97	93	95.88
	>200	Permissible	1	1.03	4	4.12
Cl^-	<200	Desirable	58	59.79	55	56.70
	>200	Permissible	39	40.21	42	43.30
F^-	<1	Desirable	87	89.69	88	90.72
	>1	Permissible	10	10.31	9	9.28
HCO_3^-	<200	Desirable	49	50.51	45	46.39
	> 200	Permissible	3	3.09	3	3.09

Table 4. Groundwater quality index for Villupuram district, 2018

WQI	Water class	Pre-monsoon season		Post monsoon season	
		Total well	%	Total well	%
< 50	Excellent	50	51.54	39	40.20
50-100	Good	38	39.17	42	43.29
100-200	Poor	9	9.27	16	16.49
200-300	Very poor	-	-	-	-
> 300	Unfit for drinking	-	-	-	-

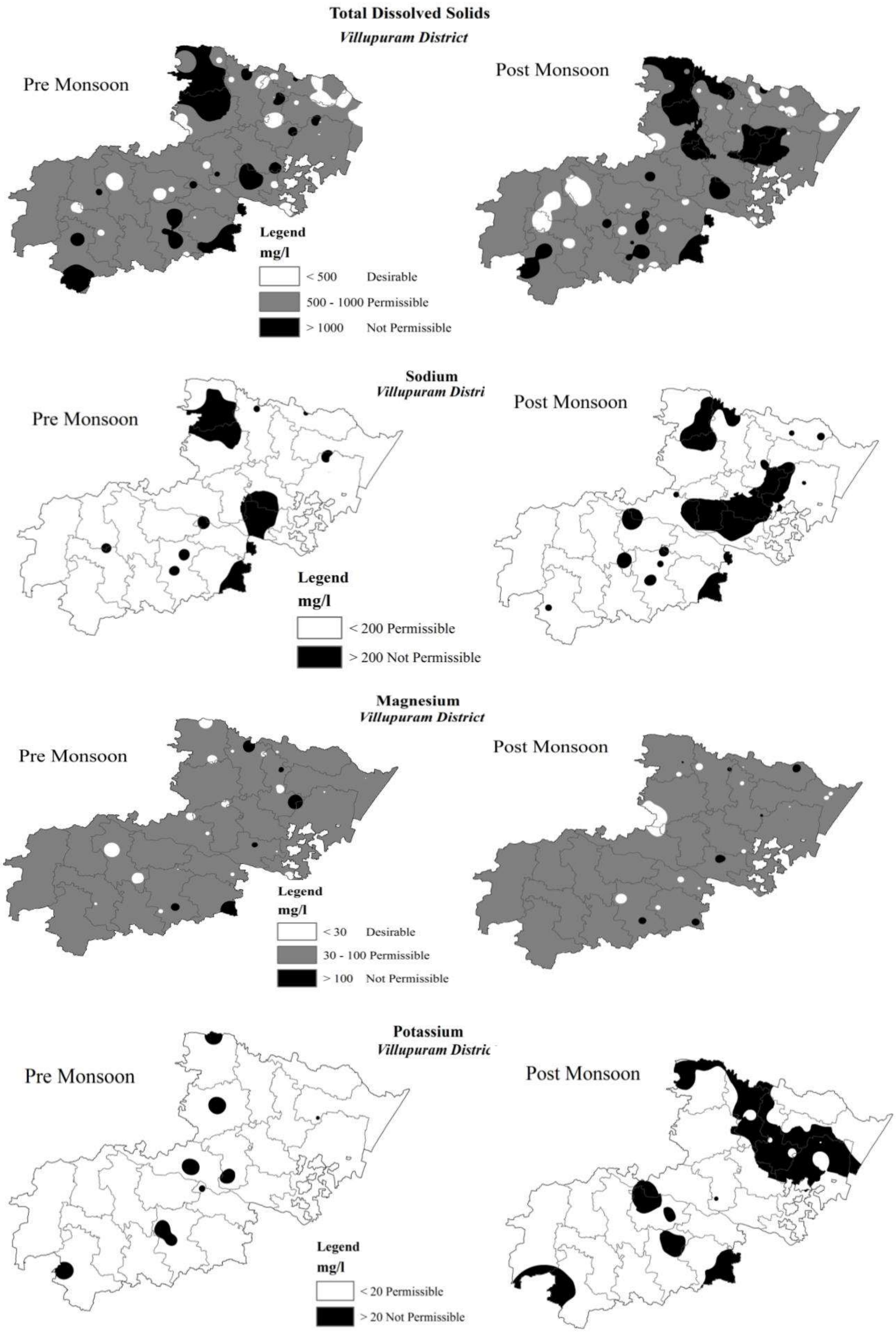


Fig. 3. Spatial distribution of WQ parameters under not permissible limit

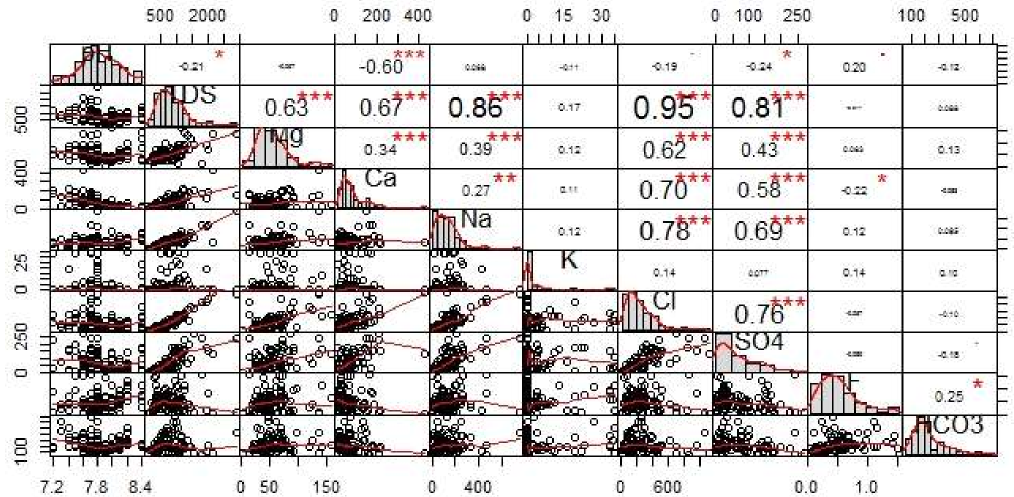


Fig. 4. Correlation plot for pre-monsoon season-2018

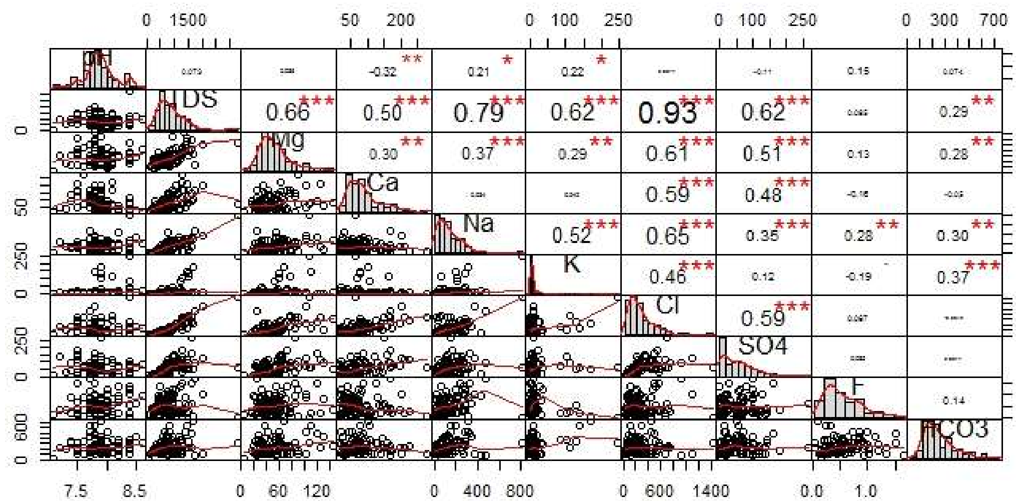


Fig. 5. Correlation plot for the post-monsoon season - 2018

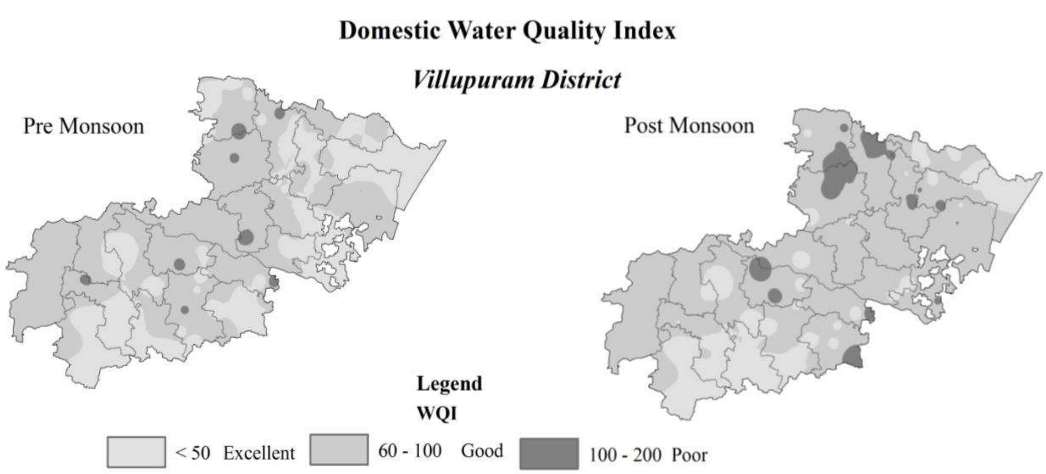


Fig. 6. Domestic water quality index - 2018

spatially distributed in the eastern part of the study area. Among the samples, 38 samples (39%) and 42 samples (43%) are under the good category during pre and post-monsoon season respectively.

The good category is spatially distributed in the entire district mainly over the western and central part of the study area in both monsoon periods. Only 9 samples in pre-monsoon and 16 samples in post-monsoon season are under poor quality for drinking purposes which are spread mainly over the northwestern and in central part as a patch over the study area (Table 4). There are no samples that fall under the very poor and unfit for drinking category during the study period over the study area (Fig. 6).

CONCLUSION

The present study evaluates the domestic groundwater quality in Villupuram one of the coastal district of Tamil Nadu. The groundwater quality parameters were determined based on BIS standards and WQI was identified. Results suggested that the quality of groundwater over the study area is excellent for domestic purposes. The use of the GIS tool for producing spatial maps is a useful technique for water quality studies. Even though the study area is safe for domestic purposes it is necessary to maintain its quality being it is near to the coastal area, speeding of natural weathering process due over exploitation of groundwater. The intrusion of saltwater may increase the salinity in groundwater. The people should have a responsibility to retain their original quality by doing proper waste management practices, avoid boreholes near coasts, etc.

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Comparison of ANN & RSM Approaches for Optimum Production of γ-Decalactone

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Abstract: γ-Decalactone is an important flavor compound widely used in food, diary and fragrances. Previously it was produced from fruits through chemical synthesis. Due to increase in demand for natural products by consumers, it has gained interest for its production through biotechnological way. The present study focusses on fermentation variables optimization for the production of γ-decalactone using *Sporidiobolus salmonicolor* via Response surface methodologies (RSM) and Artificial neural networks (ANN) using castor oil as substrate. The prediction abilities of RSM and ANN were compared based on error parameters namely Mean absolute error (MAE), Root mean square error (RMSE), chi-square (χ^2) and correlation coefficient (R^2) to suggest the best approach for modeling. The response variable (γ-decalactone production) was modelled and optimized as a function of four input variables (castor oil percentage, pH, incubation time and temperature). Training of ANN network was performed using a multilayer feed forward architecture with same experimental datasets used in RSM. Model predictions of both approaches were compared with the experimental values and reported that these are in good close agreement. The highest production of γ-decalactone 72.73 mg/l obtained at an optimum conditions of castor oil -29.68 %, pH -5.32, incubation time -99.89 h and temperature -23.22^{0}C. Hence, results were beneficial in using appropriately trained ANN over RSM for nonlinear fermentation systems.

Keywords: RSM, ANN, Fermentation, γ-decalactone and *Sporidiobolus salmonicolor*

γ-Decalactone is an important industrial flavour compound with a peachy aroma. It is approved as a food additive by FDA (Hamideh et al 2013). It has been widely used in dairy products, food, fragrances and beverages (Adelaide et al 2016, Jung-Ung et al 2013) and was produced from fruits through chemical synthesis, however, due to the increase in demand for natural flavors and has gained interest in producing through biotechnological processes using microorganisms (Dayana et al 2017). It is highly toxic for the microorganisms used for its production and accumulation in the medium depends on the difference between the formation and consumption rates by the yeast cells since lactones are toxic to the producing cells. In the last two decades, researchers have focused on the selection of suitable yeast strains, substrates, preliminary optimization of fermentation conditions, β-oxidation metabolic pathways, use of different mutant strains and mode of fermenter operation to enhance growth and production of γ-decalactone (Dayana et al 2017, Jolanta et al 2020, Eko et al 2020). However, there are few reports on the statistical optimization of fermentation conditions for γ-decalactone production. The aim of this work is to enhance γ-decalactone production and optimization of fermentation variables using statistical methods.

Castor oil is one of the main substrates used to produce γ-decalactone and it contains 86% of ricinoleic acid (Cao et al 2014, Dayana et al 2017). The ricinoleic acid transforms into γ-decalactone by yeast cells through the β-oxidation pathway (Adelaide et al 2016). The main limitation of industrial process development is lactone toxicity towards growing yeast cells. After a few hours of batch fermentation, yeast cells consume decalactone as a carbon source when a substrate is completely exhausted. Thus, results in a lower yield of γ-decalactone. One factor at a time (OFAT) method is laborious, time taken, unable to predict interaction effects and rarely guaranties the estimation of optimum conditions. The limitations of OFAT can overcome with the help of empirical methods, namely, RSM and ANN, in which levels of all desired factors can be varied simultaneously. RSM has been widely used in the medium optimization for fermentation systems (Suganthi et al 2015, Taswar et al 2017). RSM is a combination of several statistical techniques applied for model development, experimental design, determination of the influence of factors, and finding optimum values (Kalil et al 2000). The output responses in RSM are fitted according to second order polynomial equations. Thus, RSM can be considered to be the best choice for fermentation systems optimization. Recently, ANN has also been developed as an effective method for modeling of nonlinear systems due to its ability to learn from historical data and genetic structure (Kiran et al 2005). ANN does not need a predefined fitting function. It has the characteristics of universal approximation (Kiran et al 2008). Moreover, ANN provides better sensitivity analysis than RSM. The major objective of the present study was to maximize γ-decalactone production by *Sporidiobolus salmonicolor* using castor oil as substrate and to analyze modelling efficiencies of RSM and ANN for optimum production of γ-decalactone.

MATERIAL AND METHODS

Inoculum and culture conditions : *Sporidiobolus salmonicolor* (MTCC No. 485) was obtained from IMTECH, Chandigarh, India. It was rejuvenated on YM agar media at 30^0C for 2 days. A 3 ml of grown suspension was taken aseptically to a Erlenmeyer flask (250 ml) consists of 100 ml fermentation medium (castor oil-30 %, NH_4Cl-3 g/l, $CaCl_2.2H_2O$-1 g/l, KH_2PO_4-2 g/l, Tween 80-1 g/l, $FeSO_4.7H_2O$-0.5 g/l and $MgSO_4.7H_2O$-1 g/l) and incubated in rotating shaker at 180 rpm and 30^0C for 18–19 h until the cells enter the late exponential phase to obtain 10^6-10^7 cells/ml.

Biomass estimation: The biomass concentration was determined with the help of Neubauer's improved counting chamber method (Recombigen Laboratories, New Delhi) (Mather and Roberts 1998). The methylene blue method was used for estimating the viability of cells (Angelo and Donatella 1982).

Extraction and analysis of γ-decalactone: To estimate the lactones in the grown culture followed the method described by (Nelma et al 2011) after centrifugation, 2 mL of supernatant was taken and pH was varied to 2 with 1 N HCl. The lactone extraction was done with 2 ml of diethyl ether through sixty gentle shakings. After the partition of liquid phases, the diethyl ether phase was isolated and examined by gas chromatography (Analytical Technologies Limited, Baroda, India; model: GC2979 Plus) with a capillary column (300mmx280mmx270mm) using a helium carrier gas. The temperatures of the split injector and detector were set as 250^0C and 300^0C, respectively. The oven temperature varied from 60^0C to 145^0C at a rate of 5^0C/min and 145^0C to 180^0C at 2^0C/min.

RSM modeling: In previous studies, Plackett-Burman experimental design was performed to screen influential parameters on γ-decalactone production. Among eleven factors screened, five factors such as castor oil percentage, pH, incubation time, inoculum size and temperature had shown most influential effect on γ-decalactone production (Venkata Narayana et al 2019). However, inoculum size was eliminated due to a high p-value and less standard effect. Thus, the remaining four factors were considered for further optimization using RSM and ANN in this study. RSM based central composite design was adopted to determine the optimum values of screened parameters for γ-decalactone production. The parameters were designated as castor oil percentage (X_1), pH (X_2), incubation time (X_3) and temperature (X_4) (Table 1). The central values allocated for screened parameters based on preliminary experiments of OFAT were castor oil 30 %, pH 5, incubation time 100 h, and temperature 22.5^0C. In CCD, design of experiments was planned with four variables and each in five levels (-2, -1, 0, 1, 2) (Table 2). A total of thirty triplicate experimental runs were conducted in a randomized order, of which sixteen cube, eight axial and six center points as per CCD. The input variables were coded as per the equation (1) (Jamil et al 2018)

$$x_i = \frac{X_i - X_0}{\Delta X_i} \qquad (1)$$

where x_i denotes the coded form of input variable X_i and X_0 is the real value of input variable at the center and ΔX_i is the increment.

The process efficiency was estimated by analyzing the output response variable (Y) in relation to the input variables as represented by equation (2) (Jamil et al 2018)

$$Y = f(X_1, X_2, ... X_K) + e \qquad (2)$$

Where $X_1, X_2, ...X_K$ are input variables and e is the error.

Experimental data was fitted with second order polynomial equation and model terms were evaluated with Design Expert 8.0.7.1 software. Quadratic model equation is represented as per equation (3) (Jamil et al 2018)

$$Y = \beta_0 + \sum_{i=1}^{K}\beta_i X_i + \sum_{i=1}^{K}\beta_{ii} X_{ii}^2 + \sum_{i=1}^{K-1}\sum_{j=2}^{K}\beta_{ij} X_i X_j + e \quad (3)$$

Where Y is the response (γ-decalactone production), X_i

Table 1. Independent parameters (input variables) levels and ranges used in DOE

Independent parameters	Symbol	Levels and range				
		-2	-1	0	+1	+2
Castor oil (%)	X_1	10	20	30	40	50
pH	X_2	7	6	5	4	3
Incubation time (hr)	X_3	80	90	100	110	120
Temperature (^{0}C)	X_4	17.5	20	22.5	25	27.5

and X_j are coded input variables, β_0 is intercept & β_i, β_{ii}, β_{ij} are linear, square and interactive coefficients, respectively; k represents number of factors and ***e*** is the error, which is the difference of measured and observed values.

Quadratic model performance was examined with reference to R^2, predicted R^2 and adjusted R^2. The significance of model terms was confirmed with ANOVA. Factors interaction on the response was predicted from contour plots generated from regression models.

ANN modeling: The ANN feed forward architecture was employed to develop a nonlinear model between the output variable (γ-decalactone production) and four input variables (castor oil percentage, pH, incubation time and temperature) for the same data sets used in RSM. The input player consists of four neurons (input variables), while the output layer contains one neuron (response variable). The training of ANN network was performed with TRAIN tool using MATLAB 9.2 R2017a version. The process of data occurs in the forward direction from input to the output layers. The input data were scaled up by input neurons and then transferred to hidden layer through several weights. The weighted inputs are summed up via hidden layer neurons together with bias

Table 2. CCD DOE experimental runs along with experimental and predicted values of RSM and ANN for γ-decalactone production by S*poridiobolus salmonicolor*

Run No.	Castor oil % (X_1)	pH (X_2)	Incubation time (hr) (X_3)	Temperature (°C) (X_4)	Experimental γ-decalactone production (mg/L)	Predicted γ-decalactone production (mg/L)	
						RSM	ANN
1	30	5	120	22.5	47.38	46.60	46.98
2	20	6	90	20	34.29	34.96	34.32
3	40	6	110	25	44.67	45.15	44.81
4	30	5	100	27.5	50.36	50.28	50.42
5	20	6	90	25	43.58	43.16	43.52
6	30	3	100	22.5	38.95	39.61	38.73
7	40	6	110	20	28.94	29.03	28.99
8	20	6	110	25	47.29	47.49	47.01
9	30	5	100	22.5	73.23	71.74	72.67
10	40	4	90	25	35.68	34.59	36.70
11	30	5	100	22.5	69.83	71.74	71.27
12	30	5	100	22.5	71.68	71.74	71.48
13	40	6	90	25	50.27	51.17	50.27
14	50	5	100	22.5	8.25	8.28	8.26
15	30	5	80	22.5	46.74	47.10	46.92
16	20	4	110	25	38.35	38.77	38.44
17	20	4	110	20	42.75	42.27	44.96
18	20	6	110	20	37.74	38.83	37.92
19	30	5	100	22.5	70.23	71.74	71.23
20	30	5	100	22.5	72.64	71.74	73.79
21	40	4	90	20	30.85	31.08	30.92
22	30	5	100	22.5	72.83	71.74	71.92
23	10	5	100	22.5	16.73	16.28	17.86
24	40	6	90	20	35.93	35.51	35.72
25	30	7	100	22.5	53.83	52.75	53.52
26	30	5	100	17.5	38.46	38.11	38.36
27	20	4	90	20	37.23	36.75	37.12
28	40	4	110	25	30.47	30.22	30.10
29	20	4	90	25	32.46	32.79	32.62
30	40	4	110	20	25.83	26.25	25.97

as per equation (4) (Kiran et al 2008)

$$SUM = \sum X_i W_{ij} + \theta_j \quad (4)$$

Where X_i is the input parameter, θ_j is bias and W_{ij} is connection weight.

The output-weighted sum is transferred to an activation function f (sum) as per equation (5) (Kiran et al 2008)

$$f(sum) = \frac{1}{1+\exp(-sum)} \quad (5)$$

In ANN training, predefined error in minimized by controlling the weights. The root-mean-squared error (RSME) is calculated as per the equation (6) (Kalil et al 2000)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}\sum_{n=1}^{M}(y_n^i - \widehat{y_n^i})^2}{MN}} \quad (6)$$

Here 'i' is the pattern index, N is the no. of patterns, M is the output nodes number and y^i_n & y^i_n are the target and predicted responses of n^{th} node, respectively.

Comparison of ANN and RSM model abilities: The prediction capabilities and fitness of experimental data for both models were estimated by calculating RMSE (Kiran et al 2008), MAE (Youssefi et al 2009), χ^2 (Abuzer and Faruk, 2011) and R^2 (Rajendra et al 2009) as per the equations (6) – (9). In addition, the responses generated by ANN and RSM were represented in graphs against experiments as shown in Figure 2.

$$MAE = \frac{i}{n}\sum_{i=1}^{n}\left|Y_{i,e} - Y_{i,p}\right| \quad (7)$$

$$\chi^2 = \sum_{i=1}^{n}\frac{(Y_{i,e} - Y_{i,p})^2}{Y_{i,p}} \quad (8)$$

$$R^2 = \frac{\sum_{i=1}^{n}(Y_{i,p} - Y_{i,e})}{\sum_{i=1}^{n}(Y_{i,p} - Y_{i,e})^2} \quad (9)$$

Where 'n' is no. of experiments, $Y_{i,e}$ is response for i^{th} experiment, $Y_{i,p}$ is predicted response for i^{th} experiment and Y_e is experimental average.

RESULTS AND DISCUSSION

RSM modelling: In this study, RSM modeling determines the influence of four input variables (castor oil %, pH, incubation time, and temperature) on γ-decalactone production. Thirty experimental runs were conducted using CCD, of which 16 cube points, 8 axial points and 6 central points. Model abilities were evaluated in terms of degrees of freedom, mean squares and sum of squares. RSM based CCD models were analyzed through the second-order polynomial regression equation and represented as follows

$Y = -1315.866 + 8.8486X_1 + 39.3135X_2 + 13.3129X_3 + 42.017X_4 + 0.1554X_1X_2 – 0.0258X_1X_3 + 0.0746X_1X_4 – 0.0413X_2X_3 + 1.2152X_2X_4 + 4.575E – 003X_3X_4 – 0.1486 X^2_1 + 6.3906X^2_2 – 0.0622X^2_3 – 1.101X^2_4$ (10)

Where Y is the response (γ-decalactone production), while X_1, X_2, X_3 and X_4 are castor oil %, pH, incubation time, and temperature, respectively. Equation (10) was represented in terms of coded factors and is used to compare relative influence of factors with coefficient of factors (Busra et al 2020). In this case, temperature (X_4) was the most effective factor and followed by pH (X_2), incubation time (X_3) and castor oil (X_1). Castor oil was the least influential factor.

The fitness of quadratic model was analyzed, adjusted R^2 and the coefficient of determination (R^2). The model is significant and ensures good goodness of fit. The R^2 value of 0.9978 indicates that the model explains more than 99% of data variability. The predicted R^2 of 0.9927 is in reasonably good agreement with adjusted R^2 of 0.9958 and shows the model's high significance. The significance of model terms was determined based on p-values. A Lower p-value (<0.05) refers to the greater significance of respective parameters (Busra et al 2020), X_1 (castor oil %), X_2 (pH), X_4 (temperature), X_1X_2 (interaction of castor oil % and pH), X_1X_4 (interaction of castor oil % and temperature) and X_2X_4 (interaction of pH and temperature) had shown significant effects on production of γ-decalactone. The interaction effects of input variables on the response were shown with contour plots. The oval shape represents the significant interaction between a pair of input variables. The γ-decalactone production rises as castor oil percentage varies from 20 % to 29.68%, beyond which the production decreased as an increase in the percentage of castor oil (Fig. 1) and it might be due to growth inhibition of yeast cells at high percentage of castor oil (Dayana et al 2017). As pH rises from 4.0 to 5.3, γ-decalactone production also increases up to optimum value beyond which production reduced (Dayana et al 2017). Other two variables also followed same pattern as incubation time reaches to 99.8 hr obtained highest production beyond which production decreased (Dayana et al 2017). Thus, the maximum γ-decalactone production predicted by the RSM model is 72.73 mg/L at optimum values (castor oil % -29.68, pH-5.32, incubation time-99.89 hr, and temperature-23.22^{o}C).

ANN modeling: A multilayer perception with feed forward architecture ANN model was generated, which consists of four input nodes (castor oil %, pH, incubation time, and temperature) and one output node (γ-decalactone production). The RSM DOE data and the corresponding experimental response were used to train the ANN model network. Over parameterization is avoided by grading data into training, validation and testing. ANN model was optimized to minimize the error. Training of data was performed by varying neurons in the hidden layer for different

ANN parameters combination. The optimum number of hidden layers obtained was one. The transfer function generated was shown in equation (Dufosse et al 1999). The error was minimized based on trial-and-error method during the training of network. The ability of ANN model was proved by choosing parameter weights results in minimum value of RMSE. The correlation coefficient of 0.999 was obtained for γ-decalactone production.

Models validation: Model predictions of RSM and ANN were confirmed by conducting experiments in thrice at

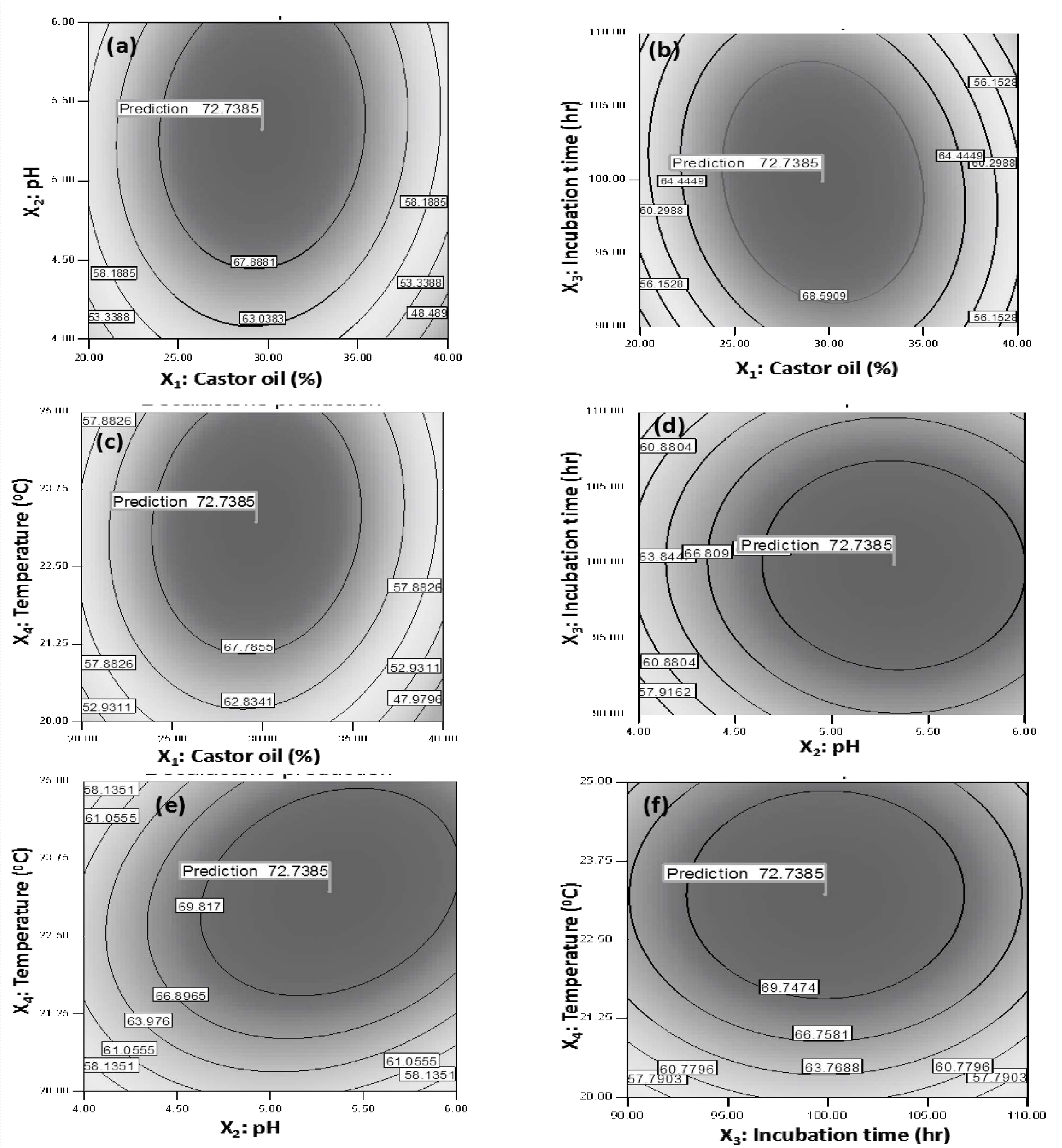

Fig. 1. Contour plots depicting interaction effect of input variables on γ-decalactone production by *Sporidiobolus salmonicolor*: Interaction effects of pH and castor oil (%) (a); incubation time and castor oil (%) (b); temperature and castor oil (%) (c); pH and incubation time (d); pH and temperature (e); incubation time and temperature (f)

optimum conditions. The predicted values of γ-decalactone production by RSM and ANN were 72.73 and 66.14 mg/L, respectively. The optimum input conditions predicted by RSM were castor oil-29.68 %, pH-5.32, incubation time-99.89 hr and temperature-23.22°C with the desirability of 0.992 for γ-decalactone production. The average of triplicate experiments for γ-decalactone production was 73.25 mg/L and it was reasonably close agreement with the response values predicted by models. The outstanding correlation coefficient of RSM and ANN confirms the validity of the models.

Optimum conditions and production of γ-decalactone: The input conditions for γ-decalactone production were optimized using RSM and ANN. The model predictions were validated with experiments. The final yield of γ-decalactone production was 72.73 mg/L at optimum conditions of castor oil-29.68%, pH-5.32, incubation time-99.89 hr and temperature-23.22°C. Earlier reports on the production of γ-decalactone revealed that a maximum production capacity of 131.8 mg/l with immobilized cells and 107.5 mg/l for free cells by *Sporidiobolus salmonicolor* CCRC 2195 after five days of cultivation and indicated that alginate immobilized cells are less susceptible to toxic effects than free cells (Shiow-Ling et al 1998). Gilles et al (1997) reported the production of γ-decalactone 1.8 ± 0.03 g/l with wild strain *Yarrowia lipolyitca* W29 and 5.5 g/l with mutant strain MTLY40-2p after 7 days of biotransformation. They revealed that mutant strain did not show any ability to degrade γ-decalactone.

Nama et al (2016) revealed that the γ-decalactone production of 62.2 mg/l with the same wild type strain used in this study and 81.9 mg/l with mutant strain UV3 after 96 h of fermentation and showed a 33% increase in production compared to wild type strain. Eko et al (2020) observed that γ-decalactone production of 282 mg/l through engineered oleaginous yeast *Yarrowia lipolyitca* from oleic acid in fed-batch fermenter. The yields of γ-decalactone reported above are slightly more compared to the current study. It is mainly due to the toxicity of lactone to producing cells and not genetically engineered strain. However, the fermentation conditions reported for γ-decalactone production in this study are in close agreement with (Dayana et al 2017) in which reported pH-5.0 and castor oil-30% using yeast *L. saturnus* CCMA 0243.

RSM and ANN models comparison: ANN and RSM models were evaluated for predictive abilities by taking the production of γ-decalactone as a case study. These models were compared based on error generated (RMSE, MAE, chi-square (χ^2) and R^2 from the predicted and experimental responses, as shown in Table 3. Thus, results revealed that ANN has good prediction ability compared to RSM for γ-decalactone production due to low error values of ANN and high correlation coefficient. Additionally, responses (γ-decalactone production) predicted by ANN in close agreement with experimental values than that of RSM (Table 2 & Fig. 2). The better prediction of ANN is mainly due to ANN can attribute to the universal approximation, while RSM is limited to a quadratic regression (Kiran et al 2008). ANN has better optimization and prediction abilities compared to RSM. ANN suitable for nonlinear systems for interactions higher than quadratic, whereas RSM is recommended for modeling new processes. Earlier studies reported a better prediction ability of ANN than RSM (Runni et al 2019, Hui-Chuan et al 2019). Thus, ANN proved to be a better prediction and optimization tool.

Table 3. ANN and RSM models comparison based on error parameters

Parameter	γ-decalactone production	
	RSM	ANN
Root mean squared error (RMSE)	0.777	0.617
Mean absolute error (MAE)	0.624	0.426
Chi-square (χ^2)	0.345	0.304
Coefficient of determination (R^2)	0.992	0.999

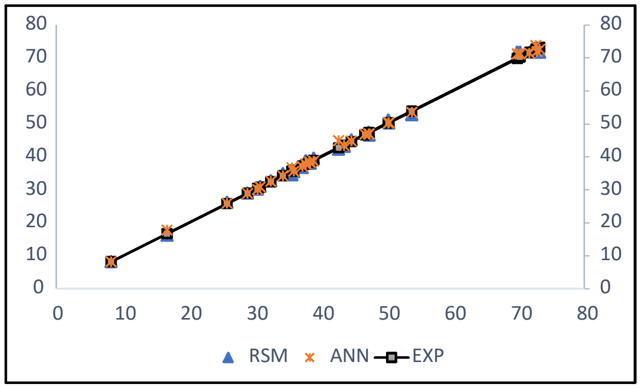

Fig. 2. Comparison of experimental values with the predicted data from ANN and RSM for γ-decalactone production

CONCLUSIONS

In this work modeling approaches of ANN and RSM were assessed for their predictive abilities by taking fermentative production of γ-decalactone as a case study. Optimized the input conditions for maximum γ-decalactone production by *Sporidiobolus salmonicolor* and validated model predictions against experiments. The maximum obtained production of γ-decalactone was 72.73 mg/L at optimum conditions of castor oil -29.68 %, pH -5.32, incubation time -99.89 h and temperature -23.22°C. ANN showed less error parameters and more predictive ability than RSM. Thus, it is showed that

ANN can be considered as alternative for RSM. And also, microbial strain S*poridiobolus salmonicolor* can be used as commercial strain for industrial production of γ-decalactone.

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Genetic Variability Analysis and Characterization for MYMV Resistance in Mungbean

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Abstract: A set of twenty-five advanced breeding lines including five released varieties were evaluated for genetic variability, heritability, and genetic advance for yield and related traits. The total of ten traits were studied including resistance to mungbean yellow mosaic virus disease (MYMV). Seed yield per plant has shown a high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) indicating greater scope for improvement of this trait. Plant height and 100 seed weight showed moderate PCV and GCV whereas days to 50 percent flowering, seed per pod, and pod length showed low PCV and GCV. High heritability estimates coupled with high genetic advance were observed for 100 seed weight and seed yield per plant revealing the presence of less environmental influence and prevalence of additive gene action which suggest that selection would be rewarding for these traits. Screening for MYMV disease under natural conditions showed seven genotypes were resistant and nine genotypes were moderately resistant. This study revealed that 65C was high-yielding and resistant to MYMV disease. Moreover, 59C(10) yielded more than 65C but it was moderately susceptible to MYMV so both of these genotypes can be improved for their respective flaws and can be incorporated in the future breeding pipelines for their further development as a variety.

Keywords: Environmental influence, Genetic advance, Genetic variability, Heritability, MYMV

Pulses are leguminous crops having an annual life cycle with the seed of variable size, shape, and color within a pod. Mungbean [*Vigna radiata* (L.) Wilczek] is a well-known pulse crop with 2n=2x=22 chromosomes and a genome size of 579 Mb (Kang et al 2014). It belongs to the Fabaceae family. Along with this, it is the third most important food legume among the thirteen food legumes grown in India (Ramakrishnan et al 2018). The presence of a high number of proteins, vitamins, minerals, enzymes, and fibers makes it a nutritionally rich crop. Its protein is a rich source of lysine but poor in methionine. However, methionine deficiency can be completed by cereal-based protein. Moreover, it also possesses a good amount of calcium, phosphorus, and iron (Tiwari and Shivhare 2016). A part from its nutritional benefit, mungbean also has an important role in cropping systems due to its short life cycle and nitrogen fixation ability in soil. Its cultivation can improve soil fertility by adding about 30-40 kg N/ha after the harvest of the crop reducing the nitrogen requirement of the succeeding crop by 25 % (Mbeyagala et al 2017). Due to its self-pollinating nature, it shows low natural variability for target traits, making selection ineffective. Knowledge of genotypic variation present in the crop for target traits is necessary for choosing a suitable selection method. Genotypic and phenotypic coefficient of variation, heritability, and genetic advance are important parameters for improving target traits and also for maximizing genetic gain through selection. High heritability along with high genetic advance indicates the presence of additive gene action. Prevalence of additive gene action is always desirable as it is the only gene action that can be fixed by selection. Therefore, this study was conducted to assess genetic variability, heritability, and genetic advance in advanced generations of green gram.

Mungbean yellow mosaic virus (MYMV) is a deadly disease, causing yield losses in green gram for years. Its damage to the production of mungbean cannot be avoided as sometimes it can lead to 75-100% yield loss (Reshami et al 2020). This virus comes under the genus *Begomovirus* which belongs to the *Geminiviridae* family. It is transmitted by the whitefly (*Bemisia tabaci*) which serves as a vector to cause the widespread of this disease (Mishra et al 2020). Using insecticides as a measure of chemical control to impede the infestation of white flies can be a useful approach (Younas et al 2021) But is not always desirable due to its high cost and less eco-friendly nature. Developing varieties having resistance to MYMV disease is a feasible and affordable approach. Identifying new sources of resistance is very important to aid the development of new resistant varieties.

After the identification of new sources, the responsible genes can be transferred from the same to develop new superior breeding lines. The lines used in this study have been screened for MYMV resistance to ascertain their response to the disease. The resistant lines than are identified can be incorporated into breeding pipeline for their further improvement**.**

MATERIAL AND METHODS

The study was conducted during the summer, of 2018 at Navsari Agricultural University, Navsari. Experimental material comprised 20 genotypes (Table 1) alongwith 5 checks viz., GM-4, GAM-5, GM-6, GM-7, and Meha. These genotypes were laid out in randomized block design along with respective checks in three replications. GM-4 was kept as infector row for establishing suitable inoculum and to identify resistant genotypes. It was planted after two consecutive rows of genotypes. Each row is comprised of 20 plants with 60 cm x 15 cm inter and intra row spacing. Each progeny row consisted of 20 plants and observations were recorded from 10 randomly selected plants. The ten characters analyzed were days to 50 percent flowering, plant height, primary branches per plant, pods per cluster, pods per plant, pod length, seed per pod, 100 seed weight, harvest index, and seed yield per plant. Genetic variability analysis of each quantitative trait was carried out using different variability parameters. The data analysis was done using Rstudio with version 2021.9.1.372. Phenotypic, genotypic, and environmental variances were estimated according to the methods suggested by Federer and Searle (1976). Estimation of Phenotypic and genotypic coefficient of variation was done according to the methods suggested by Burton and Vane (1953), whereas estimation of heritability and expected genetic advance were done according to Lush (1940) and Johnson et al (1955), respectively. Estimates of GCV, PCV, heritability, and genetic advance as percent mean were categorized as low, moderate, and high by following Sivasubramaniam and Menon (1973), Robinson et al (1951) and Johnson et al (1955), respectively. Disease scoring for mungbean yellow mosaic virus (MYMV) was done as suggested by Sekar et al 2017 and the plant was categorized to various classes accordingly.

RESULTS AND DISCUSSION

The genotypic differences were significant for most of the characters except for primary branches per plant and pods per plant, indicating a considerable amount of genetic variability among the studied genotypes for various traits (Table 2). There is a sufficient amount of variability present in genotypes that will respond to the selection (Table 3).

Mean performance of genotypes: Most of the characters have shown remarkable variation as (Table 3). Days to 50 percent flowering have depicted sufficient variability.GM-4 was the earliest in flowering whereas 64A and 65C were the last to express 50 percent flowering. The highest plant height was in 95B followed by 47D and Meha whereas, 62A was the shortest among all. Subsequently, 19C and 34A were having the highest number of primary branches per plant but, GM-6 has shown to bear the lowest number of primary branches per plant. Genotype 95B recorded highest number of pods per plant but it was with low number of pods per cluster and such type of results were also obtained by Sandhiya and Shanmugavel (2018). Besides this lowest number of pods per plant in 13A and was also with low pods per cluster. The

Table 1. Genotypes subjected to genetic variability analysis

Sr. no.	Genotype	Pedigree	Sr. no	Genotype	Pedigree
1.	13A	Meha × Pusa vishal	14.	56C	Meha × GM-4
2.	34A	Meha × Pusa vishal	15.	59C (10)	Meha × GM-4
3.	34A (7)	Meha × Pusa vishal	16.	59C (5)	Meha × GM-4
4.	42A	Meha × Pusa vishal	17.	65C	Meha × GM-4
5.	62A	Meha × Pusa vishal	18.	79C	Meha × GM-4
6.	64A	Meha × Pusa vishal	19.	37D	Meha × GJM-1008
7.	48B	Meha × GJM-1006	20.	47D	Meha × GJM-1008
8.	65B	Meha × GJM-1006	21.	Meha	Check variety
9.	94B	Meha × GJM-1006	22.	GAM-5	Check variety
10.	95B	Meha × GJM-1006	23.	GM-6	Check variety
11.	18C	Meha × GM-4	24.	GM-7	Check variety
12.	19C	Meha × GM-4	25.	GM-4	Check variety
13.	40C	Meha × GM-4			

highest pod length was observed for GM-7 which was also accompanied by higher seeds per pod. Such type of results was also observed earlier by Sushmitha and Jayamani (2018). Moreover, 42A was having shortest pods which were obviously accompanied by low seeds per pod. The highest seed yield per plant was observed for 59C (10) followed by 65C. Furthermore, 13A was having lowest seed yield and was also having lower pods per plant and such type of results were also reported by Jayaprada et al (2021). The highest 100 seed weight (g) was observed for GM-6 followed by GAM-5 whereas 79C was possessing the lowest 100 seed weight. Subsequently, 37D was having highest harvest index

Table 2. Analysis of variance (mean sum of square values) for various traits in green gram

Source of variation	DF	DTF	PH (cm)	PB	PPC	PPP	PL (cm)	SPP	SYP (g)	100 SW (g)	HI (%)
Replications	2	5.45	202.34	0.89	0.29	21.21	0.12	1.43	1.79	0.02	45.31
Genotypes	24	11.28**	86.88**	0.35	0.36*	64.13	0.68*	0.79*	2.56**	0.63**	46.59**
Error	48	1.87	22.55	0.24	0.17	43.85	0.33	0.37	0.28	0.01	12.17

DTF = Days to 50 per cent flowering PH = Plant height PB = Primary branches per plant
PPC = Pods per cluster PPP = Pods per plant PL = Pod length
SPP = Seed per pod SYP = Seed yield per plant 100 SW = 100 seed weight
HI = Harvest index

Table 3. Mean performance of green gram genotypes for various quantitative traits

Genotypes	Days to 50% flowering	Plant height (cm)	Primary branches per plant	Pods per cluster	Pods per plant	Pod length (cm)	Seeds per pod	Seed yield per plant (gm)	100 seed weight (g)	Harvest Index (%)
13A	47.33	39.83	2.53	2.77	11.50	6.75	9.25	2.33	4.00	19.09
34A	50.67	43.11	3.27	3.15	16.74	6.91	9.44	2.74	4.07	14.94
34A(7)	48.33	46.11	2.46	3.23	14.80	6.70	9.30	4.05	4.13	20.39
42A	50.33	42.51	2.63	3.04	14.70	5.90	9.19	2.97	3.92	16.22
62A	48.67	36.19	2.81	3.03	22.53	6.38	8.87	3.54	4.10	22.36
64A	51.33	44.87	2.87	3.54	25.29	6.63	9.69	2.73	4.10	6.36
48B	49.67	43.35	2.67	3.53	17.87	7.15	9.90	3.75	4.13	20.61
65B	47.33	38.50	2.17	3.17	13.30	6.24	9.48	3.51	4.43	16.62
94B	47.33	40.50	2.60	3.10	13.47	7.65	10.43	3.04	4.20	22.27
95B	50.67	57.35	3.01	2.76	28.93	6.87	9.84	3.37	4.00	20.52
18C	47.00	44.80	2.19	3.01	16.84	6.75	9.23	4.68	3.83	16.09
19C	50.67	49.67	3.48	3.57	27.13	6.43	9.74	4.56	3.97	20.86
40C	50.00	51.63	2.89	3.54	16.27	6.87	9.57	4.60	4.13	18.49
56C	50.00	47.67	3.13	2.98	18.70	7.03	9.61	3.90	3.97	16.41
59C(10)	50.33	47.91	2.84	3.81	23.49	7.04	9.86	5.88	3.70	20.25
59C(5)	46.33	42.29	2.70	4.03	18.77	6.44	9.10	4.14	3.67	17.94
65C	51.33	53.05	2.70	3.44	21.33	6.94	9.13	5.19	3.67	18.01
79C	48.67	42.66	2.77	3.53	18.20	6.83	9.63	4.57	3.40	20.95
37D	48.00	40.65	2.43	3.60	15.83	6.81	10.33	2.71	3.87	25.53
47D	48.67	53.55	2.81	3.05	17.73	6.83	9.13	4.80	4.00	25.24
MEHA	49.00	53.55	3.01	3.79	25.68	6.90	9.08	4.17	4.28	14.29
GAM-5	50.67	38.79	2.35	3.47	13.40	6.88	9.15	4.18	5.18	14.01
GM-6	48.00	45.76	2.01	2.96	16.38	7.75	9.84	4.56	5.21	18.73
GM-7	48.33	47.06	2.75	3.80	17.18	8.03	11.18	5.11	4.90	17.70
GM-4	42.67	45.38	2.50	3.33	20.08	7.61	9.60	5.13	4.91	16.58
Mean	48.85	45.47	2.70	3.33	18.65	6.89	9.58	4.01	4.15	18.42

followed by 47D and 62A whereas 64A was reported to have the lowest harvest index. The genotypes 59C(10) (5.88 g) and 65C (5.19 g) have significantly outyielded Meha and GAM-5 check varieties but not GM-4, GM-6, and GM- 7 (Fig. 1).

PCV and GCV estimates: The 25 genotypes exhibit an ample amount of phenotypic variability for different characters and it ranges from 4.58 to 38.15 % (Table 4). The phenotypic coefficient of variation (PCV) was highest for pods per plant (38.15 %) and lowest for days to 50 percent flowering (4.58 %). The highest genotypic coefficient of variation (GCV) was obtained for seed yield per plant (21.75 %) whereas days to 50 percent flowering possessed the lowest GCV (3.63%). Days to 50 percent flowering, seed yield per plant, and 100 seed weight showed a narrow difference between PCV and GCV indicating the low or negligible environmental influence on the expression of these traits hence, selection would be effective for these traits. Similar results were also obtained by Hemavathy et al (2015) and Sineka et al (2021). High PCV and GCV were exhibited by seed yield per plant showing an ample amount of variability for this trait. Plant height and 100-seed weight showed moderate PCV and GCV values and similar results were also obtained by Jangra and Yadav (2015) and Vir and Singh (2016). Low estimates of PCV and GCV values were seen for days to 50 percent flowering, pod length, and seeds per pod and these results are following Sahu et al (2014) and Jayaprada et al (2021). Primary branches per plant, pods per cluster, pods per plant, and harvest index showed low to moderate estimates for PCV and GCV showing low variability

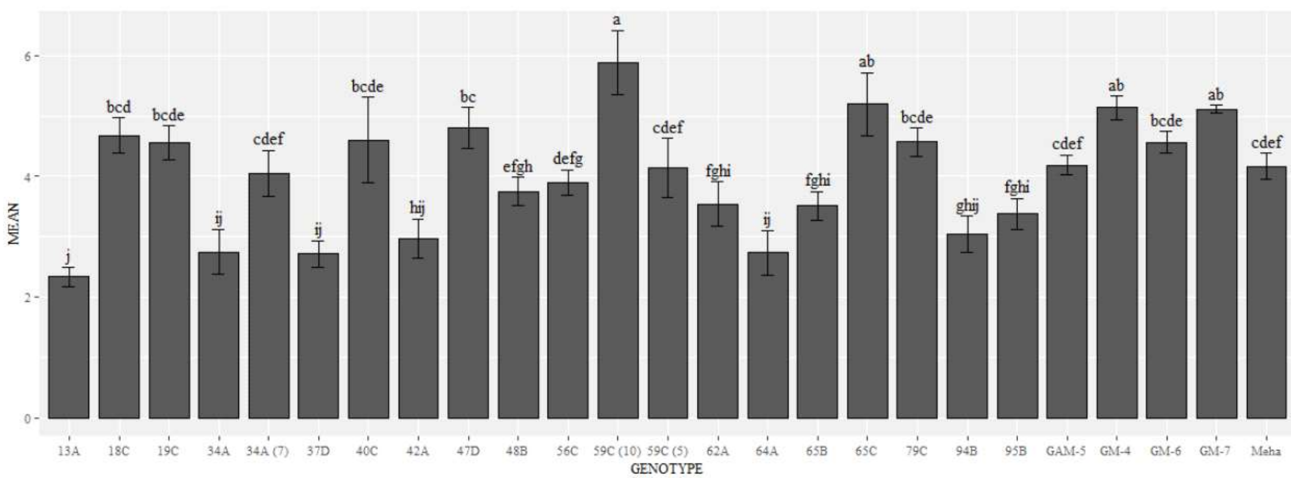

Fig. 1. Comparison of different genotypes for seed yield per plant (g). Genotypes with different letter are significantly different from each other for seed yield per plant (g)

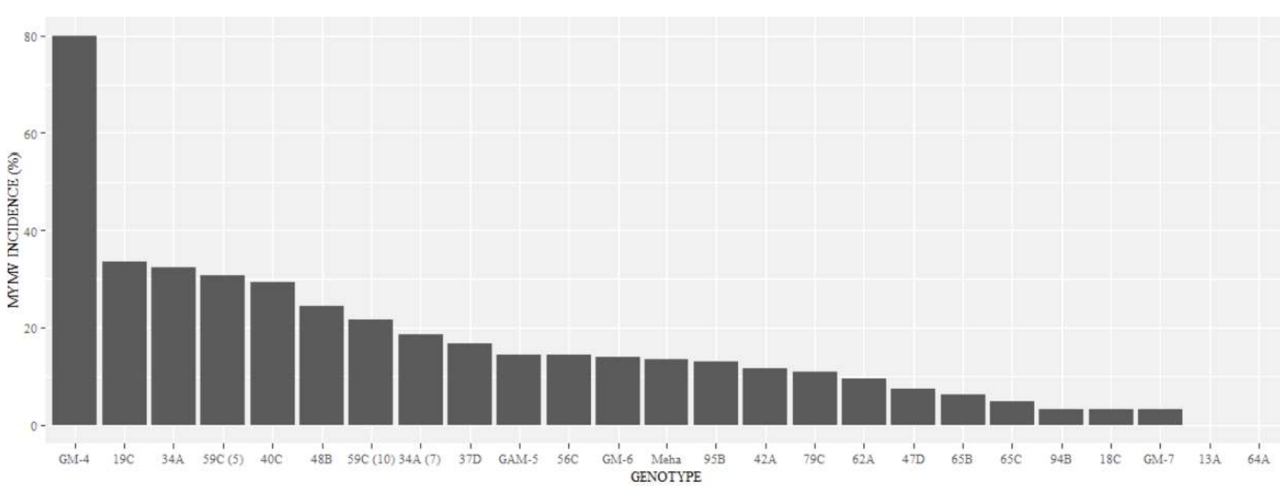

Fig. 2. Incidence of MYMV in green gram genotypes

Table 4. Estimates of genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV), heritability, genetic advance and genetic advance as per cent of mean for ten different characters of green gram

Characters	PCV (%)	GCV (%)	Heritability	Genetic advance (as % of mean)
Days to 50 per cent flowering	4.58	3.63	0.63	5.91
Plant height (cm)	14.59	10.18	0.49	14.65
Primary branches per plant	19.37	7.19	0.14	5.49
Pods per cluster	14.55	7.47	0.26	7.90
Pods per plant	38.15	13.94	0.13	10.50
Pod length (cm)	9.73	4.97	0.26	5.24
Seed per pod	7.42	3.90	0.28	4.22
Seed yield per plant (g)	25.43	21.75	0.73	38.31
100 seed weight (g)	11.23	10.93	0.95	21.92
Harvest index (%)	26.40	18.39	0.49	26.39

among these characters and indicating the limited scope of improvement of these characters through selection.

Heritability analysis: Broad sense heritability (%) is the proportion of phenotypic variability that is due to genetic reasons. The traits having higher heritability are largely governed by additive genes and selection could be rewarding for improvement of such yield attributes by individual plant selection. The heritability ranged from 13 to 95% (Table 4). The highest heritability was observed for 100 seed weight followed by seed yield per plant, indicating that these characteristics are less influenced by the environmental fluctuations. Such a trend for 100 seed weight was also observed by Hemavathy et al (2015) and Gayacharan et al (2020). High heritability estimates show the major role of the genetic constitution in the development of phenotype and such kind of traits are desirable in a breeding program of the crop. The moderate to low estimates of heritability were recorded for plant height, seeds per pod, pod length, pods per cluster, and primary branches per plant indicating more environmental influence on such traits. Similar trends for the characteristics like seed yield per plant and 100-seed weight were observed by Das et al (2010), Degefa et al (2014) and Usharani and Kumar (2016).

Genetic advance analysis: The values of genetic advance as percent of mean ranged from 4.22 (seeds per pod) to 38.31% (seed yield per plant). Seed yield per plant (38.31%), harvest index (26.39%) and 100 seed weight (21.92%) manifested high genetic advance as a percent of the mean. Moreover, these traits also possessed high heritability. High heritability coupled with high genetic advance indicates that these traits are governed by additive gene action and selection for these traits will be rewarding. Similar results were also obtained by Raselmiah et al (2016) and Sushmitha and Jayamani (2018). High heritability coupled with moderate genetic advance was seen for plant height and high heritability coupled with low genetic advance was seen for days to 50 percent flowering which clearly shows the character is governed by non-additive gene action and is highly influenced by environmental effects. Furthermore, selection for these traits will be less effective and will not yield any genetic gain. Moderate values of genetic advance as percent of mean were observed for pods per plant. These findings were similar to the results of Kumar et al (2013) and Kumar et al (2015). Low estimates of genetic advance were observed for seeds per pod, pod length, primary branches per plant, and pods per cluster suggesting that these characteristics are under high environmental influence and selection would be ineffective for these traits. Such kinds of results for seeds per pod were also obtained by Makeen et al (2007), Alom et al (2014) and Jangra and Yadav (2015).

Screening for MYMV in green gram genotypes : Among 25 genotypes studied, the variable response was observed for MYMV disease incidence as per Sekar et al (2017) (Figure 2). The 13A and 64A were highly resistant as they depicted no sign of MYMV incidence. Genotypes 47D, 62A, 65B, 94B, 18C, GM-7, and 65C were resistant where MYMV incidence was observed from 1 to 10 %. Likewise, 34A (7), 42A, 95B, 56C, 79C, 37D, GAM-5, Meha and GM-6 were categorized as moderately resistant (11 to 20%). Genotypes 48B, 40C, and 59C (10) were moderately susceptible (21 to 30%). The genotypes 34A, 19C, and 59(C)5 were susceptible (31-50%) and GM-4 was found highly susceptible (> 50%).

CONCLUSION

The present investigation revealed high heritability coupled with high genetic advance as a percent of the mean for the traits viz., seed yield per plant, and 100 seed weight.

This indicated that additive gene effects are operating for inheritance and mass selection or progeny selection would be worthwhile for further improvement of these traits. Plant height exhibited high heritability coupled with moderate genetic advance indicating environmental effects. Low heritability coupled with low genetic advance was observed for the character primary branches per plant, pods per cluster, pod length, and seeds per pod suggesting that these characteristics are under environmental influence and selection would be ineffective. Genotypes categorized as highly resistant and resistant against MYMV can be improved further by increasing yield. Genotypes 13A and 64A were highly resistant to MYMV but had low seed yield per plant and 59C(10) was high yielding but moderately susceptible to MYMV so further crossing programs can be designed for transferring genes for disease resistance and seed yield to develop high-yielding MYMV resistant genotypes.

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Host Stage Preference, Functional Response and Biological Parameters of *Aphelinus asychis* Walker on *Myzus persicae* (Sulzer) in Bell Pepper

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Abstract: *The parasitoid, Aphelinus asychis* Walker (Aphelinidae: Hymenoptera), is an important naturally occurring solitary koinobiont endo-parasitoid of green peach aphid, *Myzus persicae* (Sulzer) (Aphididae: Hemiptera). To supplement the augmentative or conservation biological control of *M. persicae* in capsicum, the host stage preference, functional response, and biological parameters of this parasitoid on *M. persicae* was studied. The parasitoid was able to parasitize all the nymphal stages of the aphid with preference to the second instar (51%) followed by the first instar (46%). The biological parameters of the *A. asychis viz.* total development, pre-oviposition, oviposition, post-oviposition periods, sex ratio (F: M), and fecundity were 16.23±0.45, 1±0.00, 6.6±0.40, 1.6±0.40 days, 1:0.97, and 58.8 eggs female^{-1}, respectively. The parasitoid when offered with different densities *viz.* 10, 15, 20, 25, and 30 of the second instar nymphs of *M. persicae* exhibited a Type-II functional response. Theoretically, parasitoid could parasitize a pinnacle of 18.25 aphids within 24 h. The present study indicates that the parasitoid has a potential for supplementing the augmentative and/or conservation biocontrol of the pest. The study also underscores the scope of optimizing the second instar nymphs of the aphid for mass production of the parasitoid.

Keywords: *Aphelinus asychis, Myzus persicae,* Relative preference, Oviposition period, Sex ratio, Functional response

Myzus persicae (Sulzer) (Aphididae: Hemiptera) commonly known as green peach aphid is a cosmopolitan and major pest of bell pepper, *Capsicum annuum L*. The aphid sucks the sap from copious portions of the plant causing leaf curling, distortion, discoloration, and premature senescence (Castle and Berger 1993, Syller 1994, Kumar et al 2019). The pest depreciates the yield and quality of bell pepper through direct feeding as well as contaminating the foliage by honeydew deposits on which sooty mold builds and represses photosynthesis (Cloyd and Sadof 1998). Additionally, the aphid transmit above 150 viral diseases (Castle and Berger 1993, Syller 1994). The ability to develop insecticide resistance, wide host range, and high biotic potential makes the aforementioned pest all the more challenging to manage (Yano 2003, Ralec et al 2010). Hence, there is an urgent need to generate alternatives for insecticides to regulate the pest. Biocontrol is one such an option in which use of chemicals is negligible, or only selective insecticides are used (Hoy 1993).

Aphelinus asychis Walker is a polyphagous, solitary, koinobiont endo-parasitoid that attacks above 40 aphid species, counting M. *persicae* (Li et al 2007, Byeon et al 2011, Gavkare et al 2013, Kumar et al 2019). In addition to parasitism, *A. asychis* annihilates the aphids through host-feeding which enhances its longevity, survival, and ovigenesis (Bai and Mackauer 1990). The host instar selection phenomenon is embraced by a parasitoid that influences the potential aphid population density and reduces their numbers (Hagvar and Hofsang 1991). The host suitability is a linear function of the host size, although it is dependable on hosts that do not feed, and not the perpetual state in aphid parasitoids (Askew and Shaw 1986, Sequeira and Mackauer 1992). According to optimal foraging theory the host selection and acceptance assist in enhancing the profits to the coming generation of parasitoids (Pyke 1984). *A. asychis* females distinguish between parasitized and unparasitized hosts (Mackauer 1982, Wahab 1985) which makes them effective biocontrol agents. According to Gavkare and Kumar (2012), *A. asychis* can result in 35 to 40 per cent parasitism in *M. persicae* under protected conditions. Although there are quite a few reports on the parasitization potential and biological parameters of the parasitoid on *M. persicae* (Takada 2002, Tatsumi and Takada 2005, Wang et al 2016), little has been reported with respect to the Indian populations of this parasitoid. Searching for local effective strains of the natural enemies has become vital, especially after the implementation of the Nagoya Protocol on access and benefit-sharing (Smith et al 2018). Before urging the parasitoid for field releases, it is crucial to scrutinize its biology and biotic potential. Consequently, we studied the relative preference, functional response, and biological parameters of *A. asychis* against *M. persicae* on bell pepper to supplement the biocontrol of the pest.

MATERIAL AND METHODS

Insect Cultures

Myzus persicae: Pure culture of the green peach aphid, *M. persicae* was maintained on bell pepper seedlings raised in plastic pots (10cm diameter). The aphid colonies were consolidated from the field and released on bell pepper plants. Before using the green peach aphids in experiments, the aphids were reared for two generations. The exhausted and dried bell pepper plants were changed systematically with fresh plants to assure a sufficient number of aphids for examination during the research.

Aphelinus asychis: The mummified aphids were collected from bell pepper plants nurtured inside the polyhouse and placed inside the glass tubes (15cm×2.5cm) for the development of the adult parasitoid. The freshly developed parasitoids were introduced onto the bell pepper seedlings *grown* in the plastic pots infested with *M. persicae* and covered with glass chimney (10cm×14.5cm). Honey solution (30%) provided as food to the adult parasitoids. Glass chimney top was covered with muslin cloth and tied with a rubber band. The parasitoid was established for one generation before using in the experiments. The adults of the parasitoid, *A. Asychis,* were identified by employing the taxonomic identification key formulated by Takada (2002).

Relative preference of *A. asychis* to parasitize different stages of *M. persicae:* The relative preference of *A. asychis* to oviposit nymphal instars of the green peach aphid was studied in a choice experiment at 25±0.5°C, 70±5% RH, and 14L:10D photoperiod. In the experiment, each pair of *A. asychis* was provided concurrently with twenty individuals each of the first, second, third, and fourth instar nymphs of *M. persicae* on capsicum seedling. For this, the instar wise aphids were carefully transferred with a fine camel hair brush on to the capsicum seedling and allowed to settle for 24 h. One pair of the parasitoid was allowed to mate for 24 hour and then the mated female was confined in the glass chimney and allowed to parasitize for 24 hour and thereafter the female was removed from the glass chimney. There were ten replications. After mummification, the mummies were counted, removed, and retain in the glass vial for the development of the adult parasitoid.

Functional response of parasitoid: Functional response of *A. asychis* to the second nymphal instar, the most preferred stage of *M. persicae* was studied on bell pepper seedlings covered with glass chimney at 25±0.5°C, 70±5% RH, and 14L:10D photoperiod. The honey solution (30%) was implemented inside a glass chimney as food for the parasitoid. The second nymphal instar of *M. persicae* were randomly assigned the bell pepper seedlings at 10, 15, 20, 25, and 30 densities. A single mated female (24 h old) was confined in the each glass chimney for parasitization. Each density was replicated ten times. After 24 hours, the female parasitoid was taken out from the glass chimney and the aphids were reared for mummification. Data on parasitized aphids in each density were recorded.

Developmental biology of the parasitoid, *A. asychis:* Development biology of *A. asychis* was studied on the second nymphal instar of *M. persicae* infesting the bell pepper seedlings raised in pots covered with glass chimney at the same environmental conditions described earlier. Twenty numbers of the second nymphal instar of *M. persicae* were restrained in potted seedlings covered with the glass chimney. In each glass chimney, a female parasitoid from the stock culture was released for parasitization for 24hour and thereafter the female parasitoid was removed. The aphids were retained for mummification. Then these mummified aphids were transferred individually in glass vials and inspected every day for adult formation. On emergence, the adult parasitoids were sexed and each pair was released into the glass chimney containing the bell pepper seedling infested with 2^{nd} instar nymphs of the aphid and 30 percent honey in the cotton swab. After 24 hour, the old batch of the aphids was substituted with a new one and this process proceeded till the mortality of the last parasitoid. The data on total development, pre-oviposition, oviposition, post-oviposition periods, sex ratio, and fecundity (mummified aphids) were observed.

Adult longevity: The adult longevity of *A. asychis* was ascertained by employing diverse foods *i.e.* honey solution (10, 30, and 70%), distilled water, and the aphid nymphs individually in separate test tubes. The honey solution and distilled water were rendered in cotton swabs and green peach aphid on the leaves. The five treatments were replicated four times. The adult parasitoids were inspected every day until they had died.

Data analysis: The data recorded on different parameters were subjected to one-way analysis of variance (ANOVA) using online software OP-STAT followed by calculation of critical difference (CD) at p= 0.05 to differentiate the significantly different means (Sheoran et al 1998). Data recorded in the functional response experiment were initially subjected to logistic regression between the proportion parasitized host (Na/N) and the host density offered (N) for determining the type of functional response as given below:

$$\frac{Na}{N} = \frac{\exp(P^0 + P^1 + N + P^2N^2 + P^3N^3)}{1+\exp(P^0 + P^1 + N + P^2N^2 + P^3N^3)}$$

Where P_0= Intercept

P_1 =Linear coefficient

P_2 = Quadratic coefficient

P_3 = Cubic coefficient

Na = Number of parasitized host

N = Number of hosts offered

The linear coefficients (P_1) from the logistic regression equation significant negative or positive indicate Type-II or Type-III, respectively (Juliano 2001). If $P_1 < 0$, it depicted Type -II functional response whereas if $P_1 > 0$, it indicated a Type- III functional response.

The functional response parameters were assessed by applying the Holling disc equation for the type II functional response as determined by the logistic regression (Holling 1959) as under:

$$Na = \frac{aNT}{1 + aT_h N}$$

Where Na = Number of parasitized host

N = Number of the host offered

T = Total time available for the parasitoid

a = Attack rate (searching efficiency)

T_h = Handling time

RESULTS AND DISCUSSION

Relative preference of *A. asychis* to parasitize different nymphal instars of green peach aphid: In a choice experiment, different nymphal stages of *M. persicae* were offered simultaneously to *A. asychis.* The parasitoid preferred the second stage (51%) followed by the first (46%) and the third (44%) (F_{cal} =7.853; df = 3, 36; P < 0.001) while the fourth instar nymphs were the least preferred stage (33%) (Table 1).

Functional response of *A. asychis* parasitoid to varied host densities: The logistic regression analysis between the parasitized host (Na/N) and host density offered (N) yielded a significantly negative linear coefficient (P_1=-0.671) confirming a Type - II functional response of the parasitoid to the second nymphal instar of the pest (Table 2). The number of second stage nymphs of green peach aphid parasitized by the parasitoid differed significantly (F =8.614; df = 4, 45; P < 0.001) at different densities. These values were 5.6, 7, 8.5, 11.1, and 9.9 at 10, 15, 20, 25, and 30 host densities, respectively (Table 3, Fig. 1). The number of hosts parasitized increased with the increase in the host density until the aphid density of 25, but at a decelerating rate while the proportion of the hosts parasitized declined with the increase in the host density (Fig. 1). The attack rate (a) and handling time (T_h) was 0.034 ± 0.004 h^{-1} and 1.32 ± 0.23 h, respectively. The estimated theoretical maximum parasitism rate (T/T_h) over the 24h period was 18.25, while the attack rate per handling time (a/T_h) was 0.03. The data fit well the Holling disc equation (R^2 =0.768) (Table 4).

Developmental biology of *A. asychis* on second instar of *M. persicae:* The parasitoid development from egg to emergence of adult occurred in 16.23 days. The oviposition to mummification and pupal period was 6.70 and 9.53 days, respectively. *A. asychis* adults had a pre-oviposition, oviposition, and post-oviposition periods of 1.00, 6.60, and 1.60 days, respectively. The parasitoid laid on an average 58.80 eggs per female in the 2nd instar nymph of *M. persicae* and the sex ratio (F: M) of the parasitoid was 1:0.97 (Table 5).

Adult longevity: Adult longevity was ascertained on diverse foods i.e. honey solution (10%, 30%, 70%), distilled water, and the aphid nymphs separately (Table 6). The adult longevity ranged from 8.75 to 17.75 days. Adult food

Table 1. Relative preference of *A. asychis*to different stages of *M. persicae*

Instars	Number of aphids parasitized	Parasitization (%)
1st instar	9.2^{ab}±0.4	46.0
2nd instar	10.1^{a}±0.6	51.0
3rd instar	8.7^{bc}±0.8	44.0
4th instar	6.6^{c}±0.5	33.0
CD (p=0.05)	1.5	

Mean values superscripted with same alphabet do not differ significantly at p=0.05

Table 2. Results of logistic regression analysis of the proportion of *M. persicae* parasitized by *A. asychis*

Coefficient	Estimates ± SE	t-value	P
Constant (p_0)	4.1962 ± 0.627317	6.69	<0.001
Linear (p_1)	-0.6713 ± 0.1262	-5.32	<0.001
Quadratic (p_2)	0.0333 ± 0.006568	5.07	<0.001
Cubic (p_3)	0.0002 ± 0.000133	-1.5	0.168

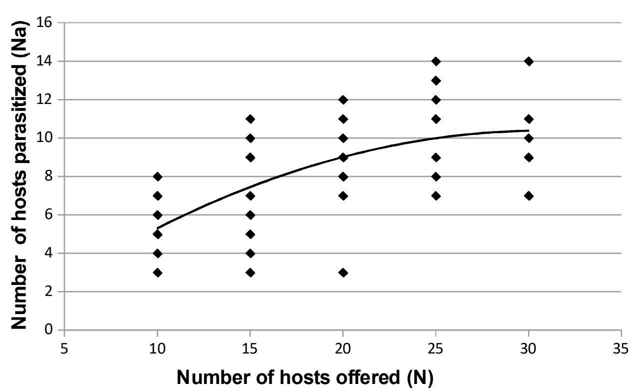

Fig. 1. Functional response of *A. asychis* to *M. persicae*: Number of host parasitized (Na) versus host density offered (N)

significantly influenced the adult longevity of the parasitoid (male: F= 27.544; df = 4, 15*; P < 0.001 and female:* F= 13.936; df = 4, 15*; P < 0.001*). The highest adult longevity for male was 16.5 days *and for female was* 17.75 days with 70 per cent honey solution which was, however, significantly at par with adults fed on the green peach aphid nymphs (male: 15.25 days and female: 15.50 days). The parasitoid adults fed on 10 or 30 per cent honey lived for 12 to 13.25 days with non-significant differences, while those allowed to feed on distilled water only survived for 8.75 (males) and 9.75 days (females) (Table 6).

In the present study, *A. asychis* parasitized all the immature stages of *M. persicae* with a preference for the second and first instar. The parasitoid preference for these early host stages could be due to their suitability for the parasitoid fitness and the lower abilities of the young aphids to defend against the parasitoid (Kouame and Mackauer 1991, Losey and Deno 1998, Liu 1985). Preference for the younger stages of *M. persicae* has also been reported in the parasitoids like *Aphidius colemani* Viereck (Hagvar and Hofsang 1991) and *Monotonus paulensis* (Ashmed) (Chau and Mackauer 2000). The selection of young hosts for oviposition by the parasitoid is considered as a desirable attribute to avoid excessive feeding by the host (Kouame and Makauer 1991). In accordance with the findings of Suck et al (2016) and Jia and Liu (2018), the present study also reported the preference of *A. asychis for the second* instar nymph of *M. persicae*.

In the present study, we further noticed that the total developmental period and the adult emergence were 16.23 days and 100 per cent, respectively. These parameters were slightly higher than reported by Ro and Long (1997) for this parasitoid-aphid combination on potato (developmental time: 14.5 days; emergence: 92.3%) indicating that the host plant influences the development and survival of the parasitoid. Earlier reports also confirmed that the host suitability for the parasitoid is effected by the host species, size, and age with specific reference to the growth period (Stary 1988, Hu et al 2002). Bernal and Gonzalez (1993) reported unsteady growth period of *A. asychis* on *Diuraphis noxia Kurdjumov.* Harley et al (1971) noticed the parasitoid development time diversified at variable temperatures. The total developmental period was 16 and 10 days at 23.9°C and 32.2°C, respectively. Highest female to male ratio of *A. asychis* to three species of sorghum aphids, greenbug, *Schizaphis graminum (Rondani)*, corn leaf aphid, *Rhopalosiphum maidis (Fitch),* and yellow sugarcane aphid, *Sipha flava (Forbes)* was 2:1 at the lowest temperature (23.9°C) and 1:1 at 32.2°C. Earlier investigations revealed that the percentage of female *A. asychis* adults may swing with host species (Jackson and Eikenbary 1971, Raney et al 1971). Bueno and Cleave (1997) reported that *Aphelinus perpallidus Gahan* had a developmental period of 18 to 22.5 days in both males and females. In this investigation, the fecundity of the parasitoid was 58.8 eggs female^{-1}, which fell within the range (33-159 eggs female^{-1}) as reported by Jackson and Eikenbary (1971). Byeon *et al* (2011) achieved highest daily fecundity (29.1 eggs for this parasitoid) on the same host. The sex ratio (F: M) of the parasitoid obtained in the current study (1:0.97) is also similar to that reported by Jackson and Eikenbary (1971).

This study yields a Type- II functional response of the parasitoid to the second instar nymphs of *M. persicae*. Type-II functional response seems prevalent in aphids parasitoidsand previously been reported in *Aphelinus thomsoni Graham against Drepanosiphum platanoidis*ese (Schrank) (Collins *et al* 1981), *Aphelinusal bipodus Hayat and Fatima, Aphidius colemani* Viereck *and, Aphidius matricariae* Haliday against *M. persicae* (Sampaio et al 2001, Tahriri et al 2007) and *A. asychis for M. persicae* (Byeon et al 2011). A type II response indicates that there is a reduction in the rate of parasitization with accretion in the prey density (Brown and Rothery 1993).

In the study, the attack rate (a) (0.034 ± 0.004 h^{-1}) and handling time (T_h) (1.32 ± 0.23 h) indicates that *A. asychis* is a suitable candidate for the control of the *M. persicae*. The handling time of *A. asychis* (present study) was slightly lower than *A. colemani* and *A. matricariae* on the same host and

Table 3. Functional response of *A. asychis* to *M. persicae*

Host density offered (N)	Number of hosts parasitized (Na) (Mean ± SE)	Proportion of hosts parasitized (Na/N) (Mean ± SE)	1/Na	1/NT (T=24h)
10	5.6^{d} ± 0.5	0.56 ± 0.48	0.19	0.004
15	7^{cd} ± 0.8	0.47 ± 0.06	0.17	0.003
20	8.5^{bc} ± 0.8	0.43 ± 0.04	0.14	0.002
25	11.1^{a} ± 0.7	0.44 ± 0.03	0.09	0.002
30	9.9^{ab} ± 0.8	0.33 ± 0.03	0.11	0.001
CD (p=0.05)	2.1			

Mean values superscripted with same alphabet do not differ significantly at p=0.05

Table 4. Functional response parameters of *A. asychis* on *M. persicae*

Parameter	Estimate ± SE
Attack rate (a)	00.034 ± 0.004
Handling time (T_h)	01.32 ± 0.23
Effectiveness of parasitoid (a/ T_h)	00.03
Maximum parasitisation rate (K) = T/ T_h	18.25
Coefficient of determination (R^2)	00.77

Table 5. Developmental biology of *A. asychis* on *M. persicae*

Parameter	Mean ± SE
Pre-oviposition period	1.00±0.00
Oviposition period	6.60±0.40
Oviposition to mummification period	6.70±0.38
Mummification to adult emergence period	9.53±0.29
Total developmental period	16.23±0.45
Post- oviposition period	1.60±0.40
Fecundity	58.80±10.44
Sex ratio (F:M)	1:0.97

Table 6. Adult longivity of *A. asychis* on different foods

Food	Longivity (Mean ± SE) (Days)	
	Male	Female
Honey solution (10%)	9.50^{c}±1.19	12.00^{cd}±0.577
Honey solution (30%)	13.00^{b}±0.408	13.25^{bc}±0.629
Honey solution (70%)	16.50^{a}±0.29	17.75^{a}±0.48
Distilled water	8.75^{c}±0.48	9.75^{d}±0.48
Green peach aphid	15.25^{a}±0.48	15.50^{ab}±1.5
CD (p=0.05)	1.98	2.52

Mean values in a column superscripted with same alphabet do not differ significantly at p=0.05

further observed that temperature had a significant influence on the handling time of these parasitoids (Zamani et al 2006).

Carbohydrate concentration in the adult diet seems to be important for their longevity as the adults feeding on 70 per cent honey survived longer than those feeding on 30 or 10 percent honey, host nymphs, and distilled water. Honey is a rich source of nutrients as it includes levulose (fructose) and dextrose (glucose) and provides food to the parasitoid. The adult longevity of the parasitoid recorded in the present study (17.75 days) was slightly less than reported by Jackson and Eikenbary (1971) (19.7 days) and Ro and Long (1997) (20 days) on the green peach aphid, *M. persicae*.

CONCLUSION

A. asychis parasitizes all the nymphal stages of *M. persicae* and prefered the second nymphal instar and followed a Type-II functional response. Based on the biological parameters, it can be concluded that the parasitoid has a potential for augmentative and conservation biological control of the pest. It is also pertinent to mention that the second instar nymphs of the aphid may be used for mass production of the parasitoid.

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Silicon and Gibberellic Acid as Resistance Inducers in Green Gram against Leaf Hopper *Empoasca kerri* (Pruthi)

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Abstract: Experiment was carried out at Nattapatti village, Madurai district to evaluate the effects of silicon (Si) fertilization on green gram plants for reducing damage of *Empoasca kerri*. Treatments comprised two types of Si sources such as silicic acid @ 0.1 and 0.2% and potassium silicate @ 0.5 and 1.0% with gibberellic acid @ 50 and 100 ppm (foliar spraying). The population density of *E. kerri* was observed weekly during the growth season. The treatment with potassium silicate 1.0% @ 10 DAS & 20 DAS with gibberellic acid 100 ppm @ 30 DAS and 40 DAS significantly decreased the population of *E. kerri*.

Keywords: Silicon, Gibberellic acid, Green gram, *Empoasca kerri,* Leaf hopper, *Rabi*, Foliar spray

Mungbean [*Vigna radiata* (L.) Wilczek] is a short-duration grain legume crop native to India that ranks third in popularity after chickpea and pigeonpea. In India, green gram is grown in an area of 34.37 lakh ha with the production of 17.83 lakh tonnes per year during 2019-20. Mungbean has a yield potential of 2.5–3.0 t/ha, however its average productivity is remarkably low at 0.5 t/ha. Abiotic and biotic stresses, inadequate crop management practices, and a lack of quality seeds of superior varieties are all contributing to low productivity (Chauhan et al 2010, Pratap et al 2019). The major biotic factors include insect-pests such as leaf hopper, whitefly, thrips, aphids, bruchids, and pod borers and diseases especially yellow mosaic, powdery mildew, anthracnose, dry root rot, cercospora leaf spot, halo blight, and tan spot (Singh et al 2000, War et al 2017, Pandey et al 2018). Among the 64 insect pest species recorded on green gram whitefly, *Bemisia tabaci* (Genn.); cowpea aphid, *Aphis craccivora* Koch; Thrips, *Caliothrips indicus* Bagnall; jassid, *Empoasca kerri* Pruthi; pod borer, *Maruca testulalis* Geyer; stem fly, *Ophiomyia phaseoli* (Tryon.); semilooper, *Plusia orichalcea* (Hubner); cutworm, *Agrotis ipsilon* (Hufnagel); galerucid beetle *Madurasia obscurella* Jacoby; green bug, *Nezara viridula* L.; pod borer, *Helicoverpa armigera* (Hubner) and blue beetle, *Raphidopalpa intermedia* are important (Dar et al 2002). Leafhoppers, *Empoasca kerri* Pruthi, and bean aphids, *Aphis craccivora* Koch, are two of the most prominent sap-feeding insects, causing detriment to the leaves and pods, respectively (Swaminathan et al 2007). Farmers use synthetic chemical pesticides inappropriately to manage insect pests, resulting in the recurrence of insect pests, the elimination of natural enemies, development of resistance and pesticide residues in food and the ecosystems. The development of an eco-friendly strategy is critical to overcoming the challenges related with the usage of insecticides. Silicon use has been reported as a novel approach for the control of green gram insect pests. Meena et al (2014) reported that deposition of silica on epidermal layers offers a physical barrier to insects of rice. Sucking pests and leaf eating caterpillars have a low preference for the silicified plant tissues. The objective of the present study was to evaluate the response of green gram crop to the Si formulation that could enhance anti-herbivore resistance against leaf hopper *E. kerri*.

MATERIAL AND METHODS

Field experiment was conducted at Nattapatti, Madurai district situated between latitude 9.97º N and longitude 77.85º E to evaluate the effects of foliar application of silicon fertilizers on *E. kerri*. The area is semiarid with a mean annual rainfall of 880 mm and 218 meters from above mean sea level. Field trial was carried out during *Rabi*, 2022. The experiment was laid out in a Randomised block design with three replications and twelve treatment combinations with plot size of 20m^2. The treatments comprised of T_1=Foliar spray of silicic acid @ 0.1%, T_2=Foliar spray of silicic acid @ 0.2%, T_3=Foliar spray of potassium silicate @ 0.5%, T_4=Foliar spray of potassium silicate @ 1.0%, T_5=T_1 + Gibberellic acid @ 50 ppm, T_6= T_2 + Gibberellic acid @ 100 ppm, T_7=T_3 + Gibberellic acid @ 50 ppm, T_8=T_4 + Gibberellic acid @ 100 ppm, T_9=Silicate Solubilizing Bacteria @ 2 kg ha^{-}

[1], T_{10}=Neem oil @ 2%, T_{11}=Chlorpyriphos 20 EC @ 1.5 ml/l, and T_{12}=Untreated check. Foliar spray was done at 10, 20, 30 and 40 Days After Sowing. All foliar sprays were applied by a 10 l volume knapsack sprayer. Foliar application of silicic acid and potassium silicate was done at 10 DAS & 20 DAS and gibberellic acid at 30 DAS & 40 DAS.

For the cultivation of green gram, all of the agronomical practices recommended by the crop production guide were followed (CPG 2021). In all plots except the untreated control, silicon nutrients were foliar sprayed at their respective doses. The population density of nymphs and adults of the leafhopper, *Empoasca kerri*, was assessed in three randomly selected leaves from the top, middle, and bottom of 10 randomly selected plants. The pretreatment population counts for the first spray were taken one day before the first spraying, and the post-treatment population counts were taken after third and ninth day of each spray from ten randomly selected plants each replicate (Fleming and Retnakaran 1985). The data collected were subjected to statistical analysis of variance by SPSS software and means were compared with Tukey's test at P≤0.05 (Tukey 1977).

RESULTS AND DISCUSSION

All the treatments were effective over the untreated check in reducing leaf hopper population (Table 1). After first spray, the treatment with foliar spray of potassium silicate @ 0.5% and gibberellic acid @ 50 ppm recorded minimum leaf hopper population of 1.01 per plant followed by foliar spray of potassium silicate @ 1.0% and gibberellic acid @ 100 ppm and the untreated check (2.41 insects/plant). Similarly after second spray, the treatment with foliar spray of potassium silicate @ 1.0% and gibberellic acid @ 100 ppm minimum mean leaf hopper population of 0.90 numbers per plant which was on par with foliar spray of potassium silicate @ 0.5% and gibberellic acid @ 50 ppm (0.93 numbers per plant). After third spray, untreated check recorded maximum mean leaf hopper of population (2.57 insects/plant) and the treatment with foliar spray of potassium silicate @ 1.0% and gibberellic acid @ 100 ppm recorded minimum mean leaf hopper population of 0.47 numbers per plant followed by foliar spray of potassium silicate @ 0.5% and gibberellic acid @ 50 ppm (0.69 numbers per plant). On fourth spray, the same trend was observed among different treatments. Hence, in the present study, minimum population of leaf hopper was recorded with foliar spray of potassium silicate @ 1.0% and gibberellic acid @ 100 ppm which was significantly effective at third and fourth spray than other treatments but on par with foliar spray of potassium silicate @ 0.5% and gibberellic acid @ 50 ppm at second spray. Nikpay and Laane (2020) who reported that four spray application of silicic acid was more effective than other treatments on sugarcane mite damage. Ramirez-Godoy et al (2018) showed that application of

Table 1. Efficacy of different sources of silica against leaf hopper, *Empoasca kerri* on green gram

Treatments	No of leaf hopper/ plant*												
	Pre-count	I Spray			II Spray			III Spray			IV spray		
		3 DAS	9 DAS	Mean	3 DAS	9 DAS	Mean	3 DAS	9 DAS	Mean	3 DAS	9 DAS	Mean
T_1 Silicic acid @ 0.1%	1.88	1.78^{ab}	1.69^{ab}	1.73^{bc}	1.62^{b}	1.56^{bc}	1.59^{bc}	1.45^{c}	1.41^{c}	1.43^{d}	1.30^{c}	1.19^{c}	1.24^{d}
T_2 - Silicic acid @ 0.2%	1.71	1.69^{ab}	1.61^{a}	1.65^{bc}	1.55^{b}	1.47^{abc}	1.51^{b}	1.55^{c}	1.35^{c}	1.45^{d}	1.24^{c}	1.12^{c}	1.18^{cd}
T_3 - Potassium silicate @ 0.5%	1.63	1.63^{ab}	1.55^{ab}	1.59^{ab}	1.48^{b}	1.40^{abc}	1.44^{b}	1.31^{bc}	1.23^{bc}	1.27^{cd}	1.11^{bc}	1.02^{bc}	1.07^{cd}
T_4 - Potassium silicate @ 1.0%	1.69	1.57^{ab}	1.50^{ab}	1.53^{ab}	1.40^{ab}	1.33^{abc}	1.37^{ab}	1.21^{bc}	1.10^{bc}	1.16^{cd}	0.99^{bc}	0.85^{bc}	0.92^{bcd}
T_5 - T_1 + Gibberellic acid @ 50 ppm	1.81	1.51^{ab}	1.45^{ab}	1.48^{ab}	1.42^{ab}	1.21^{ab}	1.31^{ab}	1.08^{abc}	0.98^{abc}	1.03^{bcd}	0.87^{bc}	0.93^{bc}	0.90^{bcd}
T_6 - T_2 + Gibberellic acid @ 100 ppm	1.88	1.47^{ab}	1.33^{ab}	1.40^{ab}	1.21^{ab}	1.09^{ab}	1.15^{ab}	0.96^{abc}	0.81^{abc}	0.89^{bc}	0.70^{abc}	0.58^{ab}	0.64^{abc}
T_7 - T_3 + Gibberellic acid @ 50 ppm	1.45	1.26^{ab}	1.07^{a}	1.01^{a}	0.97^{ab}	0.89^{ab}	0.70^{a}	0.73^{ab}	0.65^{ab}	0.69^{ab}	0.52^{ab}	0.44^{ab}	0.48^{ab}
T_8 - T_4 + Gibberellic acid @ 100 ppm	1.56	1.08^{a}	0.94^{a}	1.17^{ab}	0.81^{a}	0.64^{a}	0.73^{a}	0.51^{a}	0.43^{a}	0.47^{a}	0.35^{a}	0.27^{a}	0.31^{a}
T_9 - Silicate Solubilizing Bacteria @ 2 Kg/ha	1.89	1.89^{ab}	1.89^{ab}	1.61^{ab}	1.66^{bc}	1.60^{abc}	1.63^{cd}	1.53^{c}	1.47^{c}	1.50^{d}	1.36^{c}	1.24^{c}	1.30^{d}
T_{10} – Neem oil @ 2%	1.64	1.63^{ab}	1.34^{ab}	1.59^{ab}	1.48^{b}	1.40^{abc}	1.44^{b}	1.31^{ab}	1.23^{bc}	1.27^{cd}	1.11^{bc}	1.02^{bc}	1.07^{cd}
T_{11} – Chlorpyriphos 20EC @ 1.5 ml/l	1.34	1.57^{ab}	1.55^{ab}	1.53^{ab}	1.40^{ab}	1.33^{abc}	1.37^{ab}	1.21^{bc}	1.10^{bc}	1.16^{cd}	0.99^{bc}	0.85^{bc}	0.92^{bcd}
T_{12} - Untreated check	1.67	2.30^{b}	2.51^{b}	2.41^{c}	2.55^{c}	2.41^{c}	2.48^{c}	2.48^{d}	2.66^{d}	2.57^{e}	2.45^{d}	2.30^{d}	2.38^{d}

* Mean values of three replications; Means followed by the same letter (s) are not significantly different at p≤ 0.05 by Tukey's test; DAS – Days After Sowing

silicon in the form of potassium silicate (2 ml/L) significantly reduced the oviposition rate of *Diaphorina citri* up to 60% in Tahiti lime.

Callis-Duehl et al (2017) reported that application of potassium silicate solution (30 ml of 2 mM), reduced number of *Bemisia tabaci* on cucumber leaves whereas the number of whiteflies on untreated cucumber leaves was higher (44.5%). This finding revealed that a *B. tabaci* population has less preference to treated silicon plants. Almeida et al (2009) also observed that the mortality of *Frankliniella schultzei* nymphs was significantly higher in the calcium silicate alone @ 15g/L and calcium silicate plus organic mineral fertilizer treatments than in the control, with an increase of 50% insect mortality in calcium silicate alone compared with control. Alyousuf et al (2021) demonstrated that application of silicic acid @ 0.8% significantly decreased the population of whitefly and tomato leaf miner on tomato crop in the greenhouse.

CONCLUSION

The use of potassium silicate combined with gibberellic acid reduced the number of leaf hoppers on green gram significantly. In organic farming, the use of silicon products is widely accepted, and it may be considered as a suitable, effective, and eco-friendly strategy for reducing pest in the field condition.

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Screening of Bottle Gourd Genotypes/ Varieties for Resistance against Red Pumpkin Beetle *Raphidopalpa foveicollis* (Lucas) in Semi- arid Region of Rajasthan

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Abstract: Field experiment was carried out on screening of bottle gourd genotypes/ varieties for resistance against red pumpkin beetle, *Raphidopalpa foveicollis* (Lucas) were conducted at Horticulture farm, S.K.N. College of Agriculture, Jobner during *Kharif*, 2018.Among eight genotypes/ varieties of bottle gourd screened for resistant against red pumpkin beetle, none was found completely free from the attack of this pest. However, based on beetle population and leaf damage varieties Arka Bahar and Narendra Rashmi were found highly resistant genotypes; PL-3, DBG-5, DBG-6 and variety Pusa Smaridhi were moderately resistant and varieties Pusa Naveen and PSPL were least resistant to red pumpkin beetle.

Keywords: Bottle gourd, Red pumpkin beetle, Genotypes/ varieties, Resistance, Leaf damage

Bottle gourd, *Lagenaria siceraria* (Molina) Stand. belong to family, Cucurbitaceae is one of the important vegetable crop grown throughout the India and used as cardio-tonic, aphrodisiac, hepatic protective, anti-inflammatory, analgesic, expectorant, antioxidant agents and diuretic. In an area of 1.56 lakh hectares with the total production of 26.83 lakh tones (Anonymous 2017a). In Rajasthan bottle gourd is cultivated in an area of 4,673 hectares with an average production of 27,168 metric tons and productivity of 5,814 Kg/ hectares (Anonymous 2017b). There is a challenge to achieve the target of 182 million tons of vegetables. The red pumpkin beetle, *R. foveicolls* is a widely distributed polyphagous pest of cucurbit crops and bottle gourd is the most preferred host for this pest.The beetles feed voraciously on leaves, flower buds and flowers which may reach up to 35-75 percent at seedling stage. In some cases the losses of this pest were reported to 30-100 percent in the field (Rashid *et al* 2014). The development of varieties resistant to cucurbit pests is an important component for an integrated pest management. The pests resistant bottle gourd varieties have been limited, because of the lack of adequate information on the genetic variability and sources of resistance in the available genotypes and influence of these sources on the pest multiplication. Therefore, it becomes imperative to identify sources of resistance in bottle gourd. Hence, keeping in view the above facts, the present investigation was carried out to screening the bottle gourd varieties against red pumpkin beetle.

MATERIAL AND METHODS

The present investigations on screening of bottle gourd genotypes/ varieties for resistance against red pumpkin beetle were carried out at Horticulture farm, S.K.N. College of Agriculture Jobner, Jaipur during *Kharif,* 2018. Three genotypes (PL-3, DBG-5, DBG-6) and five varieties (Pusa Naveen, Arka Bahar, PSPL, Pusa Smaradhi, Narendra,Rashmi) of bottle gourd were screened for their comparative resistance to red pumpkin beetle. These were sown on 28th June, 2018 in randomized block design in the plots of 4.0 m x 0.5 m size with row to row and plant to plant distance of 2.5 m and 0.5 m, respectively, and each replicated thrice. All the recommended agronomical practices except pest control were followed to raise the crop.

Observations: The population of red pumpkin beetle, *R. foveicollis* was recorded on five randomly selected and tagged plants per plot early in the morning hours on whole parts of the plant. The populations were recorded from initiation of the pest at weakly interval till last picking (absolute counts). The percent leaf damage was also being recorded at weekly interval. The data obtained were statistically analyzed.

$\bar{X} \pm$

Where,

$\bar{X}$=Mean of peak insect population.

= Standard deviation of peak insect population.

RESULTS AND DISCUSSION

Population of red pumpkin beetle on bottle gourd: The

Mean insect population/ plant	Category
Below $\overline{X}$ -	Highly resistant
$\overline{X}$ - to $\overline{X}$ +	Moderately resistant
Above $\overline{X}$ +	Least resistant

mean red pumpkin beetle population of all the observations ranged from 0.75 to 4.38 beetles per plant (Table 1). The minimum beetle population was recorded on variety Arka Bahar, followed by Narendar Rashmi and both were differed non-significantly with each other in their degree of infestation. The variety PL-3 (1.95 beetles/ plant) also differed non-significant with Narendra Rashmi. The maximum beetle population was recorded on variety Pusa Naveen (4.38 beetles/ plant), followed by PSPL and these were at par with each other in their degree of infestation, the later was also at par with Pusa Smaradhi (3.32 beetles/ plant). The rest of the genotypes *viz*., DBG-6, and DBG-5 found in middle order of infestation which exhibited beetle population of 2.65 and 2.87 per plant, respectively. The ascending order of red pumpkin beetle infestation in different varieties and genotypes of bottle gourd was found in order: Arka Bahar < Narendra Rashmi < PL-3 < DBG-6 < DBG-5 < Pusa Smaradhi < PSPL < Pusa Naveen. Based on the statistical categorization ($\overline{X} \pm \sigma$), the varieties/ genotypes having mean population of red pumpkin beetle below 1.34 per plant, were categorized as highly resistant, between 1.34-3.92 per plant were categorized as moderately resistant and above 3.92 per plant, were categorized as least resistant.

Mean leaf damage (%)	Genotypes/ varieties	Category
Below 8.80	Arka Bahar, Narendra Rashmi	Highly resistant
8.80-15.84	PL-3, DBG-6, DBG-5, Pusa Smaradhi	Moderately resistant
Above 15.84	Pusa Naveen, PSPL	Least resistant

Leaf damage caused by red pumpkin beetlein different genotypes/ varieties of bottle gourd: The mean leaf damage of all the observations ranged from 7.21 to 17.17 per cent (Table 2). The minimum leaf damage was recorded on variety Arka Bahar (7.21 %) followed by Narendar Rashmi (8.26 %) and both were differed non-significantly with each other. The maximum leaf damage was recorded on variety Pusa Naveen (17.17 %) followed by PSPL (15.96 %) and both were at par with each other, the later was also at par with variety Pusa Smaradhi (14.37 %). The genotypes *viz*., PL-3, DBG-6 and DBG-5 exhibited leaf damage of 10.73, 11.94 and 12.90 per cent, respectively. The ascending order of leaf damage in different varieties and genotypes of bottle gourd was found in order: Arka Bahar < Narendra Rashmi < PL-3 <

Table 1. Population of red pumpkin beetlein different genotypes/ varieties of bottle gourd

Varieties/ genotypes	Mean population of red pumpkin beetle/ plant at weekly interval													
	06 August	13 August	20 August	27 August	03 September	10 September	17 September	24 September	01* October	08 October	15 October	22 October	29 October	Mean
Pusa Naveen	1.80 (1.52)	4.10 (2.14)	3.70 (2.05)	4.20 (2.17)	3.80 (2.07)	4.0 (2.12)	4.60 (2.26)	4.40 (2.21)	6.50 (2.64)	6.30 (2.61)	6.0 (2.55)	4.50 (2.24)	2.50 (1.73)	4.38 (2.23)
P L- 3	0.50 (0.99)	2.10 (1.61)	2.0 (1.58)	1.80 (1.51)	1.70 (1.48)	1.80 (1.51)	1.90 (1.55)	1.70 (1.48)	3.30 (1.95)	3.0 (1.87)	2.80 (1.83)	2.10 (1.61)	0.70 (1.07)	1.95 (1.55)
Arka Bahar	0.00 (0.71)	0.20 (0.83)	0.10 (1.77)	0.20 (0.83)	0.20 (0.83)	0.30 (0.88)	0.90 (1.18)	0.70 (1.08)	2.30 (1.67)	2.20 (1.64)	1.50 (1.41)	1.0 (1.22)	0.20 (0.84)	0.75 (1.11)
PSPL	1.50 (1.41)	3.60 (2.02)	3.30 (1.95)	3.40 (1.97)	3.60 (2.02)	3.80 (2.07)	4.10 (2.14)	3.90 (2.10)	6.20 (2.59)	5.90 (2.53)	5.80 (2.51)	4.10 (2.14)	2.30 (1.67)	3.96 (2.10)
DBG- 5	0.90 (1.18)	2.30 (1.67)	2.40 (1.70)	2.40 (1.70)	2.60 (1.75)	2.80 (1.81)	3.20 (1.92)	3.10 (1.89)	4.50 (2.24)	4.30 (2.19)	3.90 (2.10)	3.30 (1.95)	1.70 (1.48)	2.87 (1.84)
Pusa Smaradhi	1.20 (1.30)	2.80 (1.82)	3.0 (1.87)	3.0 (1.87)	3.10 (1.89)	3.30 (1.95)	3.60 (2.02)	3.40 (1.97)	5.0 (2.32)	4.70 (2.25)	4.60 (2.24)	3.60 (2.02)	1.90 (1.55)	3.32 (1.94)
DBG- 6	0.80 (1.14)	2.20 (1.64)	2.40 (1.69)	2.30 (1.67)	2.20 (1.64)	2.40 (1.70)	3.10 (1.90)	2.40 (1.70)	4.40 (2.21)	4.20 (2.17)	3.80 (2.07)	2.80 (1.81)	1.50 (1.41)	2.65 (1.75)
Narendra Rashmi	0.20 (0.84)	0.30 (0.89)	0.20 (0.84)	0.30 (0.89)	0.40 (0.94)	0.60 (1.03)	1.60 (1.44)	1.20 (1.30)	2.80 (1.82)	2.70 (1.79)	2.50 (1.73)	1.70 (1.48)	0.40 (0.94)	1.14 (1.28)
C.D.(p=0.05)	0.15	0.20	0.23	0.24	0.18	0.20	0.22	0.22	0.26	0.32	0.27	0.21	0.20	0.27

Figures in the parentheses are $\sqrt{X+0.5}$ values; * Peak population of red pumpkin beetle during the crop season

Table 2. Leaf damage caused by red pumpkin beetlein different genotypes/ varieties of bottle gourd (Number basis)

Varieties/ genotypes	Leaf damage (%) at weekly interval													
	06 August	13 August	20 August	27 August	03 September	10 September	17 September	24 September	01* October	08 October	15 October	22 October	29 October	Mean
Pusa Naveen	4.44 (12.16)	12.88 (21.03)	12.44 (20.65)	13.33 (21.41)	14.22 (22.15)	15.11 (22.87)	22.33 (28.20)	21.88 (27.89)	29.33 (32.79)	25.78 (30.51)	23.55 (29.03)	17.33 (24.60)	10.66 (19.05)	17.17 (24.43)
PL- 3	2.22 (8.55)	6.22 (14.35)	5.33 (13.36)	6.66 (14.96)	8.0 (16.43)	9.33 (17.78)	15.55 (23.18)	15.11 (22.83)	21.33 (27.51)	17.33 (24.60)	15.11 (22.87)	10.66 (19.06)	6.66 (14.96)	10.73 (19.12)
Arka Bahar	0.00 (0.0)	1.33 (6.61)	0.88 (5.40)	2.22 (8.56)	4.88 (12.76)	5.33 (13.35)	12.00 (20.23)	11.55 (19.82)	17.33 (24.60)	14.22 (22.15)	12.00 (20.27)	6.66 (14.95)	5.33 (13.35)	7.21 (15.58)
PSPL	4.00 (11.52)	11.55 (19.86)	10.66 (19.07)	12.88 (21.02)	13.33 (21.40)	14.22 (22.15)	20.22 (26.72)	19.77 (26.41)	28.00 (31.95)	24.44 (29.63)	22.66 (28.43)	16.00 (23.56)	9.77 (18.21)	15.96 (23.52)
DBG- 5	3.11 (10.13)	7.55 (15.95)	7.11 (15.46)	8.44 (16.89)	10.22 (18.64)	11.55 (19.87)	17.33 (24.60)	16.88 (24.26)	24.44 (29.63)	20.44 (26.88)	18.44 (25.43)	13.77 (21.78)	8.44 (16.89)	12.90 (21.04)
Pusa Smaradhi	3.55 (10.86)	9.33 (17.77)	8.88 (17.33)	9.77 (18.20)	11.55 (19.82)	13.33 (21.39)	19.11 (25.92)	18.66 (25.58)	26.22 (30.80)	22.22 (28.12)	20.00 (26.56)	14.88 (22.67)	9.33 (17.78)	14.37 (22.28)
DBG- 6	2.66 (9.38)	7.11 (15.29)	6.66 (14.80)	7.55 (15.81)	9.33 (17.69)	10.22 (18.57)	16.44 (23.92)	16.00 (23.57)	23.11 (28.73)	19.11 (25.92)	17.11 (24.43)	12.44 (20.60)	7.55 (15.93)	11.94 (20.21)
Narendra Rashmi	0.88 (5.37)	2.22 (8.56)	1.33 (6.62)	2.66 (9.38)	5.78 (13.90)	7.11 (15.46)	13.33 (21.40)	12.88 (21.03)	18.66 (25.50)	15.55 (23.12)	13.33 (21.31)	8.00 (16.43)	5.77 (13.87)	8.26 (16.68)
C.D.(p=0.05)	1.06	2.12	1.90	1.90	1.93	1.84	2.0	2.02	1.88	1.80	1.64	1.68	1.09	1.47

Figures in the parentheses are angular transformed values; * Maximum damage

DBG-6 < DBG-5 < Pusa Smaradhi < PSPL < Pusa Naveen.Based on the statistical categorization ($\bar{X} \pm \sigma$), the varieties/ genotypes having mean leaf damage below 8.80 per cent, were categorized as highly resistant, between 8.80-15.84 per cent were categorized as moderately resistant and above 15.84 per cent, were categorized as least resistant.

Red pumpkin beetle population per plant	Genotypes/ varieties	Category
Below 1.34	Arka Bahar, Narendra Rashmi	Highly resistant
1.34-3.92	PL-3, DBG-6, DBG-5, Pusa Smaradhi	Moderately resistant
Above 3.92	Pusa Naveen, PSPL	Least resistant

The present finding are in conformity with Shrikrushna (2012) where out of 25 promising varieties of bottle gourd screened against *A. foveicollis* in field condition, none was found free from beetle incidence. The varieties *viz.,* Arka Bahar, Dharwad, Narendra Rashmi, Wardan, NDBGH-4 and Narendra Madhuri was less susceptible to red pumpkin beetle and varieties/ cultivars *viz.,* Dharwad Selection, Kashi Ganga-10, NS-421, Warad, Punjab Komal, Kashi Ganga, Narendra Shiwani, Narendra Shishir, NDBG-613-4, Narendra Shiwani Selection, Pusa Santusti and Pusa Samrudhi as moderately susceptible while, Jabalpur Local (Long) was highly susceptible. Satpathy *et al.* (2002) reported bottle gourd germplasm VRBG-91 as resistant and VRBG-105 susceptible to red pumpkin beetle. Saljoqi and Khan (2007) observed three bottle gourd varieties, DIK Round Green, SW Sweet Yellow and Bottle gourd Long as moderately susceptible to the attack of the red pumpkin beetle. The similar type of work on varietal resistance in different crop was also reported by (Ram et al (2009), Khursheed et al (2013), Dubale et al (2018) and Bisen et al (2018).

CONCLUSION

Among the eight genotypes/ varieties of bottle gourd screened against red pumpkin beetle none was found completely free from their attack. The varieties Arka Bahar and Narendra Rashmi were highly resistant, genotypes PL-3, DBG-5, DBG-6 and verity Pusa Smaridhi were moderately resistant and varietis Pusa Naveen and PSPL were least resistant against red pumpkin beetle.

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Comparative Study on Demographic Traits and Knowledge Levels of Farmers, Input Dealers and Spray Men on Health Hazards in Pesticide Handling

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Abstract: The study mainly focuses on comparing the knowledge levels of farmers, input dealers and spray men who are extensively involved in pesticide handling and also the demographic traits contributing to the same. The study was carried out in Theni district of Tamil Nadu by selecting four blocks that are leading in pesticide consumption in the district. 100 farmers were selected proportionately, 30 input dealers and 30 spray men were selected by adopting snowball sampling method. Data has been collected from the selected samples using a well-prepared interview schedule. The investigation infers that very few respondents are having a high level of knowledge, even among them the contribution of farmers and spray men who are directly exposed to pesticides is very low.

Keywords*:* Knowledge, Health hazards, Pesticides, Farmers, Input dealers, Spray men

Pesticides became a crucial aspect of modern farming and play a key role in enhancing agricultural productivity. However, the excessive and indiscriminate use of pesticides is one of most serious environmental and public health issues. Pesticides can cause secondary pest outbreaks, biodiversity loss, contamination of soil, water, and air, and residues in primary and derived agricultural products, all of which are hazardous to the environment and human health (Jallow et al 2017). Pesticide poisoning has become more common throughout the world, with an estimated count of 1 to 41 million people suffering health consequences as a result of pesticide exposure annually. World Health Organization (WHO) reported that pesticide poisoning kills around 0.3 million people annually of which 99 per cent of mortalities occur in developing and underdeveloped countries (Okoffo et al 2016). Pesticide exposure can lead to reproductive crisis, birth defects, immune malfunctions, endocrine instabilities, an increase in testicular cancer, dermatitis, behavioural changes, cancers, neurobehavioral disorders, and immunotoxicity (PAN International 2007, Gill and Garg 2014). Even though the pesticides are causing the above-mentioned health hazards, the consumption of chemical pesticides in India has drastically increased from 58,634 MT in 2016-17 to 62,193 MT in 2020-21 (Directorate of Plant Protection, Quarantine, and Storage, 2022). Farmers' exposure to pesticide-related problems is surging due to insufficient knowledge on health hazards due to pesticides, and also proper and safe use of pesticides and personal protective equipment (Blanco et al 2011, Jallow et al 2017). This study mainly focuses on comparing the knowledge levels of farmers, input dealers and spray men who are extensively involved in pesticide handling and also the demographic traits contributing to the same.

MATERIAL AND METHODS

The study was carried out in Theni district of Tamil Nadu by selecting four blocks that are leading in pesticide consumption in the district namely Aundipatti, Cumbum, Uthamapalayam, and Chinnamanur. The research design adopted was "Ex-post facto Research design". The total sample size for the study was 160 of which the samples are categorized into farmers, input dealers and spray men. A list of farmers has been collected from the office of the Department of Horticulture. With the use of the above gathered secondary data, proportionate random sampling has been followed in consideration with the total number of farmers in that particular village to draw a hundred farmers being selected as samples for the study. Input dealers and spray men were selected by adopting the snowball sampling method throughout the district. Primary data has been collected from the above-mentioned samples with the use of a well-structured interview schedule specially framed by the researcher for the study. The collected data were coded and analyzed using SPSS software.

RESULTS AND DISCUSSION

Knowledge on acute symptoms of health hazards: Most of the farmers are having sufficient knowledge of the cause of skin irritation, rashes, headache (99%) nausea, vomiting (95%) and dizziness (83%) due to improper pesticide handling practices (Table 1). The findings are similar to Satya Sai et al (2019). More than two-thirds of the farmers knew the cause of eye, nose, throat irritation (72%), breathing trouble (77%), excessive sweating and fever (75%), insomnia (78%), and loss of appetite (79%) due to experience and perception about health risks. Because of their medium level of innovativeness and social participation, more than half of the farmers knew that blurred vision, stinging eyes (52%) stomach aches, and diarrhea (62%) were caused due to improper pesticide handling practices. Nearly one-fourth of the farmers knew the cause of nose bleeding (27%) and muscle weakness (25%). The considerable reason for this may be, that more than half of the farmers were educated at a lower middle school level. Similar findings have been reported by Jallow et al (2017) and Kumari et al (2018). All the input dealers knew the cause of skin irritation, rashes, Nausea, vomiting, headache, eye, nose, throat irritation, breathing trouble, stomach aches, diarrhea, excessive sweating and fever, dizziness, insomnia, loss of appetite, and the majority of the input dealers knew the cause of nose bleeding (93%) due to improper pesticide handling practices. Because cent per cent of the input dealers are educated with either diploma or collegiate and attended training programs on pesticide handling and their negative impacts. Since the input dealers are not directly involved in pesticide spraying, only half of the input dealers knew the cause of blurred vision, stinging eyes (50%) and muscle weakness (53%). All spray men knew the cause of skin irritation, rashes, nausea, vomiting, and headache, and also majority of the spray men

Table 1. Knowledge levels of farmers, input dealers, and spray men on health hazards

Health hazards	Knowledge level of respondents					
	Farmers		Input dealers		Spray men	
	No.	%	No.	%	No.	%
Acute symptoms						
Skin irritation and rashes	99	99.00	30	100.00	30	100.00
Nausea and vomiting	95	95.00	30	100.00	30	100.00
Headache	99	99.00	30	100.00	30	100.00
Blurred vision and stinging eyes	55	55.00	15	50.00	22	73.33
Eye, Nose, Throat irritation	72	72.00	30	100.00	27	90.00
Breathing trouble	77	77.00	30	100.00	26	86.67
Nose bleeding	27	27.00	28	93.33	6	20.00
Stomach aches and diarrhea	62	62.00	30	100.00	26	86.67
Excessive sweating and fever	75	75.00	30	100.00	24	80.00
Dizziness	83	83.00	30	100.00	25	83.33
Insomnia	78	78.00	30	100.00	24	80.00
Loss of appetite	79	79.00	30	100.00	27	90.00
Muscle weakness	25	25.00	16	53.33	27	90.00
Death due to suicidal poisoning	100	100.00	30	100.00	30	100.00
Chronic symptoms						
Reproductive problems	21	21.00	22	73.33	8	26.67
Birth defects	6	6.00	22	73.33	5	16.67
Respiratory disorders and Asthma	64	64.00	29	96.67	25	83.33
Nervous system problems	16	16.00	23	76.67	11	36.67
Immunotoxicity	26	26.00	16	53.33	11	36.67
Unconsciousness	26	26.00	25	83.33	14	46.67
Kidney failure	13	13.00	18	60.00	7	23.33
Cancer	21	21.00	19	63.33	10	33.33
Death due to residual poisoning	16	16.00	29	96.67	10	33.33

knew the cause of eye, nose, throat irritation, muscle weakness, and loss of appetite (90%), breathing trouble, stomach aches and diarrhea (86%), dizziness (83%), excessive sweating, fever, and insomnia (80%). Nearly three fourth of the spray men knew the cause of blurred vision and stinging eyes (73%). The considerable reason behind the knowledge about these factors is they are directly involved in the spray process and also possess a high level of perception about the health risk. Even though, only 20 per cent of the spray men knew the cause of nose bleeding due to their low educational status. Similar findings have been encountered by (Kumari et al 2018). Since suicidal poisoning is a readily observable phenomenon faced in day-to-day life by every member of the society, cent per cent of the farmers, input dealers, and spray men were aware of this crisis. The findings are similar to Kumari et al (2018).

Knowledge on chronic symptoms of health hazards: The 64 per cent of farmers knew the cause of respiratory disorders and asthma due to improper and long-term exposure to pesticides. This may be due to their own experience and medium to high level of social participation. Since the chronic symptoms are long-term effects in nature, a very few per cent of farmers have noticed it. Namely, immunotoxicity and unconsciousness (26%), reproductive problems and cancer (21%), Nervous system problems and death due to residual poisoning (16%), kidney failure (13%), and birth defects (6%). The findings are in line with Goldsmith (1988). A majority of the input dealers knew the cause of respiratory disorders, asthma, and death due to residual poisoning (96%), and unconsciousness (83%). Nearly three fourth of the input dealers knew the cause of nervous system problems (76%), reproductive problems, and birth defects (73%). About 63 percent of the input dealers knew that the pesticides can cause cancers followed by kidney failure (60%), and immunotoxicity (53%). All the Input dealers possess a higher education level, innovativeness, and health risk perception. This may be considered as the possible reason behind it. About 83 per cent of the spray men knew the cause of respiratory disorders and asthma due to improper and long-term exposure to the pesticides. This may be due to their daily experiences while spraying pesticides and high levels of perception about the health risk. In the meantime, very few per cent of spray men have noticed the causes of unconsciousness (46%), nervous disorders and immunotoxicity (36%), cancers and deaths due to residual poisoning (33%), reproductive problems (26%), kidney failure (23%), and birth defects (16%). The considerable reasons behind these are, the majority of the spray men lie under lower educational level and social participation and also not attended any trainings. Similar findings have been reported by Goldsmith (1988) and Kim et al (2017).

Knowledge on toxicity colour codes: Majority of the spray men and three fourth of the farmers knew that the toxicity colour codes red (96% and 71%) is known for extremely toxic, and green (96% and 73%) for slightly toxic respectively. Because, red and green colours are universally known for danger and nature and also, medium to high levels of innovativeness may be the reason for remembering those colour codes easily by the spray men and the farmers. But only 66 per cent and 76 per cent of the spray men and 36 per cent and 42 per cent of the farmers knew that yellow is for highly toxic and blue is for moderately toxic respectively. Because most of the spray men and farmers are finding difficulties in contrasting and remembering these two colour

Table 2. Knowledge levels of farmers, input dealers, and spray men on toxicity colour codes

Toxicity colour codes	Farmers		Input dealers		Spray men	
	No.	%	No.	%	No.	%
Red (Extremely toxic)	71	71.00	30	100.00	29	96.67
Yellow (Highly toxic)	36	36.00	30	100.00	20	66.67
Blue (Moderately toxic)	42	42.00	30	100.00	23	76.67
Green (Slightly toxic)	73	73.00	30	100.00	29	96.67

Table 3. Knowledge levels of farmers, input dealers, and spray men on exposure to pesticides in the human body

Exposure to pesticides in the human body	Farmers		Input dealers		Spray men	
	No.	%	No.	%	No.	%
Oral exposure	100	100.00	30	100.00	30	100.00
Dermal exposure	22	22.00	28	93.33	12	40.00
Inhalation exposure	82	82.00	30	100.00	29	96.67
Ocular exposure	47	47.00	29	96.67	16	53.33

codes and also most of them were not attended any training programs regarding safe pesticide handling. Since input dealers are from a well-educated background, cent per cent of them were aware of the toxicity colour codes. The findings are in contradictory with Kumari et al (2018) and Pandher et al (2021).

Knowledge on exposure to pesticides in the human body: The majority of the spray men (96%) and farmers (82%) knew the inhalation exposure and almost half of the spray men (53%) and farmers (47%) knew the ocular exposure of pesticides respectively. But only 40 per cent of the spray men and 22 per cent of the farmers knew the dermal exposure of pesticides in the human body. The probable factors behind this may be their deficient training and educational levels. Because of their high educational status and health risk perception. All the input dealers knew about the inhalation exposure. Majority of them knew ocular

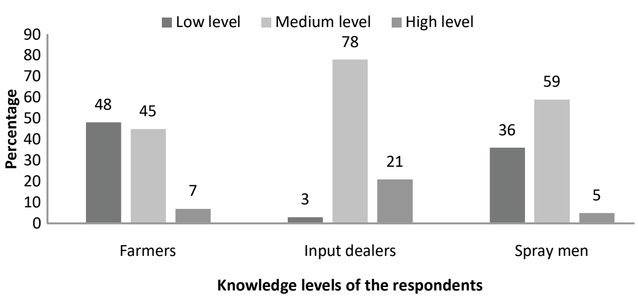

Fig. 1. Overall knowledge levels of farmers, input dealers, and spray men on health hazards in pesticide handling

Table 4. Relationship between the demographic traits and knowledge levels of farmers, input dealers and spray men

Demographic traits	Farmers	Input dealers	Spray men
Age	- 0.177	-0.407*	-0.352
Educational status	0.752**	0.605**	0.372*
Experience	0.465**	0.126	0.478**
Annual income	0.190	-0.069	0.155
Type of family	0.066	0.080	0.028
Source of information	0.236*	0.450*	0.521**
Social participation	0.282**	0.174	0.179
Innovativeness	0.203*	0.411*	0.617**
Decision making pattern	0.156	0.381*	0.429*
Training undergone on safe handling of pesticides	0.530**	0.126	0.394*
Risk orientation	0.553**	0.424*	0.496*
Perception about health risk	0.720**	0.465**	0.524**

**Significant at one percent level, *Significant at five percent level

(96%) and dermal (93%) exposures to pesticides in the human body. Since oral exposure is a readily observable phenomenon faced in day-to-day life by every member of the society, all the farmers, input dealers, and spray men were aware of this factor. Similar results have been earlier researches (Karunamoorthi et al 2011, Okoffo et al 2016, Jallow et al 2017, Kim et al 2017, Adesuyi et al 2018).

Overall knowledge on health hazards in pesticide handling: The 48 per cent of the farmers have low knowledge category followed by medium (45%) knowledge level. A small number of vegetable farmers (7%) alone belong to a high level of knowledge. Similar results have been reported previously by Jallow et al (2017) and Adesuyi et al (2018). Likewise, most of the spray men are having medium knowledge level (59%) followed by low (36%) knowledge level. Only a few spray men are having high (5%) knowledge level. The majority (78%) of the input dealers are lying under the medium knowledge level followed by high (21%) and low (3%) knowledge levels.

Relationship between the demographic traits and knowledge levels of farmers, input dealers, and spray men: Among the demographic traits, age is having an inverse relation with the farmer's knowledge level., The findings are symmetrical to earlier researchers (Blanco et al 2011, Adesuyi et al 2018, Taghdisi et al 2019 and Pandher et al 2021) Whereas, experience, source of information, social participation, innovativeness, training undergone on safe handling of pesticides, risk orientation and perception about health risk are having a significant and positive relation with the knowledge level of farmers. Similar findings have been reported by Adesuyi et al (2018) and Jallow et al (2017). Likewise, among the selected demographic traits, age is having a significant but negative relation with the knowledge level of input dealers. In the meantime, the educational status, source of information, innovativeness, decision-making pattern, risk orientation, and perception about health risk are having a significant and positive relation with the knowledge level of input dealers The findings are similar to Taghdisi et al (2019). Similarly, among the selected demographic traits, age is having a negative relation with the knowledge level of the spray men. In the meantime, educational status, experience, source of information, innovativeness, decision-making pattern, training undergone on safe handling of pesticides, risk orientation and perception about health risk are having a significant and positive relation with the knowledge level of the spray men. The findings are symmetrical to the findings of Mekonnen et al (2002).

CONCLUSION

The knowledge levels of farmers, input dealers and spray men indicate that among the selected respondents most of the farmers is low. Most of the input dealers are having a high knowledge level and most of the spray men are having a medium level of knowledge. Very few respondents are having a high level of knowledge, even among them the contribution of farmers and spray men who are directly exposed to pesticides is very low. Suitable measures must be taken into consideration for enhancing the knowledge level of pesticide handling measures among the farmers, input dealers and spray men.

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Physiological Studies on *Fusarium equiseti* and *Fusarium chlamydosporum*, the Cause of Pod Rot Disease in Mungbean [*Vigna radiata* (L.) Wilczek] in India

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Abstract: Mungbean is an important pulse crop grown in different seasons, *viz*., *Kharif, rabi* and summer in India. Pod rot disease, caused by *Fusarium equiseti* and *Fusarium chlamydosporum*, is emerging as a destructive disease affecting the quantity and quality of mungbean worldwide. Climatic factors like temperature and pH influence the growth, survival and infestation of these pathogens. In the present study, response of *F. equiseti* and *F. chlamydosporum* to different temperature and pH was assessed by analyzing there *in vitro* growth rate (mm/day) on Potato Dextrose Agar (PDA) medium. The results from the study revealed that the temperature range 25-35^{0}C and pH range 5.5-7.5 was found conducive for growth *F. equiseti* and *F. chlamydosporum* and pod rot development. This attributes make *F. equiseti* and *F. chlamydosporum* a widely distributed and potent pathogen of mungbean.

Keywords: Fusarium, Mungbean, pH, Pod rot, Temperature

Mungbean [*Vigna radiata* (L.) Wilczek] is one of the most important short duration pulse crop that is cultivated in different seasons, *viz*., *kharif* and *rabi*/summer in India. It is also used as green manure crop having the capacity to fix atmospheric nitrogen through symbiotic nitrogen fixation, which helps in decreasing soil nutrient depletion (Nadeem et al 2004, Pataczek et al 2018). However, this crop is susceptible to several abiotic and biotic stressors, which significantly reduce productivity. Fungal infections are a significant barrier to the development of mungbeans among biotic stressors. The major diseases of mungbean caused up to 40–60 percent yield reduction in mungbean (Kaur et al 2011). Among the diseases, yield loss of 10-44 percent by charcoal rot/dry root rot (*Macrophomina phaseolina*), 33-44 percent by Rhizoctonia root rot (*Rhizoctonia solani*), 30-70 percent by anthracnose (*Colletotrichum lindemuthianum* or *C. gloeosporioides*), up to 97 percent yield losses by Cercospora leaf spot (*Cercospora cruenta* or *C. canescens*) disease and up to 40 per cent losses by powdery mildew (*Erysiphe polygoni* or *Podosphaera fusca*) in mungbean have been reported (Bashir and Malik 1988, Khajudparn et al 2007, Singh et al 2013a, Bhat et al 2014, Shukla et al 2014). Different stages of mungbean such as seedling, vegetative and reproductive can be attacked by fungal pathogens and cause severe yield loss or complete production failure. Pod rot disease of mungbean, caused by *Fusarium equiseti* and *Fusarium chlamydosporum,* has emerged in India in recent years particularly in the crop grown in *Kharif* season (Buttar et al 2021).

Fusarium spp. are found in all geographic regions, including soils, plants and air. However, the presence of Fusarium in the soil and the infestation it causes in plants are influenced by a number of different factors. For the occurrence and the pattern of infestation by different Fusarium species, geographical conditions, particularly climate, are significant. Temperature, soil pH, and humidity are examples of climatic variables that have an impact on the development, survival and spread of Fusarium species, as well as the crop damage by these pathogens. The ability of Fusarium species to produce the diseases either singly or in complexes makes it difficult to determine how these factors affect disease (Doohan et al 1998). Climate may have both direct (Such as affecting reproduction) and indirect (e.g. an effect of soil and vegetation type) effects on the occurrence of *Fusarium* species. Both of the fungi that cause pod rot disease have slightly distinct biological and environmental requirements, which may help to partially explain why various locations have varied frequencies of these species. There are several findings on how different Fusarium species respond differently to environmental changes, primarily those related to temperature, source, and moisture (Conrath et al 2002). Environmental variables including temperature, moisture, and pH have a substantial impact on the production of toxins by various fungus species, and these elements are also crucial for mycotoxicosis epidemiology (Jimeneza et al 1996). *Fusarium* spp. are powerful pathogens that can endure a broad range of temperature and pH conditions and may survive in soil for a very long period. In light of this, investigated in the current study the effect of temperature and pH on the development and sporulation of *F. equiseti* and *F. chlamydosporum* inducing pod rot disease of mungbean in India.

MATERIAL AND METHODS

Isolation of pathogens from the symptomatic plants: Infected pods of mungbean with symptoms such as discolored, soft, distorted, shriveled mature pods; white powdery growth of mycelium at any part of pods; rotting of the pods; white mouldy growth on seeds; rotting and shriveling of seeds were collected from farmer fields, Krishi Vigyan Kendras and research farms of Punjab Agricultural University, Ludhiana during 2018-2021. Samples were transported to the laboratory in paper bags for additional examination and isolation. Pods were cleaned under running tap water and chopped into little pieces in the lab. Pods were divided into little pieces and cleaned in running water in the lab and placed onto water agar medium after sterilization (Burgess et al 1994) and incubated under a typical growth condition (Salleh and Sulaiman 1984). These cultures were transferred to Potato Dextrose Agar (PDA) and subsequently purified using the single spore isolation technique (Hansen 1926). The purified cultures incubated at 25 ± 1°C in the incubator. All the cultures were maintained on PDA and SNA (Spezieller Nährstoffarmer Agar) (Nirenberg 1976) medium for further studies. The same method was applied to isolate the pathogens from infected seeds.

Effect of temperature on pathogens growth: In order to study the growth of the *F. equiseti* and *F. chlamydosporum* under different temperature levels, the 100 ml of Potato Dextrose Broth (PDB) medium was poured in each glass jars (250ml) and sterilized at 15 lbs/inch^2 in an autoclave for 20 min and the active cultures of *F. equiseti* and *F. chlamydosporum* were independently inoculated into each jar using 5 mm discs. The inoculated jars were then incubated at different levels of temperature *viz*., 0, 5, 10, 15, 20, 25, 28, 30, 35 and 40°C in five replications. At each temperature level, the dry mycelial weight and sporulation was calculated after 9 days. The sporulations of both fungi were calculated by using Haemocytometer slide (0.01 cm) under the compound microscope as described by Tyagi and Pudel (2014).

Effect of pH on pathogens growth: Effect of different pH levels *viz*., 2.0, 3.0, 4.0, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0 on the growth of pod rot pathogens was studied. 100 ml autoclaved Potato Dextrose Broth (PDB) medium was poured into sterilized glass jars under aseptic conditions. The pH levels of medium were measured by the 'Elico' digital (LI 127 model) pH meter. The fifferent levels of pH were prepared by using HCl (0.1N) and NaOH (0.1N) for each jar. For replication purpose, five jars per each pH level were inoculated centrally with 5 mm culture disc of the actively growing culture of *F. equiseti* and *F. chlamydosporum* separately under aseptically conditions. Inoculated jars were incubated at 25 ± 1°C. Observations on the dry mycelial weight were taken after 9 days at each pH level. Sporulation was recorded by counting the number of macro-conidia and micro-conidia with the help of haemocytometer as described by Tyagi and Pudel (2014).

Statistical analysis: The statistical design was completely randomised in a factorial configuration of 2x10 (2 pathogens x 10 temperature/pH levels) over 20 treatments with 4 replicates each. For statistical analysis, the data were subjected to Duncan's Multiple Range Test (DMRT) at P= 0.05 by using R Statistical Software (v4.1.2; R Core Team 2021).

RESULTS AND DISCUSSION

Effect of different temperature levels on the growth of *F. equiseti* and *F. chlamydosporum*: In the present study, the effect of temperature and pH on mycelial growth and sporulation was studied. Among the external factors that influence fungi' growth, temperature plays an important role. Each fungus has its optimal temperature range for growth and sporulation. In the present study, maximum dry mycelial weight of *F. equiseti* and *F. chlamydosporum i.e*., 5.404 mg and 5.190 mg, respectively were obtained at 28°C. However, temperatures below 10°C and above 35°C were found to affect the fungal growth (Table 1). Maximum sporulation of *F. equiseti* (1.65 x 10^6 conidia ml^{-1}) and *F. chlamydosporum* (1.50 x 10^6 conidia ml^{-1}) was observed at 30°C, followed by *F. equiseti* (1.60 x 10^6 conidia ml^{-1}) and *F. chlamydosporum* (1.45 x 10^6 conidia ml^{-1}) at 28°C. Minimum sporulation of *F. equiseti* (0.25x 10^6 conidia ml^{-1}) was observed at 10°C. However, *F. chlamydosporum* showed the minimum sporulation of 0.15 x 10^6 conidia ml^{-1} at 10°C, at par with 15°C (Table 1).

Pathogens were incubated at different temperatures to study the optimum temperature for growth. It was concluded that the significant growth of the pathogens was observed at 10-35°C of temperature. The ideal temperature for best development of both fungi was 28°C, which was near to room temperature; nevertheless, moderate growth and sporulation was recorded at 30°C because it demonstrated maximum colony growth next to a temperature of 28°C and greatest in conidia generation. Gupta et al. (2010) discovered that when the temperature was 28°C, radial development of *F. oxysporum* f. sp. *psidii* and *F. solani* was at its peak. *Gibberella fujikuroi* showed great growth and sporulation at 30°C, followed by 25°, 20°, and 35°C, according to Ahamad et al. (2002). Desai et al. (2016) reported that *F. udum* showed maximum growth and sporulation at 28°C on PDA. Daami-Remadi et al. (2006) discovered that the temperature optimum for maximal mycelial development of *F. oxysporum* f. sp. *tuberose* was between 25 and 30°C, whereas it was 30°C for *F. solani*. The results of previous researchers (Boughalleb 2001, Daami-Remadi et al 2004) and current analysis also reflect the conclusion that temperatures between 25 and 35 °C were favourable for the development and sporulation of Fusarium.

Effect of different pH levels on the growth of *F. equiseti* and *F. chlamydosporum*: The pH of the medium directly affects the growth rate, amount of mycelium, and other life processes (Lilly and Barnett, 1951). At the favorable reaction of the solution, fungus utilizes the substrate effectively and yields maximum mycelium. The results of the present investigation indicated that maximum growth of fungus *F. equiseti i.e.*, 4.399 mg and *F. chlamydosporum* (4.637 mg), was observed at pH 6.5. The least growth of fungus *F. equiseti i.e.*, 1.292 mg and *F. chlamydosporum i.e.,* 1.286 mg was observed at pH 4.0. However, both fungi were unable to grow on the media with a pH level below 4.0 (Table 2). Similarly, maximum sporulation of *F. equiseti i.e*. 1.65 x 10^6 conidia ml^{-1} and *F. chlamydosporum i.e.* 1.45 x 10^6 conidia ml^{-1} was observed at pH 6.5 followed by *F. equiseti* (1.55 x 10^6 conidia ml^{-1}) and *F. chlamydosporum* (1.40 x 10^6 conidia ml^{-1}) at pH 6.0. Minimum sporulation of *F. equiseti* (0.20 x 10^6 conidia ml^{-1}) was observed at pH 8.0 and *F. chlamydosporum* (0.10 x 10^6 conidia ml^{-1}) was observed at pH 4.0 (Table 2).

Fusarium spp. may survive in a wide pH range, from 4.0 to 8.0. However, the findings showed that for *F. equiseti* and *F. chlamydosporum*, a suitable pH for maximum mycelial mass and spore production was 6 to 6.5. Thus, it is abundantly obvious that the tested Fusarium spp. preferred an pH less than 7 for the development and sporulation of its spores. The current results are consistent with the preceding studies. At

Table 1. Effect of different temperature regime on the growth and sporulation of *F. equiseti* and *F. chlamydosporum*

Temperature (^{0}C)	*F. equiseti*		*F. chlamydosporum*	
	Mean dry mycelial weight (g)	Sporulation (conidia ml^{-1})	Mean dry mycelial weight (g)	Sporulation (conidia ml^{-1})
0	0.000^G	-	0.000^F	-
5	0.000^G	-	0.000^F	-
10	1.476^F	0.25 x 10^6	1.131^E	0.15 x 10^6
15	2.409^E	0.30 x 10^6	2.399^D	0.15 x 10^6
20	3.613^C	1.00 x 10^6	3.297^C	0.70 x 10^6
25	4.731^B	1.45x 10^6	4.212^B	1.25 x 10^6
28	5.404^A	1.60 x 10^6	5.190^A	1.45 x 10^6
30	4.740^B	1.65 x 10^6	5.142^A	1.50 x 10^6
35	3.036^D	0.80 x 10^6	3.146^C	1.10 x 10^6
40	0.035^G	-	0.000^F	-

The values following the same letter are not significantly different according to Duncan's Multiple Range Test (DMRT) at P= 0.05

Table 2. Effect of different pH levels on the growth and sporulation of *F. equiseti* and *F. chlamydosporum*

pH	*F. equiseti*		*F. chlamydosporum*	
	Mean dry mycelial weight (g)	Sporulation (conidia ml^{-1})	Mean dry mycelial weight (g)	Sporulation (conidia ml^{-1})
2.0	0.000^G	-	0.000^G	-
3.0	0.000^G	-	0.000^G	-
4.0	1.292^F	0.50 x 10^6	1.286^F	0.10 x 10^6
5.0	2.513^E	0.85 x 10^6	2.874^D	0.35 x 10^6
5.5	2.816^D	1.10 x 10^6	3.892^{BC}	1.20 x 10^6
6.0	3.442^C	1.55 x 10^6	4.526^A	1.40 x 10^6
6.5	4.399^A	1.65 x 10^6	4.637^A	1.45 x 10^6
7.0	4.104^B	1.50 x 10^6	4.101^B	1.35 x 10^6
7.5	3.457^C	1.10 x 10^6	3.626^C	0.95 x 10^6
8.0	1.302^F	0.20 x 10^6	2.005^E	0.25 x 10^6

The values following the same letter are not significantly different according to Duncan's Multiple Range Test (DMRT) at P= 0.05

pH 6.0, *Fusarium oxysporum* f. sp. *ciceri* saw its fastest growth (Desai et al. 1992). *G. fujikuroi* was grown on broth medium at four different pH levels by Ahamad et al (2002) and at pH 5 saw great growth and sporulation. Sharma et al (2005) investigated how pH affected *F. oxysporum* f. sp. *lini* growth and sporulation and found that the tested *Fusarium* spp. could sporulate and thrive at 5.5 pH. The current findings support prior researchers' accounts of their physiological research on *Fusarium* spp. (Kulkarni 2006, Chittem and Kulkarni 2008). Conclusively, the findings of this study will help to improve understanding of the epidemiology of *F. equiseti* and *F. chlamydosporum*, as well as forecast the risk of pod rot disease in mungbean. With this knowledge, breeders may be better able to recognise the resistant mungbean cultivars, taking into consideration the fact that temperature has a significant impact on the development of pod rot and the aggressiveness of pathogens. Quantifying the impact of environmental factors may aid in the creation of more effective management approaches by identifying environmental conditions to restrict disease development through soil pH modification, planting dates and the usage of cultivars that may exhibit a temperature-dependent responses.

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Assessment of Fish Diversity in Relation to Water Quality in Ramganga River, India

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Abstract: The Ramganga River is comparatively cleaner in the hills (upper stretch) than the plains (middle and lower stretches) where it faces fragmentation, water abstractions, municipal sewage as well as industrial pollution from the industrialized and urban districts of Moradabad, Rampur and Bareilly. The water quality index (WQI) values are calculated for four sites in the middle and lower stretches using 15 water quality parameters (pH, EC, TDS, TSS, TS, Alk, Cl^-, $NO3^-$, $NO2^-$, NH_4^+, PO_4^{-3}, SO_4^{-2}, DO, BOD, COD). Excellent water quality is not reported at any location during the sampling. Katghar in Moradabad (RRG2) has the lowest water quality and low fish diversity indicating a loss of suitability for sustaining aquatic life due to the destruction of natural habitats, increased level of pollution, and over-exploitation of the species. The habitat type at RRG2 is dominated by pools that are not suitable for sustaining ample diversity. Chaubari in Bareilly (RRG3) has a great ichthyofaunal diversity because of the variety of habitats at this site from pools to rifles, runs, grassed banks and backwaters which provide suitable habitats for sustaining a good diversity. This study will serve as a baseline study for the fish diversity status of River Ramganga and its relation to water quality.

Keywords: Ramganga River, Fish diversity, Water quality index, Anthropogenic pollution, Heterogenous pollution sources

Freshwater is important for all forms of life on earth; however, it comprises less than 3% of the total available water on the planet (Slathia and Langer 2022). Freshwater habitats cover less than 1% of the global expanse and provide shelter to greater than 7% species of the total available species on the earth (Dudgeon et al 2006). Approximately 29,000 species of fish have been already identified; however, researchers believe that the number could be higher (Stendera et al 2012). Almost 13,000 species, 2513 genera of freshwater fish have been reported recently (Leveque et al 2008). Most fish belong to a few groups like *Cypriniformes, Clupeiformes, Osteoglossiformes, Beloniformes, Synbranchiformes, Siluriformes,* and *Perciformes*. The freshwater ichthyofaunal population in the tropical and subtropical regions is very diverse (Aguirre et al 2021). However, the temperate and polar regions are less diverse as cold-water conditions prevail. Because of their unique distribution patterns and habitat structures, riverine (stream) habitats harbour diverse biological communities and warrant extensive study of the patterns and drivers of community structure. These habitats occupy less than 1% of the earth's surface and are comprised of a variety of habitat types, harbour a disproportionately large number of species (Dudgeon et al 2006, Vorosmarty et al 2010).

The ichthyofaunal diversity is an important indicator of the ecological significance and understanding of a river, as sentinels of ecological integrity can be used for the endorsement of specific environmental flows (Jyothirmaye et al 2022). Because of comparative durability and agility, fish are regarded as valuable indicators for estimating the effect of many years in a riverine ecosystem. The extreme low flows (baseflow) conditions determine the hydraulic habitation and also the life cycle phases needed by various species of fish whereas the high flows determine the life cycle indications or habitat necessities. Throughout the phases of the life cycles in some distinct habitats, certain fish require permanent base flows whereas the others require high flows for migration and spawning. Such flows in a high quantity are also required for starting the development of the gonads and cleaning spawning beds and nursery areas. Various benthic fauna inclusive of the ichthyofauna gets a habitable environment due to diverse bedload materials that are responsible for the formation of pools, riffles, and bars. The spawning habitats and promising nursery grounds determine the species richness and fish community structure. Comparatively greater densities, higher biomass, and diversity as well as an abundance of species are present in the natural unaffected pristine channels (Dutta et al 2018). Damming, water abstractions, over-fishing, illegal fishing methods (use of dynamites) and the introduction of exotic fish species are some of the reasons behind declining fish diversity (Sarkar and Pal 2021).

River Ramganga is a good habitat for the Golden Mahseer (*Tor putitora*) fish which is found in the upper segment of the river. This river is also a favourable habitat for several species of Indian Major Carps (*Labeo calbasu, Labeo rohita, Labeo bata*), turtles (*Geoclemys hamiltonii, Melanochelys trijuga, Batagur dhongoka*), gharial (*Gavialis gangeticus*) and dolphins. The Ramganga is comparatively clean in the hills than the plains where it faces fragmentation at Kalagarh Dam, water abstractions at the Hareoli Barrage, municipal sewage as well as industrial pollution from the industrialized and urban districts of Moradabad, Rampur and Bareilly. The groundwater over-abstraction, floodplain encroachment and wetlands deterioration lead to reduced recharge and base flows. However, before its confluence with River Ganga, the Ramganga replenishes its health which is evident from Dabri that serves as favourable habitat for some of the endemic aquatic species of the Ramganga.

MATERIAL AND METHODS

Study area: With a catchment area of 24340.82 km^2, the Ramganga River is the first major tributary of the river Ganga (Khan et al 2016). The river originates in the form of a tiny spring in Diwali Khal from Namik glacier located in the Dudhotali range in Gairsain village of Chamoli district, Uttarakhand. The river passes through the Western Kumaon Himalayas before the confluence with the Ganga on its left bank in Farrukhabad district. It traverses 158 Km in the Western Himalayas before coming out through a U-shaped valley from the mountains in the most fertile Ganga Alluvial Plains (GAP). The river also covers the well-known Jim Corbett National Park where it placates the water requirements of the park. After covering a distance of 158 km, the river emerges out at the famous Kalagarh dam at an elevation of 365 m above mean sea level (MSL) in Kalagarh town. The river is a major water source fulfilling the daily water demands of two densely populated states of Uttarakhand and Uttar Pradesh. The river flows through Chakhutia, Bhikia Sain, Darchula, and Kalagarh areas in Uttarakhand and through Bijnor, Moradabad, Rampur, Bareilly, Shahjahanpur, Hardoi and Farrukhabad districts of Uttar Pradesh which are thickly populated and exploit the water from Ramganga for various agricultural, industrial and domestic needs (CWC 2012). The river also takes away the treated as well as untreated effluents load from highly industrialized districts of Moradabad, Rampur and Bareilly situated along the banks. Binao, Gagas, Mandal, Deota, Kosi, Kho, Phika, Dhela, Bhakra, and Baigul are the tributaries draining into this spring-fed river (Khan et al 2016). The details of the sampling sites and related features are given in Table 1 and the map of the study area is shown in Figure 1.

Water sampling: Water samples were collected from the sampling sites in the month of June 2019 for the water quality analysis. The water samples were collected at approx.1-foot depth in 1.5 L plastic bottles previously treated with 0.01 N nitric acid followed by washing with distilled water and

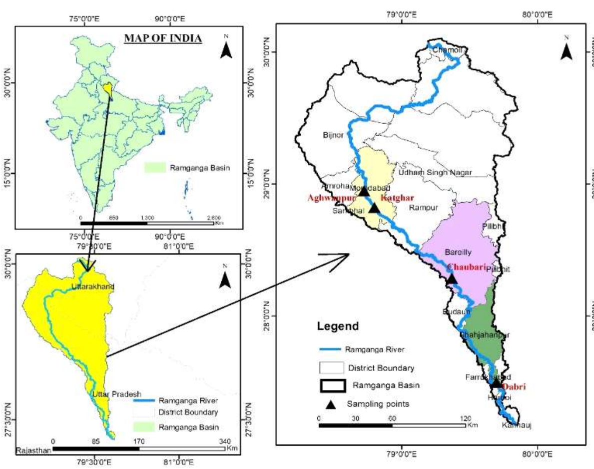

Fig. 1. Study area map of the Ramganga River Basin

Table 1. Detailed description of the sampling sites

Segment	Midstream	Midstream	Midstream	Downstream
Station name	Aghwanpur (Moradabad)	Katghar (Moradabad)	Chaubari (Bareilly)	Dabri (Shahjahanpur)
Sample Id	RRG1	RRG2	RRG3	RRG4
Pollution sources and features	Agricultural run-off (pesticides and fertilizers) from the nearby fields, sugar mill discharge, fishing, low velocity	Sewage discharge, waste dumping, illegal sand mining, thickly populated banks, low river velocity, domestic sewage and effluent discharge, urban effluents – e.g., domestic and industrial effluents, no riparian vegetation	Washing clothes/utensils, ritual activities, agricultural run-off, low flow velocity, decreasing riparian vegetation	Illegal fishing, agricultural run-off, body disposal, moderate velocity, decreasing riparian vegetation
Land use	Agriculture	Residential	Agriculture	Agriculture
Canopy	Shaded	Open	Mostly open	Open
Human settlement	Present	Present	Absent	Absent

brought to the Department of Environmental Sciences, BBAU for laboratory analysis under preserved conditions according to standard protocols. The samples were analysed for the physico-chemical parameters as per standard protocols (APHA 2017).

Water quality index: WQI is a mathematical tool that yields a single numerical figure from large water quality data. The data of the physicochemical parameters are calculated and a number is generated utilizing the values (Dutta et al 2018, Iqbal et al 2019). The water quality index is developed by the weighted arithmetic index method using 15 physicochemical parameters (pH, EC, TDS, TSS, TS, Alk, Cl^-, $NO3^-$, $NO2^-$, NH_4^+, PO_4^{-3}, SO_4^{-2}, DO, BOD, COD) that are of paramount interest while studying the freshwater ecosystems. The generated WQI value is classified in different ranges and allotted a definite class on the basis of the WQI value (Table 2). The Weighted Arithmetic Water Quality Index (WAWQI) was generated using the following equations (1-4) (Goel et al 2018).

$$Qn = 100\,(Vn - Vi)/Vs - Vi) \quad (1)$$

where Vs is the standard value and Vi is the ideal value

$$Wn = k/Sn \quad (2)$$

$$K = \sum 1/Sn \quad (3)$$

$$WQI = \frac{\sum QnWn}{Wn} \quad (4)$$

Fish sampling: Experimental fishing was done from morning to late evening during the month of June 2019 in five different habitats (pool, run, riffle, rapid, and cascade) at each site with the help of expert local fishermen. Fish were caught with gill nets of different sizes (mesh size 2 × 2 cm, 3× 3cm) and cast net (sized 6 m diameter, mesh size 1-1.8 cm) with heavy iron sinkers so that the net settles down quickly in fast flowing water. The nets were positioned at sampling points to obtain the maximum number of fish samples from particular habitat. The collected fishes were preserved in 10% formaldehyde solution and brought to the laboratory for species-level taxonomic identification. Taxonomic identification was done on the basis of morphometric and meristic characters using standard keys (Jayaram 1994) with the help of experts in NBFGR (National Bureau of Fish Genetic Resources). The ecological diversity indices of each sampling site were calculated using PAST (Paleontological Statistics) software (VERSION 4.03) that included: Shannon index, Simpson index, Species richness, and evenness, Berger-Parker index, etc.,

Cluster analysis: Cluster analysis is a form of multivariate statistical technique that categorizes the complete data into various classes called clusters. The set of variables organized in groups or clusters is similar to each other than the variables of the other cluster. In the hierarchical agglomerative clustering analysis (HCA), the variables are classified into clusters on the basis of their inherent properties resulting in a tree-like structure called the dendrogram. In this study, the squared Euclidean distance technique and Ward's method were used. Statistical and computational analyses were performed using Microsoft Excel 2016 with XLSTAT (Student trial version) and IBM SPSS 20 software.

RESULTS AND DISCUSSION

Spatio-temporal variations in water quality: The pH ranged from 7.63 at RRG3 to 8.16 at RRG4. EC varied from 182.16 to 348.16. Dissolved oxygen (DO) is an important variable of water quality as it is required by the living organisms to sustain their life in water bodies ranged from 1.20 mg/L at RRG2 to 5.90 mg/L at RRG3. The biochemical oxygen demand (BOD) represents the organic matter load in the water body and was the lowest at RRG4 (7.43 mg/L) while it was the highest at RRG2 (33.35 mg/L). Fluoride in river water is mostly of geogenic origin and the level was comparatively high at RRG2, RRG3 and RRG4 except at RRG1 (0.12 m/L). Chemical oxygen demand (COD)

Table 2. Description of water quality index values with usage possibilities and health effects

Values	Water quality ranking	Usage possibilities and health effects
WQI < 25	Excellent	Quality of water is pristine; good for drinking, recreation, bathing, washing, crop irrigation, industrial purposes with no adverse health effects
26 ≤WQI < 50	Good	Quality of water closes to pristine but with little threat; conditions rarely depart from desirable levels; can be used for drinking after treatment but for all other purposes without treatment. No adverse health effects.
51 ≤ WQI < 75	Poor	Quality rarely threatened and usually protected; requires proper treatment before consumption, bathing or washing; can be used for crop irrigation and industrial purposes. Potential adverse health effects.
76 ≤ WQI < 100	Very poor	Quality is frequently impaired and the levels are undesirable; requires proper treatment so that it could be used for useful purposes. Potential adverse health effects.
WQI ≥ 100	Unfit for living being consumption	Water quality is continuously threatened; requires immediate curative action for improving the water quality; can be used only after proper treatment. Can adversely affect health

represents the organic as well as the inorganic load in the water bodies and it varied from 52.31 mg/L at RRG4 to 84.70 mg/L at RRG2 (Table 3).

Water quality index: WQI enables us to understand the extent to which the water body has been impacted by anthropogenic activity (Ustaoglu et al 2021). Excellent water quality is not reported at any locations during the sampling. The WQI values varied from 85.43 at RRG1 to 239.70 at RRG2 (Table 4). All the sites except RRG1 fall under the "Unfit for living being consumption" category which means that the water is heavily polluted with various pollutants from heterogeneous pollution sources. Anthropogenic disturbance and land use are quite probably important factors affecting the spatial patterns of water quality in rivers (Wu et al 2021). RRG1 falls under the "Poor" category as it has a comparatively lower pollutant load than the other sites. Human activities strongly affected the water quality of the Ramganga River. At RRG2, the WQI was 239.70 as this place receives pollution from domestic wastewater drains and municipal sewage. This place also receives the heavy industrial effluent load from the industries via drains. At RRG3, the WQI is reported to be 179.19 as this place receives a huge pollutant load from agricultural run-off and domestic wastewater drains from nearby villages. RRG3 is also an important religious spot as many rituals are performed on the banks of Ramganga at Chaubari, hence the ritual remains are directly thrown into the river. The WQI at RRG4 was 112.47 where the most dominant source of pollution is agricultural run-off from the nearby fields that use chemical fertilizers, pesticides as well as insecticides. The dead bodies are also cremated on the banks of the Ramganga River and the wastes are washed away from the banks of the river. The villages also discharge their household wastewater into the river directly through drains. The expanding practice of agriculture and the amount of sewage was probably the causes of gradual changes in water quality in the Ramganga River.

Fish diversity: A total of 19 fish species from 8 families were recorded from the study area. *Cyprinidae* was found to be the dominant family followed by *Bagridae, Ambassidae, Belonidae, Channidae, Cobitidae, Heteropneustidae, Mastacembelidae* (Table 5). The species richness in the four sampling sites exhibited substantial differences (Table 6, Fig. 2). Maximum species richness was found in RRG3 (18 species) while lowest in RRG2 (7 species). This is justified by the fact that RRG2 faces severe anthropogenic pollution. The human settlements at the bank of the Ramganga river discharge their domestic sewage into the river directly. The municipal drains as well as the industries also discharge their

Table 4. WQI of the study region using the weighted arithmetic method

Site	WQI	Status
RRG1	85.43	Very poor
RRG2	239.70	Unfit for living beings
RRG3	179.19	Unfit for living beings
RRG4	112.47	Unfit for living beings

Table 3. Physiochemical parameters of water quality at the studied sites

Parameters	RRG1	RRG2	RRG3	RRG4
pH	7.98±0.277	8.05±0.133	7.63±0.126	8.16±0.145
EC(micro mhos/cm)	187.48±0.585	348.16±0.579	208.60±2.067	182.16±2.367
TDS (mg/L)	288.50±6.557	520.26±0.451	345.02±23.889	273.39±0.899
TSS (mg/L)	64.59±0.866	74.52±0.487	50.86±2.478	57.41±0.515
TS (mg/L)	353.09±6.076	594.78±0.458	395.88±25.204	330.80±1.198
Alkalinity (mg/L)	176.88±1.035	358.64±0.338	187.75±6.497	191.37±0.446
Nitrate (mg/L)	3.11±0.019	2.77±0.029	2.88±0.086	1.95±0.030
Nitrite (mg/L)	5.31±0.050	4.99±0.081	3.86±0.090	3.21±0.064
Phosphate (mg/L)	2.33±0.043	2.77±0.022	0.72±0.033	1.27±0.220
Sulphate(mg/L)	31.47±0.071	43.86±0.030	37.38±0.804	29.06±0.155
DO (mg/L)	1.78±0.171	1.20±0.141	5.90±0.319	4.42±0.045
BOD (mg/L)	25.76±0.346	33.35±5.075	9.69±0.545	7.43±0.046
COD (mg/L)	71.68±0.454	84.70±0.136	59.69±0.986	52.31±0.298
Cl- (mg/L)	31.57±0.270	38.87±0.031	29.29±0.470	26.44±0.310
F- (mg/L)	0.12±0.005	0.19±0.008	0.29±0.008	0.33±0.01

Table 5. Fish species composition and distribution recorded from the four sampling locations in river Ramganga

Fishes Name	Common name	RRG1	RRG2	RRG3	RRG4	IUCN Status	Habitat	Type	Economic importance	Food items
Ambassidae										
Parambassis ranga (Hamilton 1822)	Indian glassy fish			✓		Least Concern	Freshwater, brackish	Demersal	Ornamental	Feeds on crustaceans, annelid worms, and other invertebrates
Bagridae										
Hemibagrus menoda (Hamilton 1822)	Belawna, Belaunda	✓	✓			Least Concern	Freshwater	Demersal	Food and Ornamental	
Mystus bleekeri (Day 1877)	Day's mystus			✓		Least Concern	Freshwater	Demersal	Food and Ornamental	
Mystus cavasius (Hamilton 1822)	Gangetic mystus		✓	✓	✓	Least Concern	Freshwater, brackish	Demersal	Food and Ornamental	Phytoplankton, zooplankton, insects, their larvae, worms and molluscans
Mystus vittatus (Bloch 1794)	Striped dwarf catfish	✓	✓	✓	✓	Least Concern	Freshwater, brackish	Demersal	Food and Ornamental	Zoobenthos, benthopelagic crustaceans, insects and fish
Belonidae										
Xenentodon cancila (Hamilton 1822)	Freshwater garfish			✓	✓	Least Concern	Freshwater, brackish	Pelagic-neritic	Food and Ornamental	Zoobenthos, benthopelagic crustaceans, and insects
Channidae										
Channa punctata (Bloch 1793)	Spotted snakehead	✓	✓	✓	✓	Least Concern	Freshwater, brackish	Benthopelagic	Food and Sports	Crustaceans, insects, molluscs
Cobitidae										
Lepidocephalichthys guntea (Hamilton 1822)	Guntea loach	✓		✓	✓	Least Concern	Freshwater, brackish	Demersal	Ornamental	Feeds on small crustaceans, insect larvae, worms and bottom detritus
Cyprinidae										
Bangana dero (Hamilton 1822)	Kalabans	✓		✓	✓	Least Concern	Freshwater	Benthopelagic	Food	Feeds on insect, larvae, molluscs, algae, zooplankton and detritus
Barilius bendelisis (Hamilton 1807)	Khoksa/Indian Hill Trout	✓		✓	✓	Least Concern	Freshwater	Benthopelagic	Ornamental	
Cabdio morar (Hamilton 1822)	Morari	✓		✓	✓	Least Concern	Freshwater	Benthopelagic	Food and Ornamental	Omnivore with a higher feeding preference for phytoplankton
Cyprinus carpio (Linnaeus 1758)	Common carp			✓	✓	Vulnerable	Freshwater, brackish	Benthopelagic		
Labeo boga (Hamilton 1822)	Boga	✓		✓	✓	Least Concern	Freshwater	Benthopelagic	Ornamental	Grazers and detritivores and feeds on algae and invertebrates
Pethia conchonius (Hamilton 1822)	Rosy barb		✓	✓		Least Concern	Freshwater	Benthopelagic	Ornamental	Zoobenthos, benthopelagic crustaceans, detritus, debris, insects, worms and other aquatic organisms
Puntius chola (Hamilton 1822)	Swamp barb	✓	✓	✓	✓	Least Concern	Freshwater	Benthopelagic	Ornamental	Zoobenthos, worms, insects, detritus, debris, benthic algae and weeds
Puntius sophore (Hamilton 1822)	Pool barb	✓	✓	✓	✓	Least Concern	Freshwater, brackish	Benthopelagic	Food and Ornamental	

Cont...

Table 5. Fish species composition and distribution recorded from the four sampling locations in river Ramganga

Fishes Name	Common name	RRG1	RRG2	RRG3	RRG4	IUCN Status	Habitat	Type	Economic importance	Food items
Osteobrama cotio (Hamilton 1822)		✓		✓	✓	Least Concern	Freshwater	Benthopelagic		
Heteropneustidae										
Heteropneustes fossilis (Bloch 1794)	Stinging catfish			✓	✓	Least Concern	Freshwater, brackish	Demersal	Food	Small fishes, zoobenthos, insects, worms and crustaceans
Mastacembelidae										
Macrognathus pancalus (Hamilton 1822)	Barred spiny eel	✓		✓		Least Concern	Freshwater, brackish	Benthopelagic	Food and Ornamental	Zoobenthos, benthopelagic crustaceans, shrimps, prawns, nekton, mollusks, other cephalopods, worm, insects, fish

effluents into the river with partial or without treatment. Maximum richness was recorded in RRG3 which is downstream of RRG2. By the time, the river reaches this place; it modifies itself due to its self-replenishing abilities as the Ramganga River at this place flows at a good velocity. RRG3 has a great ichthyofaunal diversity because of the variety of habitats found at this site from pools to rifles, grassed banks, and backwaters. The downstream before the confluence of the Ramganga with the Ganga, RRG4 is located which showed a richness of 14 species. This place receives agricultural run-off from both sides of the banks as large croplands are located at this site. This site, being a rural region receives organic pollutant load from the animal manure and human excreta. RRG4 also faces the problem of heavy illegal fishing for commercial purposes. The WQI of RRG4 is 112.47 which is comparatively lower than RRG3 signifying that RRG4 is less polluted than RRG3. The Shannon and Simpson fish diversity index (H) of the sites ranged from 1.71-2.59 and 0.80-0.91 respectively. The Shannon and Simpson fish diversity index of all the sites is in the order RRG3>RRG4>RRG1>RRG2 signifying that RRG3 has the highest and RRG2 has the lowest fish diversity among all the studied sites. The Berger-Parker Dominance index ranged from 0.176 at RRG4 to 0.31 at RRG2 denoting that RRG4 has the lowest while RRG2 has the highest dominance of the common fish species. The species evenness showed variation among the sites with values of 0.79 (RRG2), 0.74 (RRG3), 0.73 (RRG1) and 0.72 (RRG4). Even though RRG2 has a low richness but has the highest evenness (Fig. 3). Diversity indices showed that RRG3 followed by RRG4, RRG1, and RRG2 are the most preferred habitats as they show the highest number and diversity of fish species. It may be due to abundant food resources present in these sites like benthic organisms, algae, and planktons. Fish feed on various trophic levels, therefore, there is a significant positive correlation between their abundance and food resources. Low diversity was observed at site RRG2, indicating loss of its suitability for sustaining life due to destruction of natural habitats, increased level of pollution, and over-exploitation of the species.

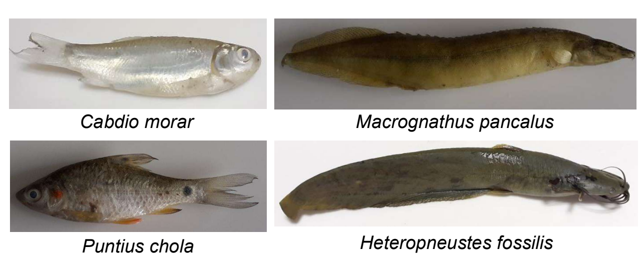

Fig. 2. Photographs of some fish species of the Ramganga River

Table 6. Diversity indices at various stretches of the river

Indices	RRG1	RRG2	RRG3	RRG4
Taxa_S	12	7	18	14
Individuals	117	158	395	221
Dominance_D	0.13	0.20	0.09	0.11
Simpson_1-D	0.87	0.80	0.91	0.89
Shannon_H	2.17	1.71	2.59	2.31
Evenness_e^H/S	0.73	0.79	0.74	0.72
Brillouin	2.04	1.65	2.51	2.22
Menhinick	1.11	0.56	0.91	0.94
Margalef	2.31	1.19	2.84	2.41
Equitability_J	0.87	0.88	0.90	0.87
Fisher_alpha	3.35	1.50	3.89	3.32
Berger-Parker	0.26	0.31	0.177	0.176
Chao-1	12	7	18	14

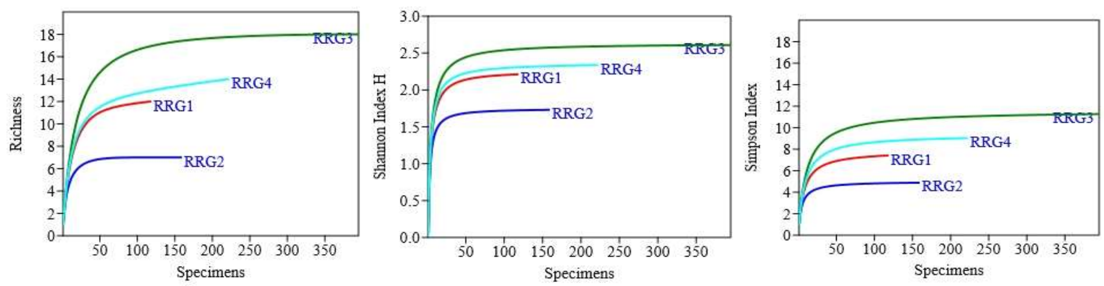

Fig. 3. Richness, Shannon index and Simpson index of the fishes at the sampling sites

Cluster analysis: In the dendrogram obtained by performing hierarchical agglomerative cluster analysis using Ward's Linkage, similar observation sites were grouped in separate clusters (Fathi et al 2019). The two separate clusters are formed (Fig. 4). In cluster one, RRG1 and RRG2 are present while in the second cluster RRG3 and RRG4 are present representing the same level of fish diversity which is evident from the fact during sampling, RRG1 faced rural pollution including agricultural run-off from the adjoining fields, and RRG2 faces the problem of urban pollution from industrial, municipal as well as domestic sources and the reduced flows from the dams augments the problem of pollution. The reduced oxygen levels and increased BOD are the issues that make the aquatic environment unsuitable for the fish thereby causing fish mortality and decreased diversity. At RRG3 and RRG4, there is less urban pollution stress and moderate agricultural pollution. The river moves away from pollution sources, the intensity of pollution decreases. So, these places don't suffer from severe pollution problems, hence the diversity here is similar to these two sites.

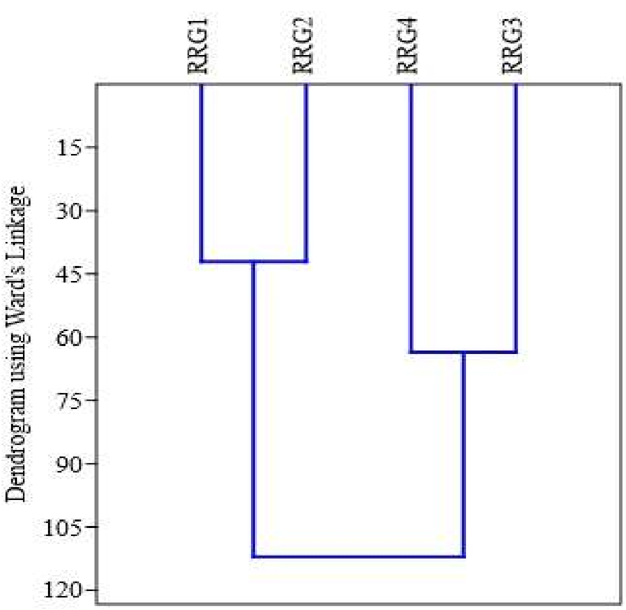

Fig. 4. Hierarchical agglomerative clustering on the basis of fish diversity

CONCLUSION

The spatial fish diversity and associated variability in the River Ramganga were evaluated in this study along with its relationship with water quality and habitat types. There was a drastic change in the WQI and fish diversity from the middle to lower stretches of the Ramganga River. The possible reason for this could be that at the time of sampling, there was not enough water flowing in the river. The Kalagarh Dam controls the water of the river in the reservoir due to which there is not enough water flow in the river in June. The water quality is not good enough to support rich ichthyofaunal diversity. The physicochemical parameters of water were proven to shape the fish diversity patterns. The increased human activities may accelerate species loss because high levels of disturbance result in reduced immigration of fishes at the local habitat scale. Over the last few decades, streams all over the country are under pressure from immense anthropogenic disturbances along with dam construction, industrialization near streams, illegal sand mining, illegal fishing, and mismanaged agricultural practices. The study suggests that the Moradabad stretch (RRG2) needs appropriate management and conservation strategies to prevent the further loss of ichthyofaunal populations.

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Morphometric Relationships and Sexual Dimorphism in *Pethia punctata,* An Endemic Barb of Western Ghats, India

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Abstract: Length-length relationships and morphometry-based sexual dimorphism in *Pethia punctata*, an endemic barb having food and ornamental importance have been determined using 33 morphometric parameters. The species exhibits persistent dichromatic characteristics with the possession of two to three rows of black spots on the dorsal fin in males vs lacking the same in females. Males' develop bright golden nuptial color with faintly red-tipped anal and pelvic fins while females do not exhibit any such color development. LLRs revealed that various lengths vs. standard length follow an allometric relationship (1<b>1). Total length and standard length are correlated positively as well as significantly correlated with a good fit ($R^2>0.9$). Six morphometric parameters showed significant differences ($p<0.05$) between males and females (HL, SPD, PoDL, CPL, ML and FPL). The first pectoral-fin ray length showed significant variation between males and females ($p=0.003$). This firsthand basal information on morphometrics and biometry based sexual dimorphism in *P. punctata* will be aiding life-history studies as well as conservation and sustainable use of the fish species.

Keywords: Allometry, Morphometric relationships, Sexual dimorphism, Nuptial coloration, Conservation

Morphometric relationships, particularly the length-length relationships are useful parameters for the prediction of the well-being of fish species, vital tool aiding in resolving taxonomic ambiguities as well as comparing life-history traits among populations of fish species (Nazir and Khan 2017, Parvin et al 2018). In fishes, length-length relationships are also relevant in the assessment of stock vis-a-vis population. The present study is aimed to analyse the morphometric relationships and sexual dimorphism (based on color pattern as well as biometric features) in the 'dotted sawfin barb', *Pethia punctata*, a small indigenous fish of Western Ghats. This Smiliogastrin barb is traded as an aquarium fish (Dahanukar 2015) as well as consumed by the tribal fishers in Kerala (Prajith et al 2016). As there is a great dearth of information on biological aspects of the species including biometric relationships and sexual dimorphism aiding in conservation and sustainable exploitation actions, the current study was undertaken to fill these gaps.

MATERIAL AND METHODS

Sample collection: Individuals of *Pethia punctata* were obtained from the tributary of Periyar River adjoining the Bhoothathankettu Dam (10˚07'56.77" N and 76˚39'48.40" E) in Ernakulam district, Kerala state, India for a year from August 2020 to July 2021. A total of 274 samples were used for analysis with 33 morphometric parameters measured from individual specimens following Armbruster (2012) using a Yamayo dial calliper (Table 1). For analyzing the sexual dichromatism and secondary sexual characters in the species, images of males and females were captured separately during the spawning season.

Statistical analysis: Length-length relationships of 33 morphometric measurements were estimated for 274 individuals (males =137; females =137) using linear regression after log transformation over standard length. Based on slope (b) values LLRs were divided into isometric and allometric categories (Oliviera and Almada 1995) i.e. if the upper limit of confidence level (CL) is lesser than one than its negative allometry and if lower limit of CL is greater than one than positive allometry. Significant ($p<0.05$) morphometric differences between males (n=137) and females (n=137), all the 33 measurements were analysed using the Mann-Whitney U test as well as regression analysis using PAST software.

RESULTS AND DISCUSSION

Morphometric data of *Pethia punctata* from Periyar river is presented in Table 1. The coefficient of determination (R^2) was >0.9 for SL vs. TL depicting that were highly significant and correlated, while for other parameters it was less than 0.9. The regression analysis showed that 13 parameters showed negative allometry, four morphometric parameters showed positive allometry while for the remaining parameters the 95% CL of 'b' does not exhibit much variation from isometry (b=1) (Table 2). TL vs SL relationship was reported as highly significant (R^2>0.9) and similar results have been obtained for congeneric species viz. *Pethia ticto, P. ornatus, Puntius chola* and *P. sophore* from wetlands of Lakhimpur district, Assam, India (Kaushik and Bordoloi 2015). The similar trend of allometry of SL with other morphometric parameters has been reported in other fish species viz. *Salmostoma bacaila* from Bangladesh (Parvin et al 2018) and *Oreochromis mossambicus* from Incomati River, Mozambique (Oliviera and Almada 1995).

Distinct sexual dichromatic characteristics of persistent and non- persistent types have been exhibited by the species. Possession of three rows of black spots on the dorsal fin of males and its absence in the female counterparts, is recognized as a persistent character (Katwate et al 2014). The males developed a golden yellow nuptial color with slight red coloration on the tips of the anal fin and pelvic fins while females retain the natural olive green color with silvery flanks in mature condition (Fig. 2 & 3). The smallest male that has developed rows of black spots on the dorsal fin had 22 mm TL

Table 1. Morphometric data of *Pethia punctata* (n=274) from Periyar river

Parameter	Code	Mean	S.D
Total length	TL (mm)	42.663	6.718
Standard length (SL)	SL (mm)	32.076	5.320
	%SL		
Predorsal length	PDL	53.412	4.458
Snout-supraoccipital distance	SnSuD	22.373	2.336
Head length	HL	28.621	2.530
Snout-pectoral distance	SnPD	29.173	2.603
Snout-gill distance	SnGD	24.352	2.334
Postorbital head length	PoHL	11.425	1.546
Gill-pelvic distance	GPvD	28.493	3.022
Supraoccipital-dorsal distance	SuDD	31.387	3.148
Supraoccipital-pelvic distance	SuPvD	33.126	3.665
Dorsal-pelvic distance	DFL	17.172	1.883
Dorsal-fin base length	DPvD	33.126	3.665
Postdorsal length	PoDL	2.766	3.532
Dorsal-anal distance	DAD	25.465	2.766
Anal-fin base length	AFL	9.808	1.713
Caudal-peduncle length	CPL	19.182	2.039
Caudal-peduncle depth	CPD	13.102	1.382
Inter-pectoral width	IPW	11.299	1.777
Inter-pelvic width	IPvW	6.509	1.100
Vent-anal distance	VAD	2.402	0.625
First dorsal ray length	FDL	28.104	3.147
First pectoral ray length	FPL	20.175	2.329
First pelvic ray length	FPvL	22.950	2.287
First anal ray length	FAL	16.915	2.058
	%HL		
Orbit length	OL	33.792	3.575
Internarial width	INW	18.201	3.106
Interorbital width	IOW	32.615	4.081
Head width	HW	45.812	4.303
Gape width	GW	18.129	3.222
Snout length	SnL	25.036	2.908
Upper-jaw length	UL	17.939	3.312
Mandible length	ML	11.385	2.600

confirming this as a unique persistent sexually dimorphic character of the species. But on contrary, two individuals (length class 50-55 cm) out of the 274 individuals examined, were found to possess rows of black spots on the dorsal fin with mature ovary and retained here as a serious subject of further investigation. Sexual dimorphism and dichromatism help in the estimation of the range of sexual selection in a species (Mieno and Karino 2017). Smiliogastrin cyprinids usually develop secondary sexual dimorphic characters of different types, viz tubercles in *Barbodes carnaticus* (Basavaraja et al 2019)*, Dawkinsia tambraparniei* (Rajesh et al 2014)*, Haludaria melanampyx* (Harikumar 1992); filamentous prolongation of anterior few rays of dorsal fin during the spawning season in *D. filamentosa* (Mahadevi et al 2020) and development of stripes or bands with intense coloration during breeding season in *Puntius chola* (Angami 2012)*, P. parrah* (Vincent 2013). Though *P. punctata* belongs to the same subfamily, did not develop any such nuptial secondary sexual characters, but as an alternative, the males developed a bright golden color in par with the dull coloration of the female. Sexual dimorphism using morphometric characteristics revealed that six-length measurements of males differed significantly from females viz. HL, SPD, PoDL, CPL, ML, and FPL whereas, other morphometric parameters

Table 2. Length-length relationships of *Pethia punctata* (n=274) from Periyar river

Equation	Regression parameters		95% CL of a		95% CL of b		R^2
	a	b					
SL=a+bTL	1.681	0.932	1.545	1.828	0.908	0.956	0.954
SL=a+bPDL	0.613	0.960	0.511	0.736	0.907	1.031	0.824
SL=a+bSnSuD	0.618	0.710	0.289	1.322	0.490	0.930	0.129
SL=a+bSnL	0.088	0.938	0.062	0.123	0.839	1.036	0.563
SL=a+bUL	0.163	0.658	0.088	0.303	0.479	0.837	0.162
SL=a+bHL	0.522	0.826	0.444	0.612	0.780	0.872	0.819
SL=a+bSnPD	0.417	0.843	0.343	0.507	0.787	0.900	0.762
SL=a+bSnGD	0584	0.801	0.257	1.329	0.563	1.039	0.139
SL=a+bOL	0.497	0.524	0.391	0.630	0.455	0.593	0.453
SL=a+bPoHL	0.151	0.918	0.108	0.210	0.821	1.014	0.562
SL=a+bGPvD	0.233	1.057	0.185	0.294	0.990	1.124	0.780
SL=a+bSuPD	0.533	0.927	0.252	1.124	0.711	1.143	0.207
SL=a+bSuDD	0.200	1.129	0.164	0.245	1.071	1.187	0.843
SL=a+bDPvD	0.277	1.051	0.217	0.353	0.980	1.121	0.761
SL=a+bDFL	0.188	0.943	0.146	0.242	0.899	1.046	0.715
SL=a+bDAD	0.141	1.169	0.113	0.178	1.103	1.234	0.818
SL=a+bPoDL	0.328	1.007	0.248	0.433	0.927	1.088	0.691
SL=a+bAFL	0.063	1.121	0.039	0.102	0.984	1.259	0.485
SL=a+bCPL	0.215	0.966	0.167	0.277	0.892	1.039	0.711
SL=a+bCPD	0.112	1.043	0.086	0.147	0.966	1120	0.722
SL=a+bINW	0.141	0.705	0.080	0.250	0.540	0.869	0.207
SL=a+bIOW	0.089	1.008	0.063	0.126	0.909	1.108	0.592
SL=a+bHW	0.195	0.883	0.139	0.273	0.785	0.980	0.538
SL=a+bML	0.110	0.640	0.061	0.196	0.472	0.807	0.172
SL=a+bGW	0.098	0.812	0.035	0.274	0.517	1.107	0.097
SL=a+bIPW	0.062	1.167	0.0403	0.097	1.040	1.295	0.544
SL=a+bIPvW	0.023	1.293	0.013	0.039	1.140	1.447	0.502
SL=a+bVAD	0.018	1.066	0.009	0.036	0.870	1.263	0.295
SL=a+bFDL	0.609	0.775	0.480	0.774	0.706	0.844	0.641
SL=a+bFPL	0.276	0.907	0.210	0.362	0.829	0.986	0.656
SL=a+bFPvL	0.555	0.743	0.464	0.665	0.691	0.795	0.743
SL=a+bFAL	0.304	0.829	0.231	0.400	0.750	0.908	0.609

were not found differing (Table 3). The regression equations and coefficients of determination were estimated for all the six significantly different parameters (Fig. 4). The results differed when each length class was analysed separately. First pectoral ray length showed significant variation between sexes for lower length classes but differed in large length classes (Table 4), similarly post dorsal length also could be a predictor for different length classes. Length class-wise assessment of morphometric characteristics showed variation for different parameters for different size classes in *P. punctata*, but no prior data was available on size class morphometric sexual variation for any Indian *Pethia* spp. for comparison. In *Oreochromis mossambicus* size class was considered separately and reported that pelvic fins showed significant variation between sexes in small and medium-size class but not in large (Oliviera and Almada 1995). Biometry based sexual difference has been reported in *Pethia ticto* (Bahuguna et al 2010) while, in *Pethia conchonius* no

Table 3. Analysis of biometry based sexual dimorphism in *Pethia punctata* (n=274) using U test

Parameter	Male		Female		U test (p)
	Mean	±S. D	Mean	±S. D	
TL	42.8567	±5.97304	42.4643	±7.42493	0.137
SL	32.2685	±4.71379	31.8772	5.89069	0.0826
PDL	17.2229	±2.60154	17.1267	3.12647	0.1473
SnSuD	11.8946	±56.5746	7.08886	1.03893	0.0723
SnL	2.31069	0.38552	2.29157	0.49259	0.2572
UL	1.65708	0.27777	1.62943	0.36886	0.4458
HL	9.24618	1.21717	9.08429	1.48263	0.0443*
SnPD	9.40194	1.26487	15.6848	76.6563	0.0487*
SnGD	7.81507	1.06515	7.78379	1.34021	0.3236
OL	3.09521	0.32512	3.04629	0.41365	0.0854
PoHL	3.64938	0.6332	3.68564	0.77147	0.7691
GPvD	9.28056	1.6421	9.09853	1.92543	0.0625
SuDD	10.1621	1.91599	10.1624	2.25002	0.4405
SuPvD	13.2141	2.00605	20.3824	86.9154	0.2046
DPvD	10.5227	1.79186	10.8523	2.40938	0.879
DFL	5.51007	0.87981	5.55493	1.15767	0.6121
DAL	8.15493	1.54496	8.31721	1.99349	0.6217
PoDL	11.0028	1.80443	10.759	2.23295	0.0077*
AFL	3.15514	0.72897	3.18464	0.82688	0.6854
CPL	6.26306	1.04804	6.09493	1.21767	0.0449*
CPD	4.21931	0.709	4.23193	0.89645	0.3768
INW	1.67618	0.30162	1.65507	0.33827	0.4644
IOW	3.00625	0.53648	2.99571	0.62115	0.4321
HW	4.20715	0.6708	4.20179	0.76319	0.3834
ML	1.0666	0.24249	1.00264	0.2291	0.0104*
GW	1.66736	0.30062	2.95379	15.4162	0.379
IPW	3.62847	0.78925	3.69121	0.93812	0.6484
IPvW	2.12364	0.45798	2.10614	0.58273	0.1828
VAD	0.7961	0.24868	0.7675	0.2327	0.2471
FDL	8.96375	1.26623	8.9982	1.42414	0.6402
FPL	6.65319	1.03442	6.27164	1.21323	0.0003*
FPvL	7.38681	0.95678	7.26107	1.07082	0.0591
FAL	5.46035	0.81311	5.35471	0.94825	0.0869

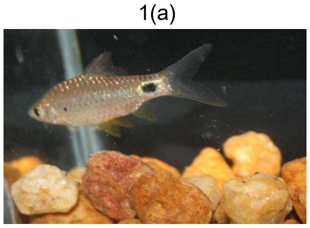
Table 4. Length class wise morphometric sexual dimorphism using two sample t-test

Parameter	35-40	40-45	45-50	50-55	55-60
HL	0.0305	NS	NS	NS	NS
SnPD	NS	NS	NS	NS	NS
PoDL	NS	NS	0.040	NS	0.011
CPL	0.030	NS	0.002	NS	NS
CPD	NS	NS	NS	0.006	NS
ML	0.009	NS	NS	NS	NS
FPL	0.012	0.014	0.002	NS	NS
SuPvD	NS	NS	NS	NS	0.047

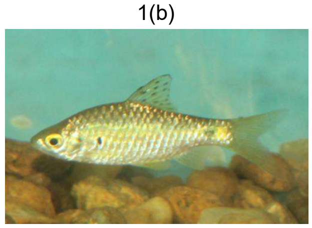
significant morphometric differences have been reported between sexes (Dobriyal et al 2007). In *Puntius singhala*, CPL (caudal peduncle length), PFL (pectoral fin length), and FBD (dorsal fin base) revealed signification variation between males and females (Gunawickrama 2009). No significant differences have been observed between male and female body sizes but the males possessed significantly longer pectoral fin than females in *P. punctata*; the exact function of this character in *P. punctata* needs to be investigated. No such character has been reported in any of the Indian Smiliogastrin cyprinid; similar results have been reported in *Pethia titteya* (a species endemic to Sri Lanka) from Japan under captive conditions, among sexes a difference in lengths of fins observed (Mieno and Karino 2017). Similarly, in Korean

1(a)

1(b)



2(a)



2(b)

3

Fig. 1a) Juvenile female b) Juvenile male, 2a) Mature female b) Mature male, 3) Nuptial coloration developed by mature male and female of *P. punctata* during courtship

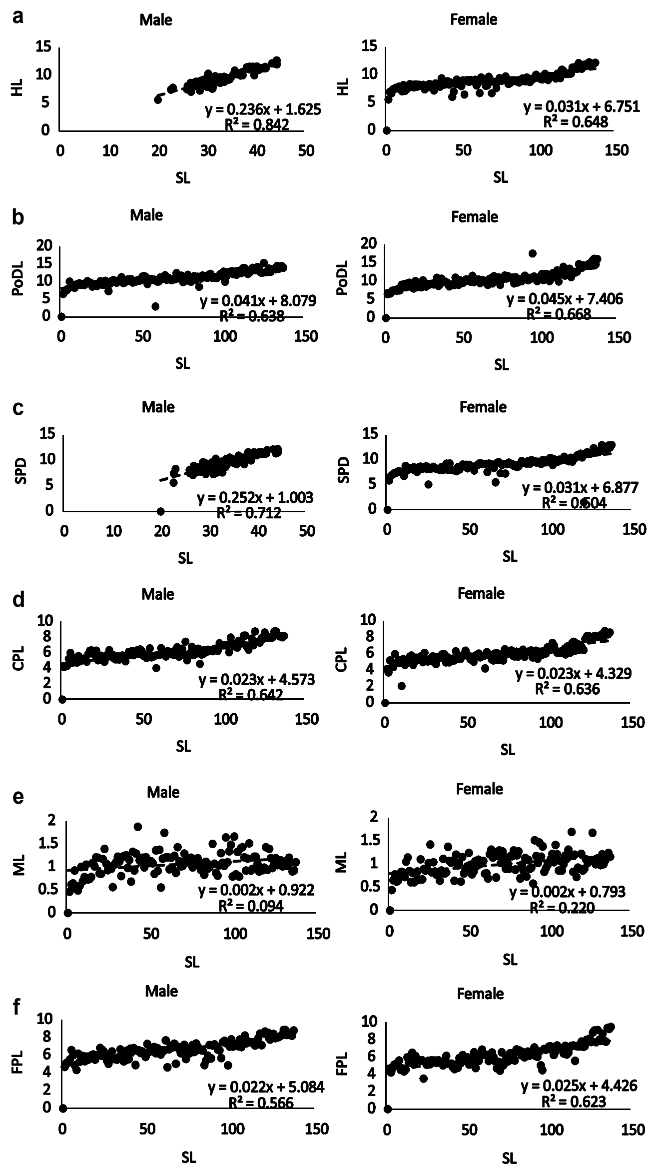


Fig. 4. Linear regression graph of standard length of males and females with a) head length b) post dorsal length c) snout pectoral distance d) caudal peduncle length e) mandible length f) first pectoral-fin ray length

chub *Zacco koreanus*, the significant differences in pectoral fin i.e. males possessing longer pectoral fin than females have been reported (Kim et al 2008). It is reported in several studies that females prefer males possessing longer fins for mating (Basolo 1990, Karino 2009, Karino et al 2011). Similarly, *Schsitura cf. aurantiaca,* males possess longer pectoral fins as compared to females (Plongsesthee et al 2012). In *Cobitis sp*. length of pectoral fins are longer in males as compared to females and differs significantly between sexes in five species studied (*C. bilineata, C. dalmatine, C. narentana, C. ilyrica, C. herzegoviniensis*) (Buj et al 2015).

CONCLUSION

The dichromatism of persistent and non-persistent modes can play a vital role in distinguishing sexes of *Pethia punctata*. This firsthand information on morphometric relationships, dichromatism and biometry based sexual dimorphism of this endemic fish species will be of great use in understanding the ecology, adaptations, and life history.

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Seasonality of Micro Inhabitants and Abiotic Parameters of Perennial Pond of Jammu

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Abstract: The present study aimed to analyse the seasonal variations and zooplankton composition of a lentic water body located at Kathua district of UT Jammu and Kashmir. The main water source of this perennial pond is rain. In the present study, 27 species of zooplankton were recorded, out of which, group Rotifera was represented by 15 species, Cladocerans by 6 species and Protozoa and Copepoda both were represented by 3 species each. During present investigation, the rotifer count was found to be the highest and constituted around 62.99% of total zooplankton reported, followed by cladocerans, protozoa and copepoda. The peak in the zooplankton population density was observed during summer season while the lowest density was recorded during the spring season. Among all the zooplankton studied, *Brachionus calyciflorus,* belonging to group Rotifera, outnumbered others. Different abiotic parameters were also analysed seasonally, of which the highest value of dissolved oxygen was obtained in winter season while carbonates were recorded only during autumn season. The concentrations of sulphates remained negligible throughout the study period and all parameters (biotic and abiotic) showed seasonality.

Keywords: Lentic water body, Zooplankton, Physico-chemical parameters, Seasonal variations

Each and every organism on the earth plays its role and helps to stabilize the concerned environment along with biodiversity of that ecosystem. Climatic conditions of an ecosystem determine the biodiversity of that system (Prakash and Srivastava 2019). Freshwater ecosystems are crucial for the survival of humans as well as numerous aquatic organisms. Despite their valuable contribution for mankind, many lakes, rivers and wetlands around the world are being severely damaged by anthropogenic activities. Due to which, these waterbodies are degrading at a much faster rate than other ecosystems and many significant changes in the biotic and abiotic parameters associated with them have been recorded by limnologists. In order to prevent these changes, a strict check is required and parameters of water bodies should be assessed on a regular basis. Water quality parameters can be broadly classified into 3 groups-physical, chemical and biological (Boyacioglu 2007, Katyal 2011). Various physico-chemical parameters signify the health of an aquatic ecosystem (Sharma et al 2009). Among the biological fauna, zooplankton along with other higher taxa are the important components. Zooplankton serve as food organism for many aquatic animals and they play a significant role in determining the trophic status of water bodies (Mashkova et al 2020). Zooplankton are a pivotal linkage in aquatic food chains and help to process energy flow within the aquatic ecosystem (Sharma et al 2013). Many of them also serve as bioindicators and hence can be used to access the trophic status of any water body (Contreras et al 2009).Many water bodies of lower Shiwaliks have been scanned for physico-chemical parameters and zooplankton but still many are left untouched. Hence, the present study was conducted on one such unexplored pond located in Kathua district with emphasis on detailed information regarding the seasonality of zooplankton and physico-chemical parameters associated with a local water body of Jammu.

MATERIAL AND METHODS

Study area: The present study was conducted on a temple pond situated at Kathua district (32.37°N latitude and 75.52° longitude) in the Union Territory of Jammu and Kashmir for the study period between February, 2020-January, 2021. This perennial pond has cemented embankments. The main source of water in the pond is the rain water.

Physico-chemical analysis: Measurement of abiotic parameters like temperature, pH, dissolved oxygen, free carbon dioxide was done on the spot. Air and water temperatures were measured using Mercury centigrade thermometer. pH was recorded using digital pH meter (Hanna). Rest of the parameters (Carbonates, Bicarbonates, Chlorides, Calcium, Magnesium, Sulphates, Phosphates, Nitrates) were analysed in laboratory from the collected water sample. Analysis of all the physico-chemical parameters was done by following standard methodology of APHA (1975) and Adoni (1985).

Qualitative and quantitative analysis: Qualitative and quantitative parameters of zooplankton were also studied. For qualitative analysis, sample collection was done during morning hours by filtering 50 litres of water through a plankton net (made up of bolting silk no. 25). The sample was then concentrated to 20ml volume and finally preserved using 5% formalin. Sample was then observed under compound microscope. Zooplankton species were identified by following Pennak (1978), Adoni (1985), Michael and Sharma (1988) and Edmondson (1992).

Quantitative analysis of zooplankton was done by using drop count method. The number of zooplankton per drop of concentrated sample was counted and the number of zooplankton per litre were calculated by using following formula:

Organisms per litre = A*1/L*n/v (Adoni 1985)

Where, A= number of organisms in one drop,V = Volume of original sample (l),n = Total volume of concentrated sample (ml),v = Volume of one drop (ml).

RESULTS AND DISCUSSION

Abiotic parameters: Seasonal variation in the abiotic parameters showed well marked fluctuations throughout the year (Table 1). Highest air and water temperatures were recorded during summer season. This might be due to lower water level and greater amount of penetration of light (Umerfaruq and Solanki 2015). Rise in temperature catalyses the process of decomposition by microorganisms, hence increases the consumption of dissolved oxygen (Mahobe 2013). Due to release of carbon dioxide during the respiration process by these creatures, a rise in the BOD value and fall in pH were observed during this period (Hussain et al 2021). Moreover, the value of total hardness was maximum in summer which might be due to lower water level during summer season as rate of evaporation increases with rise in temperature (Ibrahim et al 2009). During monsoon season, sediments inflow along with rain water and make water less transparent which could be the cause of minimum transparency during monsoon season (Abba et al 2016). Due to dilution effect of rain, a fall in the concentration of parameters like calcium, chlorides and total hardness was also recorded (Jindal and Sharma 2011). Dissolved oxygen showed concentration maxima during winter season as solubility of oxygen in water increases with fall in water temperature (Umerfaruq and Solanki 2015). Concentrations of parameters like sulfates and nitrates remained almost constant throughout the study period while carbonates were recorded only during autumn season as free carbon dioxide was absent during this period.

Zooplankton: In the present study, total of 27 species of zooplankton have been enlisted. Zooplankton diversity comprised of Rotifera (15 species), Cladocera (6 species), Copepoda (3 species) and Protozoa (3 species). Among the presently studied groups, Rotifera was the most dominant group contributing about 62.99% of the total zooplankton population followed by Cladocera (14.02 %), Copepoda (10.03 %) and Protozoa (12.95%).Group Protozoa was represented by three species (*Centropyxis aculeata, Difflugia* sp. and *Vorticella* sp.) during the present

Table 1. Seasonal variations in the physico-chemical parameters (February 2020-January 2021)

Abiotic parameters	Winter	Spring	Summer	Monsoon	Autumn
Air temperature (°C)	14	23	29	23	22
Water temperature (°C)	13	21.5	30	25	20
pH	7.5	7.6	7.3	7.8	7.5
DO (mg/l)	8.32	2.24	2.1	3.22	4.48
FCO_2(mg/l)	12.32	24.23	29.92	22.88	-
Carbonates (mg/l)	-	-	-	-	15.6
Bicarbonates (mg/l)	148.84	172.6	390.4	366.0	434.3
Chlorides (mg/l)	12.0143	11.01	14.64	8.00	12.01
Calcium (mg/l)	18.5031	16.18	21.86	15.13	17.66
Magnesium (mg/l)	11.1014	8.60	11.71	9.76	12.12
Total Hardness (mg/l)	86	90	96	78	94
BOD (mg/l)	2.56	1.64	3.02	1.8	1.7
Phosphates (mg/l)	0.044142	0.049316	0.037122	0.091878	0.068478
Sulfates (mg/l)	0.00184	0.00185	0.0021147	0.00205	0.00206
Nitrates (mg/l)	0.57671	0.62312	0.47351	0.57621	0.57461
Transparency (cm)	14.05	14.25	13.65	10.06	14.75

Table 2. Seasonal variations in Zooplankton density (no./l)

Zooplankton	Winter	Spring	Summer	Monsoon	Autumn
A. Rotifera					
Class:Monogonata, Order: Ploima					
Family:Brachionidae					
Keratella tropica	18.42	-	26	3	2.56
Keratella sp.	-	1.33	-	-	0.48
Brachionus bidentata	6.3	15.2	-	-	-
B. quadridentata	1.58	9.06	1.50	-	3.36
B. rubens	0.69	-	-	-	-
B. calyciflorus	0.61	12.93	172.94	67.4	52.16
B. falcatus	-	-	-	3	1.92
B. caudatus	-	-	-	2	-
B. angularis	-	5.86	1.69	1.6	-
Family: Lecanidae					
Lecane sp.	0.61	-	-	-	-
Family: Euchlanidae					
Euchalanis dilatata	6.32	-	1.03	-	-
Family: Asplanchnidae					
Asplanchna brightwelli	1.42	4.2	2.63	4.2	2.4
Family : Synchaetidae					
Polyarthra vulgaris	0.24	-	-	0.6	-
Order : Flosculariaceae					
Family: Trochosphaeridae					
Filinia longiseta	-	-	0.75	-	-
Class : Bdelloidea, Order : Bdelloida					
Family : Philodinidae					
Philodina sp.	1.32	3.93	-	1.2	-
Total	37.51	52.51	206.54	83.0	62.88
B. Cladocera					
Class : Branchiopoda Order : Cladocera					
Family : Moinidae					
Moina micrura	2.46	2.66	0.75	1.8	0.48
Family :Daphniidae					
Ceriodaphnia sp	_	-	0.47	-	-
Family : Macrothricidae					
Macrothrix sp.	-	-	1.41	-	-
Family : Sididae					
Diaphanosoma sp.	-	1.33	70.90	5.6	0.64
Family : Chydoridae					
Chydorus sphaericus	-	-	-	7.4	-
Alona karua	0.98	0.8	0.84	-	-
Total	3.44	4.79	74.37	14.8	1.12
C. Copepoda					
Order : Cyclopoida					
Family : Cyclopidae					
Cryptocyclops bicolor	15.44	12.63	4.22	4.35	7.89
Mesocyclops leuckarti	5.24	3.52	3.23	0.35	1.62
Cyclops sp.	4.7	2.39	-	1.23	3.64
Total	25.38	18.54	7.45	5.93	13.15
Naupilus larvae	25.96	14.66	53.55	33.6	70.34
Copepodites	21.41	45.86	18.72	206	68
D. Protozoa					
Class : Ciliata					
Family : Vorticellidae					
Vorticella sp.	0.73	1.6	-	-	1.28
Class : Tubulinea					
Family : Centropyxidae					
Centropyxis aculeata	0.6	-	-	0.36	-
Family: Difflugiidae					
Difflugia sp.	3.6	24	8.09	45.90	4.8
Total	4.93	25.6	8.09	46.26	6.08

investigation. Protozoa showed luxuriant growth during monsoon (46.26 ind./l) which might be due to the entry of organic matter into the pond from the catchment areas along with rain (Sharma et al2013). Abundance of copepods in winter can be related to decline in protozoa population (4.93 ind./l) during this period as copepods utilize protozoa as their feed (Gifford 2018). The rotifer families obtained during the study were – Asplanchnidae, Brachionidae, Euchlanidae, Philodinidae, Synchaetidae and Trochosphaeridae. Seasonal diversity of rotifers was well marked during all the seasons (Table 2). Quantitatively, population density ranged from 37.51 to 206.54 ind/l. These wheel animalcules showed abundance in all the seasons but the peak in density was obtained during summer season. This peak in summer might be due to increase in food availability viz. bacteria and organic detritus, which results into an increase in the overall density of rotifers (Vaishali et al 2012). Peak in density of rotifers during certain period of the year depicts that the water body has rich concentrations of organic matter (Kar and Kar 2016). A fall in the population density of rotifers was observed during winter season as low temperature during this period hampers their growth (Gupta 2017). Cladocerans constituted the second most abundant group of zooplankton and were represented by 5 species belonging to 4 families – Chydoridae, Daphnidae, Macrothricidae and Sididae. The maximum diversity of cladocerans was observed in summer season while the minimum diversity was obtained during autumn season. Of all species recorded, *Moina* sp. showed its presence in all seasons. Availability of food material like bacteria, nanoplankton and suspended particles during summer attributed to the abundance of cladocerans (74.37 ind./l) during this period (Manickam et al 2015). The lowest density of cladocerans during autumn season (1.12 ind./l) (Table 2) might be due to the reason that these creatures accumulate heavy silts in their digestive tracts, leading to their sinking at the bottom of water bodies (Baba et al 2015 and Verma 2021). Copepods are represented by 3 species belonging to family Cyclopidae. *Cryptocyclops bicolor* and *Mesocyclops leuckarti* were obtained during all the seasons but *Cyclops sp.* was absent during summer months (Table 2). Highest density of copepods (25.38 ind./l) was observed during winter. This may be due to availability of phytoplankton during this period (Sharma et al2013). Numerically, *Cryptocyclops bicolor* was the dominant species. Density of copepods (5.93 ind./l) declined during monsoon season which might be due to the dilution effect of rain leading to lowering of food material (Gupta 2017).

CONCLUSION

Zooplankton, though present throughout the year, showed numerical abundance during warmer period of the year. Abiotic parameters like air and water temperature, fCO_2, calcium, total hardness, chlorides and BOD were highest in the summer months resulting in optimum growth of plankton during this period. Rotifera and Cladocera showed positive growth with rise in temperature due to the availability of abundant food whereas Copepods showed inverse relationship with water temperature as their maximum abundance was recorded during winter months due to high DO levels of the water at that time. Among all the zooplankton, *B. calyciflorus* was numerically dominant species, while *Polyarthra vulgaris* contributed the least. Different species of zooplankton marked their presence in one or the other season depending upon the conditions suitable for their survival. Zooplanktonic species like *Brachionus* sp. and *Asplanchna* sp. were present throughout the year which depicts the presence of organic pollution in the pond and shows that the pond is heading towards eutrophication. Further studies should be conducted in order to monitor the pond ecosystem to access the future impact of anthropogenic activities on zooplankton distribution.

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Effect of Different Stocking Density on Growth and Survival of Monosex Tilapia Cage Culture in Perumpallam Reservoir, Tamil Nadu

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***Abstract*:** The study was carried out to assess the effect of stocking density on the growth and survival of GIF Tilapia (*Oreochromis niloticus)* for a period of 90 days from June to August 2016 in the Perumpallam reservoir, Erode District, Tamil Nadu. Uniform size tilapia fingerlings with an average weight of 11 g were released in three different cages with the stocking density of 40 50 and 60 /m^3. Fishes were fed with a commercial floating pellet feed containing 28% protein to observe the growth of the tilapia in cages. The present study demonstrated that 40 fish/m^3 was the best stocking density in terms of growth, food conversion ratio, and survival for tilapia culture in the cage culture and the experiment revealed that the low stocking density in the cage showed better growth than the high stocking density.

***Keywords*:** GIF Tilapia, Growth, Survival, Stocking density, Cage culture and Perumpallam dam

Fish culture in cages are age-old practice and it was first described by Lafont and Saveun, in 1951 in Kampuchea and Japan. In the early years, the cages were utilized to culture the freshwater fishes. Due to the increase of the interest in aquaculture activities in the world the industry continuously growing more rapidly than all other animal food-producing sectors in many countries and growing with an average annual growth of 4.5% during 2011 to 2018. When compared with only 2% for capture fisheries production and 5% for aquaculture production in the world (FAO 2020). Cage culture is used widely in fish production in most parts of the world and tilapias are farmed in more than 85 countries, especially in countries like the Philippines, Japan, Malaysia, Vietnam, Taiwan, U.S.A., Norway Federal Republic Germany, and Britain (Pillay and Kutty 2005). It is widely cultured in many tropical and subtropical countries of the world. The tilapia fishes are suitable for the cages due to their rapid growth rates, high tolerance to adverse environmental conditions, efficient feed conversion, ease of spawning, resistance to disease, and good consumer acceptance. Presently the annual fish yield from small, medium and large reservoirs is 100, 75, and 50 kg/ha, suggesting substantial scope to enhance fish yield through wild capture and culture-based fisheries in these water bodies. Cage culture practices have numerous advantages over other culture systems. By integrating the cage culture system into the aquatic ecosystem, carrying capacity per unit area is optimized because the free flow of current brings in water and removes metabolic wastes, excess feed, and faecal matter. The growing popularity of tilapia among consumers and the ever-increasing need to improve food production, impose the need to seek production alternatives to culture tilapia. Hence, the present study was conducted to observe the effects of different stocking densities on the growth and survival of tilapia in cage culture and to analyse a suitable stocking density.

MATERIAL AND METHODS

Study area: The present study was carried out in the Perumpallam dam located in the Latitude 11.56' and Longitude 77.30' of Erode district in Tamil Nadu with a total water spread area of 60 ha and an average depth of 21 feet.

Fish species: The *Oreochromis niloticus* (GIF Tilapia) seeds 2.0g to 3.0cm in size of 20,000 number was procured from the Department of Fisheries, Krishnagiri. The seeds were transported to the Aliyar seed farm in oxygen-aided plastic tanks. The seeds were acclimated and stocked with 50x20m and 20x10m size cement tanks in the Aliyar seed rearing centre for raising fish seeds from fry to fingerlings. The Gift tilapia late fry were fed with Rice bran protein 10 % and groundnut oil cake protein 25-30% @ 10 % of the body weight.

Experimental setup (Growth-out cages): The rectangular cages made of HDPE, measuring 6x4x3m (72m^3) were installed at the Perumpallam dam. The cages net was enclosed with floats and sinkers supported with cement concrete blocks on each side to withstand the cages in the water. The concrete blocks weight 40kg were used as 50 blocks total of 2 tons were used for 3 cages. The experiment was carried out in three stocking densities (40, 50 and 60 fishes /m^3) having three floating HDPE cages. Gift tilapia fingerlings with a uniform size (11 g) were stocked.

Feeding schedule: The average initial body weight of fingerlings was 12g. The commercial floating pellet feeds were supplied daily at the rate of 5 % of the bodyweight of stocked fingerlings and the sampling was done regularly at an interval of 10 days to adjust daily feeding and monitor the growth and survival of animals in the cages. The fishes were fed twice daily; half of the ration was given in the early morning from 6.30 am to 7.00 am and another half in the evening around 5.00 pm to 5.30 pm.

Water quality parameters: The water quality parameters such as pH, temperature, and dissolved oxygen were recorded each day during the experimental period. Water temperature was measured using a thermometer with an accuracy of 0.1^{0}C. The pH of the water was measured using a pH meter, the dissolved oxygen using a DO meter, and total Ammonia-N, Nitrite-N, and Nitrate-N were analyzed twice a week using water quality kits.

Sampling and growth parameters: The fishes were sampled at 10 days intervals. For every sampling, 10 fishes were randomly sampled from each cage and the weight of the individuals was recorded to the nearest gram in the field weighing balance. After 90 days of the rearing period, growth data of gift tilapia length and weight gain, mean length and mean weight gain, and Specific Growth Rate (SGR) were pooled for further analysis.

Data analysis: Data collected during the experiment were analyzed by using the following formula to evaluate the fish growth.

1. Length gain (mm) = Final length – Initial length
2. Weight gain = Final weight – Initial weight

$$\text{Mean length (gain/day(mm)} = \frac{\text{Final length} - \text{Initial length}}{\text{Experimental duration (days)}}$$

$$\text{Mean weight (gain/day(g)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Experimental duration (days)}}$$

$$\text{Specific Growth Rate (\%)} = \frac{\text{Ln Wt} - \text{Ln Wo}}{t} \times 100$$

Where,

Wt = Final mean wet weight; Wo = Initial mean wet weight

t =Duration of experiment; Ln = Natural log

The result of the present study was analyzed statistically using MS Excel Office, 2019.

RESULTS AND DISCUSSION

Water quality parameters: The water quality parameters were within the acceptable range of fish culture and all of them were more or less similar without any abrupt changes in any parameters of the cages (Table 1). The water quality parameters like water temperature, pH, dissolved oxygen, total alkalinity, Ammonia-N, Nitrite-N, and Nitrate-N were within the suitable ranges for tilapia culture in cages (Rashid 2008, Swann 2009).

Growth parameters: The highest weight of 192.5g/individual was observed in the cage with the lowest stocking density cage (40 Nos/m^3) and was 164.5 and 130 g/individual stocking density cage of 40 and 50 per m^3 (Fig. 1). The specific growth rate, food conversion ratio, and survival rate were 11.30%, 2.12 kg, and 98% in the stocking density cage of 40 and 50 /m^3 followed by 10.60%, 2.45 kg, and 96% in the T2 cage and 9.19%, 2.84kg and 95% in the T3 cage respectively (Table 2). The result indicates that the lowest stocking density has the highest rate of SGR, FCR, and survival rate than the highest stocking density cages ie., 50/m^3, 60/$m^{3,}$ and which shows an inverse relationship between final weight, weight gain, and stocking density. The present experimental findings were supported by the earlier reports concerning the SGR of the experiment (Roy 2002, Carro-Anzallota and McGinty 2007, Gibtan et al 2008, Rashid 2008, Alam 2009). The survival rate of the fish was

Table 1. Various water quality parameters of the experimental cages

Water quality parameters	Value range
Water temperature ^{0}C	28-33
pH	7.6-8.4
Dissolved oxygen (mg/l)	3.6-4.4
Total alkalinity mg/l	90-120
Ammonia- N (mg/l)	0.05-0.10
Nitrite –N (mg/l)	0.03-0.50
Nitrate-N (mg/l)	0.05-1.45

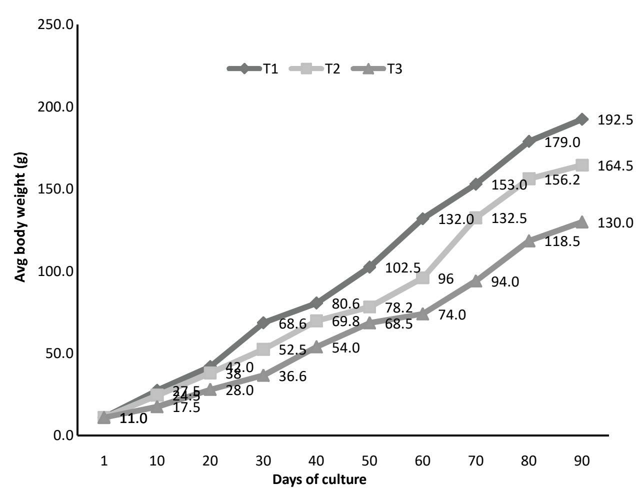

Fig. 1. Average bodyweight of GIF tilapia in different cages

Table 2. Growth parameters of Gift tilapia in three stocking densities

Treatment	Initial wt (g)	Final wt (g)	Final wt gain (g)	SGR (%)	FCR	Survival rate (%)
T1 (40/m^3)	11.0±1.73	192.5±1.45	13.5±0.06	11.30±0.39	2.12±0.08	98±1.08
T2 (50/m^3)	11.0±1.08	164.5±1.27	11.5±0.02	10.60±0.08	2.45±0.04	96±1.47
T3 (60/m^3)	11.0±1.26	130.0±0.90	8.30±0.01	9.19±0.01	2.84±0.02	95±1.35

the major problem in the cage culture and which has achieved the highest in the low stocking cage (T1). The present study revealed that the survival of the individual and stocking density is always expressed with an inverse relationship (Hasan 2007, Rashid 2008).

CONCLUSION

The present investigation, indicate that low stocking density provided the better growth rate and survival of GIF Tilapia production in cages and hence to increase the aquaculture fish production from natural reservoirs.

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Development and Evaluation of Adjustable Self-Propelled Rotor Power Weeder for Row Crops

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Abstract: Weed cause serious damage to the crop yield by sharing land, water, soil nutrients, sunlight, etc., which increases cost of cultivation, impairment of quantity and quality. Weed causes reduction in yield, if proper farming practices are not followed. The objective of study is development and evaluation of self-propelled rotor power weeder by considering weeding efficiency, plant damage, field efficiency, performance index, fuel consumption, cost and time of operation. For power weeder an adjustment provision was made to suitable for both 30 and 60 cm spaced crops i.e., groundnut, maize, chilli and cotton. The weeding efficiency and plant damage was evaluated at 30 and 60 days after sowing (DSA). At an optimum moisture content of 13%, the weeding efficiency attained a maximum in all four crops of 30 and 60 DAS. A 3 to 4% of more plant damage was observed at 60 DAS as compared to 30 DAS in all the crops. The highest field efficiency and performance index was found to be 80.07% and 93.09 in maize crop. The average reduction in cost of weeding and time saving by power weeder over manual weeding were 74.84% and 94.51% duly.

Keywords: Rotor power weeder, Weeding efficiency, Plant damage, Field efficiency, Performance index, Cost of operation

Agriculture is most key sectors of Indian economy. India's population is 1.39 billion in 2021. According to National Commission on Population Government of India has estimated that 1.807 billion population by 2050 (Anonymous 2021). To meet the demands of an expanding population, more food must be produced, this can be accomplished by increasing the area under cultivation or by using farming techniques that enhance crop yield. India has about 329 million hectares of land, of which 156 million hectares are cultivated land, 181 M ha of land is under cultivable and the net area sown is about 140 M ha, agricultural statistics at a glance 2015. There is no way to increase the area under cultivation, increasing crop productivity is a viable alternative. A crop yield raised by adopting high-yield variety of seed with good agricultural practises. Weed has a negative impact on crop yield, this includes decreased crop yield, impairment of crop quality, harbouring of plant pests and diseases, which increases like irrigation cost, production cost, lower the quantity and quality of a crop. Weed is responsible for one-third of total yield losses, as well as lowering quality and increases production costs (NRCWS 2007). Due to weeds, the yield reduction in cotton, groundnut, and vegetables like chilli crops ranges from 40-45% (Veerangouda et al 2010), 30-80%, and 30-40% (Rao et al 2014) and sometimes it can be as high as 80-90% which indicate the complete crop failure if adequate management practices are not followed effectively. Weed control is costliest and labour-intensive operations. Weeding operation takes 25% great labour force and 900 to 1200 man-hours per hectare by manually (Weide et al 2008). A study at DWSR suggested that efficient weeding techniques, add extra amount of one crores rupee annually (NRCWS 2007). The developed nations have placed a large emphasis on mechanization of different farming operations, several agriculture machineries were developed and implemented successfully. In India most of the farmers belong to small and marginal, the large heavy machines are high initial investment and it is not affordable to small-scale farmers. The status of landholding in the context of Indian agriculture reveals about 80% of landholdings were below 2-hectare area which comes under small to marginal landholding.

The productivity of farms greatly depends on the availability and use of power in farms. Agricultural implements and machines enable farmers to employ the power for production. Day by day the human power in agricultural operations is diminishing and using of bullock power is also reduced due to its maintenance. Mechanical weeding reduces the drudgery and ensures a comfortable posture during weeding. Weeder is mechanical tool, it uproots partially or completely and burying weeds into soil. Weeding by animal, tractor-drawn, and power operated weeder is carried out when crop is sown in rows. Row crop weeders are simple, cost-effective, and beneficial to small and medium-scale farmers. Weeding operation requires huge manpower and agriculture workers are not easily available in peak seasons. Traditional methods are costly and time-consuming operations, on the other hand, bullock-drawn implements have certain drawbacks like low field capacity, high maintenance cost and limitations of adverse weather conditions, etc., therefore not affordable to the small farmers. Because of growing demand for organically produced foods and concerns about environmental damage, the use of mechanical weeding is increasing in the current context. Mechanical, chemical, and biological weed control methods are available, but mechanical weeding is favoured since the agriculture industry requires non-chemical weed control to assure food safety. Tractor operated weeders can save time 75% and cost by 20% cost over animal drawn, but there are some limiting factors for tractor drawn weeders such as more plant damage, wastage in headlands, more compaction of soil and not suitable for the crops which are having small row to row spacing and the crop height is a limiting factor (Anil et al 2014). Weeding by engine-operated weeders results in one-third cost benefit over manual method (Tajuddin 2006). A power weeder is efficient equipment for weeding operation for line sowing crops (Shekhar et al 2010). The principal aim of designers, scientists of farm machinery are to develop a suitable technology for small to medium-scale farms. However, some of the Indian farmers widely adopted the concept of row cropping and the development of adjustable self-propelled rotor weeder is the need of today's agriculture. In this view, present research is viable option due to its medium cost and small size implying better manoeuvrability in the small landholdings.

MATERIAL AND METHODS

A series of experiments were conducted to develop adjustable self-propelled intercultural equipment and tested its performance for the weeding operation of four different crops. The detailed description of the development and its evaluation is discussed in the following sections.

Experimental site: The research work is carried at college of agricultural engineering, Madakasira, Anantapur district, Andhra Pradesh. The geographical location of the experimental site is 13º 56'58''N and 77º 18'42''E with elevation of 641.6 m mean sea level. A field of 800 m^2 area selected for field evaluation. Field area is split into 4 plots each 200 m^2 of groundnut, maize, chilli, and cotton crops, and each plot has dimensions of 20×10 m^2. is arid place with low precipitation of 532 mm and the maximum temperature is 35 ºC, whereas the minimum temperature of 23 ºC. The average temperature, relative humidity and wind speed is 25.7 ºC, 53% and 10.3 km/h. Soil have proportions of sand, silt, and clay defines the texture of soil (sand 68.0%, silt 14.5%, and clay 17.5%). Sandy loam soils with gravel characterise the Madakasira region for the most part.

Crops: The four major crops are selected for experiment i.e., Groundnut, T_1 (K-9), Maize, T_2 (Priya Gold 4545), Chilli, T_3 (Demon F1), and Cotton, T_4 (Star1, Bollgard-II SCH 234).

Crop morphological parameters: The plant height, plant width, root length, and weed density of four crops were measured with scale by selecting 1 m^2 area at 30 and 60 days after sowing.

Soil moisture content: Soil moisture content was estimated during evaluation of weeder by a digital moisture meter. The probe of moisture meter is inserted into the soil which senses moisture content and directly shows the value of moisture content in the monitor display. The 10, 13, 16, and 19% moisture contents were selected to study the maximum weeding efficiency at optimum moisture content among the four moisture content levels.

Adjustable self-propelled rotor weeder for row crops: The performance of developed adjustable self-propelled rotor weeder was evaluated on maize, chilli, groundnut, and cotton fields to investigate weeding efficiency, plant damage, field efficiency, performance index**,** fuel consumption, and cost of operation.

Weeding efficiency: Weeding efficiency is ratio of number of weeds before operation to number of weeds after operation, a 1 m × 1 m plot selected to counting number of weeds per square meter area. The weeding efficiency was calculated (Shekhar et al 2010).

$$\text{Weeding efficiency (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

Where, W_1 = Number of weeds before operation and
W_2 = Number of weeds after operation.

Plant damage: Plant damage (P_d) was estimated by counting number of injured plants after and before the operation in a sample plot. The plant damage was calculated (Yadav and Pund 2007).

$$\text{Plant damage (\%)} = \left\{1 - \left(\frac{q}{p}\right)\right\} \times 100 \quad (2)$$

Where, q = Number of plants in 10 m row length after operation

p = Number of plants in 10 m row length before operation.

Field efficiency: Field efficiency (F_e) is ratio of effective to theoretical field capacity and expressed as a percentage (Nagesh et al 2014).

$$\text{Field efficiency (\%)} = \frac{\text{E.F.C}}{\text{T.F.C}} \times 100 \quad (3)$$

Where, E.F.C = Effective field capacity, ha/h and

T.F.C = Theoretical field capacity, ha/h.

Theoretical field capacity is calculated by (Patange et al 2015).

$$TFC\ (ha/h) = \frac{S \times W}{10} \qquad (4)$$

Where, S = Forward speed, km/h

W = Width of the implement, m

Effective field capacity is calculated by (Manjunatha et al 2014).

$$EFC\ (ha/ha) = \frac{A}{T_p = T_{NP}} \qquad (5)$$

Where, A = Area of coverage, ha

T_P = Productive time, h and

T_{NP} = Non-productive time, h.

Performance index: The performance index (PI) of the weeding equipment was calculated (Thorat et al 2014).

$$\text{Performance index} = \frac{FC \times (100\text{-}PD) \times WE}{\text{Power (hp)}} \qquad (6)$$

Where, FC = Field capacity, (ha/h)

PD = Plant damage, % and

WE = Weeding efficiency, %

Fuel consumption: Top-fill method is used to measure fuel consumption, initially tank is fill to full capacity before testing on levelled surface. After the test, amount of fuel required to fill tank again gives the fuel consumption for given test run and it is expressed in litre per hour. Fuel consumption is calculated (Raghavendra et al 2013).

$$\text{Fuel consumption (l/ha)} = \frac{V}{t} \qquad (7)$$

Where, V = Volume of fuel consumed, l

t = Total operating time, h

Cost of operation: The designed and developed machine should be consideration for its cost economics. A developed machine should be considered for cost economics and it perform minimum cost with good performance. The developed adjustable rotor power weeder was determined by straight-line method. Total cost of power weeder was considered by adding both material cost and labour cost for fabrication. Total cost of operation was estimated by fixed and variable costs.

Statistical analysis: The experimental data was analysed by using the SAS 9.3 software.

RESULTS AND DISCUSSION

Developed machine evaluated by considering soil parameters as moisture content, crop parameters like plant width, plant height, weed density, and performance parameters, such as weeding efficiency, plant damage, field efficiency, performance index, fuel consumption, cost of operation and obtained results were discussed in the following sections.

Weeding efficiency: The mean weeding efficiency was77.77 and 72.87% at 30 and 60 days. Among the four crops, the best result was reported as 79.49 and 75.59% at 30 and 60 days in maize crop (Fig. 4).

The weeding efficiency highest and lowest was 79.49% in maize and 76.33% in groundnut at 30 days after sowing, Similarly highest and lowest weeding efficiency at 60 days after sowing were reported as 75.59% in maize and 70.57% in groundnut. The moisture content is increased from 10 to 13%, the weeding efficiency in all the crops varied between

Fig. 1. Developed adjustable rotor weeder

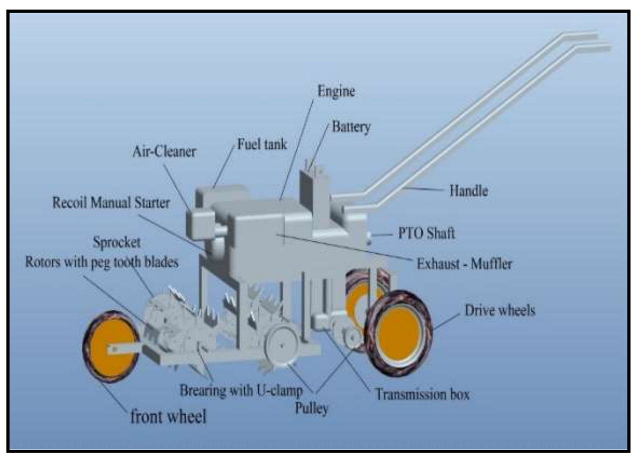

Fig. 2. Isometric view drawn in Pro-e Software

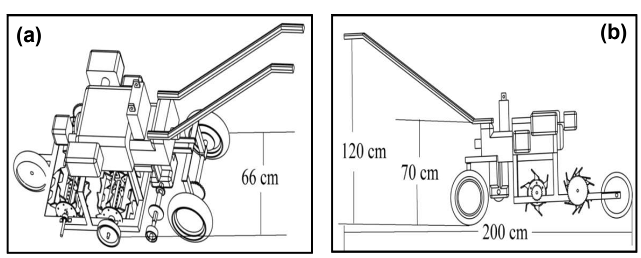

Fig. 3. Line diagram of (a) isometric and (b) side view of rotor weeder

13 and 15%, and then weeding efficiency declined slightly. At an optimum moisture content of 13%, the weeding efficiency attained maximum among all crops. Ojomo et al (2012) observed that moisture contents of 13% recorded maximum weeding efficiency.

Plant damage: Plant damage was estimated using (Eq.2). The mean plant damage was 3.84 and 6.92% at 30 and 60 days. Among four crops, lowest plant damage was observed as 2.91 and 5.59% at 30 and 60 days in maize crop (Table 1).

There were significantly differences among the crops, and plant damage indicated no significant difference among treatments; However, the high and low values of plant damage was 4.65% of 7.14 cm of plant width in groundnut crop and 2.91 of 7.89 cm plant width in maize at 30 days weeding. The high and low values of plant damage at 60 days of weeding were 8.24% of 7.16 cm plant width in chilli crop and 5.59% of 19.06 cm plant width in maize crop. The plant width increased plant damage. Plant width cause 3 to 4% plant damage at 60 days weeding over 30 days of weeding. Aman et al (2014) observed that plant damage at pre-square, square, flowering stages increase with plant width.

Plant height: The plant height of the four crops was measured at 30 and 60 days (Fig. 5) indicated that among four crops maize recorded the highest value of plant height as 69.01 and 47.99 cm at 30 and 60 days and for lowest plant height was recorded in groundnut crop as 10.46 and 14.88 cm at 30 and 60 days.

Weed density: The weed density of the four crops was measured at 30 and 60 DAS (Fig. 6). It indicated that the high and low weed density was 96.5 in maize and 73.75 in groundnut at 30 days weeding (Fig. 6). The high and low weeding at 60 days were 123 and 91.75 in maize and chili.

Effect of depth of cut on weeding efficiency: Depth of cutting is a very important factor in assigning machine efficiency. This greatly influences the weeding efficiency and power requirement. The mean depth of cutting was found to be 4.11 cm. Among the four crops, the best depth of cutting was reported as 4.20 cm in maize crop and was depicted in (Table 2).

The higher depth of cutting as 4.20 cm of 77.54% weeding efficiency in maize crop and lowest was 4 cm of 73.45% in groundnut crop. In chilli crop the depth of cut was 4.07 cm with corresponding weeding efficiency 0f s 74.64% and for cotton, depth was 4.17 cm with corresponding weeding efficiency of 75.73%. The results indicate the depth of cut was increased linearly and the weeding efficiency also increases linearly. Jagvir and Intikhab (2008) reported the same trend on effect of depth of cutting over the weeding efficiency. Field efficiency was estimated using (Eq. 3). The mean-field efficiency was be 79.74% (Fig. 4). Among all crops, the best field efficiency was s 80.07% in maize. Table 2 which indicated that there is no significant difference between treatments of field efficiency. However, the high and low values of field efficiency were 80.07% in maize and 79.39% in chilli. Senthilkumar et al (2014) evaluated 4 hp diesel and 5.5 hp petrol engines and observed that field efficiency of 64.1 and 71.5%.

The performance index gives the overall performance of the weeder (Table 3). The high and low values of performance index were 93.09 in maize and 86.31 in groundnut. The performance index of rotor weeder was 85 in

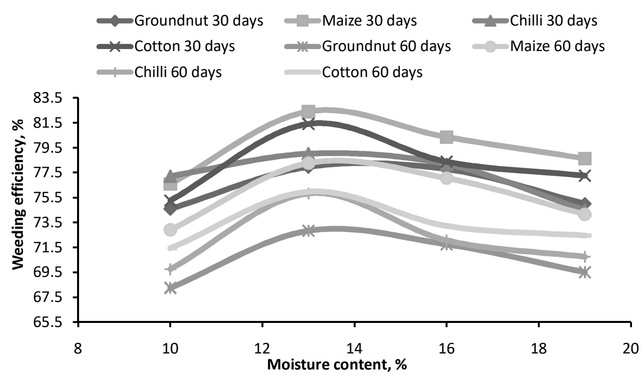

Fig. 4. Effect of moisture content on weeding efficiency

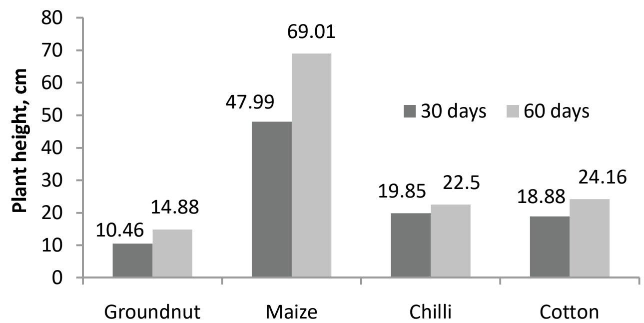

Fig. 5. Plant height at 30 and 60 days

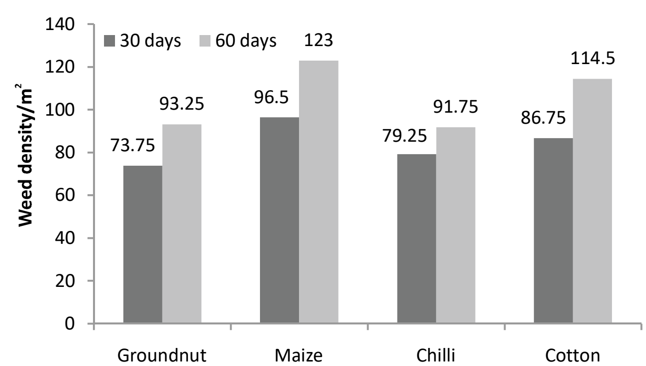

Fig. 6. Weed density at 30 and 60 days

all the four crops, the highest was recorded in maize. The plant damage was more; the performance index was ultimately reduced. Present study the plant damage ranges from 4 to 9%, and plant damage influences the performance index. Fuel consumption was high and low as 0.62 l/h in maize and 0.58 l/h in chilli. The mean fuel consumption was 0.6 l/h. Anil et al (2014) observed power weeder fuel consumption of 5 hp diesel engine as 0.65 l/h, which is nearly equal to developed self-propelled rotor weeder.

The operating cost of weeding was found by using fixed and variable cost of rotor weeder. The weeding operation cost depends on time required for completing the weeding operation. (Table.3) indicated highest and lowest weeding cost were Rs. 1677/ha in chilli crop and Rs. 1662/ha in maize crop. The mean cost of operation was Rs. 1669.25/ha. The cost of operation by manually with khurpi comes as Rs. 6635.36/ha. However, the developed weeder is beneficial to reduce the cost, time, and drudgery of the farmer. The average reduction in cost of weeding by using a self-propelled rotor weeder over the manual weeding was 74.84%. The average saving of time by using a self-propelled rotor weeder over manual weeding was 94.51%.

Table 1. Plant width (cm) and plant damage (%) of row crops

Treatments	Plant width*		Plant damage*	
	30 days	60 days	30 days	60 days
Groundnut	7.14 b	11.27 b	4.65 a	7.07 a
Maize	7.89 b	19.06 a	2.91 a	5.59 a
Chili	6.13 b	7.16 c	4.24 a	8.24 a
Cotton	11.95 a	13.50 b	3.56 a	6.93 a
CD (p=0.05)	1.20	1.86	NS	NS

*There is no significant difference between treatments with similar letters in column

Table 2. Depth of cutting, average weeding efficiency and field efficiency of row crops

Treatments	Depth of cutting (cm)*	Average weeding efficiency (%) of 30 and 60 days*	Average field efficiency (%)
Groundnut	4.00 a	73.45 a	79.63a
Maize	4.20 a	77.54 a	80.07a
Chilli	4.07 a	74.64 a	79.39a
Cotton	4.17 a	75.73 a	79.89a
CD (p=0.5)	NS	NS	NS

Table 3. Performance index, fuel consumption and cost of operation

Treatments	Performance index	Fuel consumption (L/h)	Cost of operation (Rs./ha)
Groundnut	86.31a	0.60a	1672a
Maize	93.09a	0.62a	1662a
Chilli	87.92a	0.58a	1677a
Cotton	89.75a	0.60a	1666a
CD (p=0.05)	NS	NS	NS

CONCLUSION

The optimum moisture content of 13% recorded the maximum weeding efficiency at 30 and 60 DAS in all the crops. A 3 to 4% of more plant damage was at 60 DAS compared to 30 DAS. The depth of cut was increased linearly, the weeding efficiency also increases linearly up to certain limits, beyond the permissible limits, a decreasing trend was observed. The average field efficiency was 79%. Higher performance index was due to less plant damage. The average reduction in cost of weeding and time saving by using developed power weeder over manual weeding were 74.84 and 94.51% respectively.

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Application of Diversity Indices: Insights into Ecological Perspectives from the Karnataka Milch Biodiversity Exploratories

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Abstract: Policymakers have always been and will also continue to be concerned about food and nutritional security. Among its various sources, the livestock and dairy sector alone contributes a lion's share in global caloric and protein consumption. However, the diversity of livestock, especially of milch animals, has been reported to be threatened in different regions. In addition, biodiversity is often onerous to quantify because of the multitude of indices proposed for this purpose. With this backdrop, an exertion has been made in this study to empirically evaluate the milch diversity in different agro-climatic zones of Karnataka in terms of various indices. Outcomes emanated from this investigation have clearly revealed that among the agro-climatic zones, the northern dry zone and the coastal zone are the most and least biodiverse, respectively. However, among the years, the highest and lowest biodiversity is observed in 2007 and 2019, respectively. On the patterns of biodiversity, the agreement among the agro-climatic zones over the years and vice-versa have also been evident for all the biodiversity indices considered in this study. Despite the strong relationships among these diversity measures, the utilisation of multiple indices instead of any single index is suggested to obtain a better insight into the ecological perspectives.

Keywords: Biodiversity, Diversity index, Karnataka dairy, Livestock, Nutritional security

Food and nutritional security has always been and will continue to be a huge concern for policy planners. To satisfy the demands of a growing population in a changing climate, the productivity and efficiency of the food systems need to be improved in terms of both quality and quantity. Among the various sources of food and nutrition, the livestock and dairy sector alone provides around 13 percent of global caloric consumption and around 28 percent of global protein consumption (FAO 2011). India is one of the few countries in the world, which has a rich contribution towards the international livestock gene pool and improved animal productivity. In India, the livestock and dairy sector has multi-faceted contributions to the socio-economic development of rural masses. Due to the inelastic absorptive capacity for labour in other economic sectors, it has better potential for creating new employment possibilities, particularly for marginal and small farmers as well as for landless labourers (Yasmeen et al 2019). Consequently, it can play a vital role in poverty alleviation and smoothening of the income distribution (Birthal et al 2002). However, the diversity of livestock, especially of milch animals, has been reported to be threatened in different regions (Barnes et al 2012). In addition, the ever-expanding human populace will further pressurise the production needs favouring the high output breeds (Hoffman 2010). Hence, there is an urgent need to investigate afresh the biodiversity aspect of the milch animals with a regional focus.

Biodiversity, on the other hand, can be considered as a multidimensional feature of the natural systems and is often onerous to quantify partly because of the multitude of indices proposed for this purpose (Morris et al 2014). These indices are used to define the general characteristics of communities as well as to compare them across regions, time periods, trophic levels, etc. Singh et al (2006) have schematised the pattern of crop diversification across states in India with the help of Simpson's indices. Abay et al (2009) have utilised the Shannon's diversity index to assess the on-farm crop diversity in northern Ethiopia. Morris et al (2014) have tested several common diversity indices in order to determine whether some are better suited for certain analyses than others by investigating sixty temperate grassland plots. Outcomes emanated from their experiment have indicated that simultaneous consideration of multiple indices can provide better insight into the interactions of a system. Therefore, the literature reviews clearly suggest that even though the indices are critical for environmental monitoring and conservation, there is no consensus about which indices are more appropriate and informative. With this backdrop, an exertion has been made in this study to empirically evaluate the milch diversity in different agro-climatic zones of Karnataka.

MATERIAL AND METHODS

Description of the study area: Karnataka is the eighth largest state in India consisting of 31 districts. It is bordered on the northwest by Goa, on the north by Maharashtra, on the southeast by Tamil Nadu, on the southwest by Kerala, on the northeast by Telangana, on the east by Andhra Pradesh, and on the west by the Arabian Sea. It experiences winter in January and February, followed by summer in March and May, the monsoon in June and September, with the post-monsoon season occurring in October and December. To ensure the efficient utilisation of the available resources for improved agricultural production, the total area of Karnataka is subdivided into ten agro-climatic zones (Vanitha et al 2017). As agro-climatic parameters have a pronounced effect on biodiversity (Singh et al 2012), an assessment of biodiversity has been carried out for these zones and as well as for Karnataka as a whole.

Collection of data: This study utilises data on milch animals (Cattle, Buffalo, Sheep, and Goat) based on seven consecutive quinquennial district-wise livestock census data of Karnataka (1990-2019). The data have been collected from the Commissionerate of Animal Husbandry & Veterinary Services, Bengaluru, Government of Karnataka. The district-wise data have further been clustered into the agro-climatic zones for the purpose of biodiversity assessment.

Biodiversity Indices

Herfindahl-Hirschman index: Herfindahl-Hirschman Index (HHI) is one of the commonly used metrics of diversification. It was first introduced to measure the regional concentration of industries (Ellison and Glaeser 1997). It relies on the squares of the proportions (p_i) of the objects. As a result, with an increase in the diversity, the sum of the square of the proportions decreases, and so as the index.

$$\text{Herfindahl} - \text{Hirschman Index(HHI)} = \sum_{i=1}^{n} p_i^2$$

The index is constrained between 0 and 1, with 0 signifying complete specialisation and 1 suggesting complete diversification.

Simpson's diversity index: Simpson's diversity index (D_1) is the complement of Simpson's original index (Simpson 1949) and indicates the probability that the randomly selected individuals belong to a distinct category (McCune and Grace 2002).

$$\text{Simpson's diversity index}(D_1) = 1 - \sum_{i=1}^{n} p_i^2$$

where p_i has the same meaning as stated above.

Simpson's dominance index: Like D_1, Simpson's dominance index (D_2) is another modified form of the Simpson's original index. Both of these transformations serve to make the index increase as the diversity intuitively increases. However, in practice, D_2 is more common (Magurran 2004).

$$\text{Simpson's diversity index}(D_2) = 1 \Big/ \sum_{i=1}^{n} p_i^2$$

where p_i has the same meaning as stated above.

Shannon's diversity index: Shannon's diversity index (H') is grounded on information theory and depicts the uncertainty about the identity of an unknown individual. An unknown individual may belong to any category in a highly diverse and uniformly dispersed system, resulting in significant uncertainty in its identity predictions. It is simpler to identify an unknown individual in a less diversified system dominated by one or a few categories because of the reduced uncertainty (Shannon 1948). Despite its abstract conception, this metric is extensively used in ecological studies (Magurran 2004).

$$\text{Simpson's diversity index}(H') = -\sum_{i=1}^{n} p_i \ln(p_i)$$

where p_i has the same meaning as stated above.

Berger–Parker dominance index: Berger–Parker dominance index (BP) is a simpler metric and considers only the maximum proportion among the proportions (p_i) of the categories (Morris et al 2014).

Berger – Parker dominance index (BP) = p_{max}

Simpson's evenness index: Evenness, if calculated from H', is of only limited use as it directly correlates with H'. However, Simpson's evenness index (E), as computed from D_2, is mathematically independent of D_1 (Smith and Wilson 1996) and therefore, in many situations, it is a far more useful metric of evenness.

Simpson's evenness index (E) = D_2/S

where D_2 and S denote Simpson's dominance index and the number of categories, respectively.

Evaluation of biodiversity patterns: Kendall's coefficient of concordance (W) has been utilised in this study to evaluate the biodiversity patterns among the agro-climatic zones as well as among the years (Baumgartner et al 1999). For an index, there are 10 agro-climatic zones and 7 years in our study. Now if years are ranked from 1 to 7 for each agro-climatic zone on the basis of that biodiversity metric values, agreement among the agro-climatic zones can be assessed in the following way. Let r_{ij} be the rank of i^{th} year for the j^{th} agro-climatic zone. For the i^{th} year.

$$R_i = \sum_{j=1}^{10} r_{ij}$$

Let $\overline{R}$ denote the mean of R_i and R be squared deviation such as then

$$R = \sum_{i=1}^{7} (R_i - \overline{R})^2$$

$$\text{Kendall's coefficient of concordance (W)} = \frac{12R}{10^2(7^3 - 7)}$$

W is constrained between 0 and 1, with 0 implying no agreement and 1 implying complete agreement among the agro-climatic zones. Similarly, the agreement between years has also been examined.

RESULTS AND DISCUSSION

Insight from Herfindahl-Hirschman index: Herfindahl-Hirschman indices (Table 1) indicate that over time, the coastal zone has the least biodiversity, followed by the hilly zone. Even though the northern dry zone is observed to be the most biodiverse for most of the years, a quantum jump in biodiversity increase is evident for the north eastern transition zone. On an overall basis, Karnataka has remained more biodiverse than the majority of its constituent agro-climatic zones.

Insight from Simpson's diversity index: Simpson's diversity indices (Table 2) indicate the presence of the highest biodiversity in the northern dry zone for the majority of the time period under study. However, with gradual improvement over the years, the north eastern transition zone is currently the most biodiverse. The coastal zone, followed by the hilly zone, has demonstrated to have the least biodiversity throughout the study period. The majority of the agro-climatic zones have been evident to have lesser biodiversity than Karnataka as a whole.

Insight from Simpson's dominance index: Simpson's dominance indices indicate that for the majority of the period under investigation, the northern dry zone has the highest biodiversity (Table 3). The north eastern transition zone, on the other hand, has gradually improved through time and is now the most biodiverse. The least biodiversity has been found in the coastal zone, followed by the hilly zone, across time. The higher biodiversity of Karnataka as a whole than most of its constituent agro-climatic zones is also being evident.

Table 1. Herfindahl-Hirschman Indices(HHI) for the milch animals in the agro-climatic zones of Karnataka

Agro-climatic zone	1990	1997	2003	2007	2012	2019
North eastern transition zone	0.3193	0.3012	0.3239	0.2852	0.2821	0.2689
North eastern dry zone	0.3126	0.2844	0.2787	0.2511	0.2902	0.2970
Northern dry zone	0.2614	0.2597	0.2557	0.2610	0.2789	0.2843
Central dry zone	0.2869	0.2871	0.2939	0.2704	0.3309	0.3819
Coastal zone	0.6319	0.6908	0.7784	0.9245	0.8504	0.8633
Eastern dry zone	0.3102	0.3334	0.3309	0.2751	0.3509	0.3711
Southern dry zone	0.3257	0.3101	0.3090	0.2755	0.3234	0.3237
Southern transition zone	0.3427	0.3216	0.3374	0.2655	0.3483	0.3522
Northern transition zone	0.3069	0.2879	0.2879	0.2644	0.2939	0.3005
Hilly zone	0.5699	0.5044	0.5325	0.7897	0.5711	0.5750
Karnataka	0.3074	0.2856	0.2822	0.2586	0.2907	0.2929

Table 2. Simpson's diversity indices (D_1) for the milch animals in the agro-climatic zones of Karnataka

Agro-climatic zone	1990	1997	2003	2007	2012	2019
North eastern transition zone	0.6807	0.6988	0.6761	0.7148	0.7179	0.7311
North eastern dry zone	0.6874	0.7156	0.7213	0.7489	0.7098	0.7030
Northern dry zone	0.7386	0.7403	0.7443	0.7390	0.7211	0.7157
Central dry zone	0.7131	0.7129	0.7061	0.7296	0.6691	0.6181
Coastal zone	0.3681	0.3092	0.2216	0.0755	0.1496	0.1367
Eastern dry zone	0.6898	0.6666	0.6691	0.7249	0.6491	0.6289
Southern dry zone	0.6743	0.6899	0.6910	0.7245	0.6766	0.6763
Southern transition zone	0.6573	0.6784	0.6626	0.7345	0.6517	0.6478
Northern transition zone	0.6931	0.7121	0.7121	0.7356	0.7061	0.6995
Hilly zone	0.4301	0.4956	0.4675	0.2103	0.4289	0.4250
Karnataka	0.6926	0.7144	0.7178	0.7414	0.7093	0.7071

Insight from Shannon's diversity index: Shannon's diversity indices (Table 4) indicate the northern dry zone to be the most biodiverse over years. The north eastern transition zone, on the other hand, has recently topped the list as a result of steady improvement over time. The coastal zone has the least biodiversity, followed by the hilly zone, for the entire period under study. It is also evident that the majority of agro-climatic zones have lesser biodiversity than Karnataka as a whole.

Insight from Berger-Parker dominance index: Berger-Parker dominance indices (Table 5) indicate that the least biodiversity is present in the coastal zone followed by the hilly zone over the years. A recent significant improvement in biodiversity is also observed in the north eastern transition zone. The north eastern dry zone has steadily remained mostly biodiverse over the years in spite of the initial and late dominance of the northern dry zone and the north eastern transition zone, respectively. The overall biodiversity of Karnataka has remained higher than most of its constituent agro-climatic zones.

Insight from Simpson's evenness index: Simpson's evenness indices indicate that over years, the northern dry zone has shown to be the most biodiverse (Table 6). The north eastern transition zone, on the other hand, has lately risen to the top of the list as a consequence of consistent progress. However, the coastal zone has the least biodiversity, followed by the hilly zone, across the study period. The majority of the agro-climatic zones have been evident to be less biodiverse than Karnataka as a whole.

Diversity pattern of the agro-climatic zones over the years: The mean ranks of the agro-climatic zones over the years are provided in Table 7. The higher the index value, the lower the rank is. In order to test whether the years agree on the biodiversity patterns among the zones, Kendall's coefficient of concordance has been computed (Table 8) for all the biodiversity indices considered in this study. The highly significant W value has clearly indicated the agreement among the agro-climatic zones on biodiversity patterns over the years in each case.

Table 3. Simpson's dominance indices (D_2) for the milch animals in the agro-climatic zones of Karnataka

Agro-climatic zone	1990	1997	2003	2007	2012	2019
North eastern transition zone	3.1314	3.3199	3.0878	3.5063	3.5453	3.7194
North eastern dry zone	3.1986	3.5158	3.5880	3.9833	3.4464	3.3668
Northern dry zone	3.8261	3.8510	3.9101	3.8319	3.5851	3.5177
Central dry zone	3.4860	3.4826	3.4031	3.6981	3.0223	2.6187
Coastal zone	1.5826	1.4475	1.2846	1.0816	1.1760	1.1583
Eastern dry zone	3.2233	2.9998	3.0218	3.6346	2.8497	2.6948
Southern dry zone	3.0707	3.2248	3.2364	3.6297	3.0922	3.0897
Southern transition zone	2.9182	3.1091	2.9634	3.7665	2.8708	2.8396
Northern transition zone	3.2587	3.4729	3.4738	3.7825	3.4027	3.3283
Hilly zone	1.7547	1.9826	1.8778	1.2663	1.7510	1.7390
Karnataka	3.2531	3.5019	3.5442	3.8674	3.4401	3.4142

Table 4. Shannon's diversity indices (H') for the milch animals in the agro-climatic zones of Karnataka

Agro-climatic zone	1990	1997	2003	2007	2012	2019
North eastern transition zone	1.2563	1.2874	1.2465	1.3117	1.3244	1.3466
North eastern dry zone	1.2727	1.3119	1.3245	1.3842	1.2896	1.2718
Northern dry zone	1.3650	1.3668	1.3749	1.3642	1.3328	1.3222
Central dry zone	1.3153	1.3191	1.2975	1.3428	1.2289	1.1417
Coastal zone	0.6252	0.5550	0.4390	0.1708	0.3295	0.2928
Eastern dry zone	1.2624	1.2100	1.2108	1.3300	1.1645	1.1153
Southern dry zone	1.2506	1.2751	1.2780	1.3366	1.2472	1.2339
Southern transition zone	1.2192	1.2425	1.2109	1.3568	1.1721	1.1395
Northern transition zone	1.2860	1.3114	1.3143	1.3550	1.2955	1.2794
Hilly zone	0.7846	0.8723	0.8394	0.4664	0.8081	0.8207
Karnataka	1.2846	1.3189	1.3235	1.3678	1.3011	1.2937

Diversity pattern of the years over the agro-climatic zones: The mean ranks of the years (Table 9) over the agro-climatic zones have shown a similar pattern. The lower rank indicates the higher index value. The highly significant Kendall's coefficient of concordance (W) value (Table 10) has further confirmed the claim of agreement among the years on biodiversity patterns over the agro-climatic zones for each biodiversity index.

Table 5. Berger–Parker dominance indices (BP) for the milch animals in the agro-climatic zones of Karnataka

Agro-climatic zone	1990	1997	2003	2007	2012	2019
North eastern transition zone	0.4632	0.4297	0.4683	0.3811	0.3927	0.3220
North eastern dry zone	0.4610	0.3743	0.3619	0.2781	0.3382	0.3658
Northern dry zone	0.3416	0.3164	0.3042	0.3024	0.3927	0.4018
Central dry zone	0.3980	0.4149	0.3861	0.3164	0.4679	0.5518
Coastal zone	0.7661	0.8156	0.8764	0.9608	0.9201	0.9269
Eastern dry zone	0.4074	0.4243	0.3975	0.3184	0.4636	0.5058
Southern dry zone	0.4825	0.4509	0.4509	0.3758	0.4681	0.4575
Southern transition zone	0.5063	0.4549	0.4817	0.3526	0.4854	0.4774
Northern transition zone	0.4558	0.3915	0.4042	0.3140	0.3740	0.3892
Hilly zone	0.7249	0.6591	0.6881	0.8855	0.7303	0.7377
Karnataka	0.4559	0.4005	0.3839	0.2917	0.3500	0.3854

Table 6. Simpson's evenness indices (E) for the milch animals in the agro-climatic zones of Karnataka

Agro-climatic zone	1990	1997	2003	2007	2012	2019
North eastern transition zone	0.7828	0.8300	0.7719	0.8766	0.8863	0.9299
North eastern dry zone	0.7997	0.8790	0.8970	0.9958	0.8616	0.8417
Northern dry zone	0.9565	0.9628	0.9775	0.9580	0.8963	0.8794
Central dry zone	0.8715	0.8707	0.8508	0.9245	0.7556	0.6547
Coastal zone	0.3957	0.3619	0.3212	0.2704	0.2940	0.2896
Eastern dry zone	0.8058	0.7500	0.7554	0.9087	0.7124	0.6737
Southern dry zone	0.7677	0.8062	0.8091	0.9074	0.7730	0.7724
Southern transition zone	0.7295	0.7773	0.7409	0.9416	0.7177	0.7099
Northern transition zone	0.8147	0.8682	0.8685	0.9456	0.8507	0.8321
Hilly zone	0.4387	0.4956	0.4694	0.3166	0.4377	0.4347
Karnataka	0.8133	0.8755	0.8860	0.9669	0.8600	0.8536

Table 7. Mean ranks for the agro-climatic zones of Karnataka

Zone	Diversity indices					
	HHI	D_1	D_2	H'	BP	E
North eastern transition zone	6.67	5.33	5.33	5.33	6.00	5.33
North eastern dry zone	9.00	3.00	3.00	3.67	9.67	3.00
Northern dry zone	10.50	1.50	1.50	1.50	9.33	1.50
Central dry zone	6.50	5.50	5.50	4.83	6.67	5.50
Coastal zone	1.00	11.00	11.00	11.00	1.00	11.00
Eastern dry zone	4.33	7.67	7.67	8.33	6.33	7.67
Southern dry zone	5.17	6.83	6.83	6.67	4.50	6.83
Southern transition zone	4.33	7.67	7.67	7.50	3.67	7.67
Northern transition zone	7.67	4.33	4.33	4.17	8.00	4.33
Hilly zone	2.00	10.00	10.00	10.00	2.00	10.00
Karnataka	8.83	3.17	3.17	3.00	8.83	3.17

Table 8. Kendall's coefficient of concordance for the agro-climatic zones of Karnataka

Diversity index	HHI	D_1	D_2	H'	BP	E
Kendall's coefficient of concordance (W)	0.800	0.800	0.800	0.809	0.780	0.800
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 9. Mean ranks for the years under study

Year	Diversity indices					
	HHI	D_1	D_2	H'	BP	E
1990	2.91	4.09	4.09	3.82	2.55	4.09
1997	4.27	2.73	2.73	2.64	3.73	2.73
2003	4.27	2.73	2.73	2.82	3.82	2.73
2007	4.73	2.27	2.27	2.36	5.00	2.27
2012	2.82	4.18	4.18	4.27	3.18	4.18
2019	2.00	5.00	5.00	5.09	2.73	5.00

Table 10. Kendall's coefficient of concordance for the years under study

Diversity index	HHI	D_1	D_2	H'	BP	E
Kendall's coefficient of concordance (W)	0.329	0.329	0.329	0.328	0.229	0.329
p value	0.003	0.003	0.003	0.003	0.027	0.003

CONCLUSION

This study has empirically evaluated the milch diversity in different agro-climatic zones of Karnataka in terms of various indices. Among the agro-climatic zones, the highest and lowest biodiversity is observed in the northern dry zone and the coastal zone, respectively. However, among the years, 2007 is observed to be the most biodiverse and 2019 to be the least. On the patterns of biodiversity, the agreement among the agro-climatic zones over the years and vice-versa have also been evident for all the biodiversity indices considered in this study. Similar insights from the different diversity measures should not be surprising as they are facets of the same phenomena. In reality, the majority of the metrics employed in this study may be derived using the same generalised entropy formula. Despite the strong relationships between these diversity measures, these are neither interchangeable nor similarly sensitive. Hence, it is suggested that instead of using any single index, multiple indices should be utilised to obtain a better insight.

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Influence of Soil Moisture and Bioamendments on the Speciation and Bioavailability of Chromium in Contaminated Soils

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Abstract: Chromium (Cr) is a strategic and dangerous heavy metal with many applications in the leather tanning and chemical industries. Cr has gained importance due to the greater understanding of its persistence and toxicity in ecosystems. To protect our environment from severe contamination threats, it is essential to remove Cr. But, before developing a remediation strategy, it is necessary to understand various factors and soil parameters that influence the bioavailability and fractionation of heavy metals. The investigation was conducted in a laboratory closed incubation experiment with bioamendments in a completely randomized design with three replications for 60 days. The study examined the impact of amendments like farmyard manure, composted poultry manure, pressmud compost, and biochar on Cr speciation in contaminated soil under different moisture conditions. The findings revealed that organic amendments substantially impacted soil chemical parameters such as pH, Cr mobility, and bioavailability. The significant reduction of bioavailable fractions was observed in biochar (75 to 80%) amended soil, followed by farmyard manure and poultry manure (60 to 70%). As a result, bioamendments can effectively reduce the bioavailability of Cr in contaminated soil and play a significant role in designing a bioremediation technology for the chromium contaminated soil.

Keywords: Bioremediation, Bioavailability, Chromium contamination, Moisture regimes, Bioamendments

Heavy metal contamination is one of the world's major environmental issues, resulting in crop yield losses. Chromium (Cr) is the seventeenth most abundant element on the planet and the second leading cause of groundwater, soil, and sediment contamination (Avudainayagam et al 2003). When contaminants enter the food chain, they impact human health. Several industrial processes and anthropogenic activities, such as leather tanning, chrome ore mining, fertilizers, pesticides producing factories, electroplating, metal finishing, corrosion control and pigment manufacturing industries releases various forms of chromium in soil and water (Yadav et al 2017). The majority of groundwater samples were unsuitable for irrigation based on index values this is due to anthropogenic activities such as excessive and pesticide are the main sources of chromium (Kumar and Balamurugan 2019). There are two stable forms of chromium, trivalent Cr (III) and hexavalent Cr (VI), which is more toxic and are interconvertible in soil. Cr in some locations shows that greater pollution and human health may be a concern as the landfill matures and the process of maturing continues (Elamin et al 2021).

Similarly, soil contamination caused by tannery wastes in Vellore district and textile industries in Tiruppur District of Tamil Nadu has deteriorated soil health (Rajendiran et al 2015). Cr is one of the heavy metal released through tannery waste, which is highly toxic to humans and plants, and it has been a primary environmental concern for several decades (Tiwari et al 2019). Cr levels in contaminated soils in the Vellore District were extremely high, indicating that the soils surrounding tannery industries are heavily contaminated with Cr (Rangasamy et al 2015, Sathya et al 2021). Large amounts of Cr (16,731-79,865 mg kg^{-1}) were found in surface and subsurface soils in Vellore Districts, where many tanneries exist (Mahimairaja et al 2011). Chromium contamination in soil and water has drastically reduced the crop yields (25 to 40%) over the years (Dotaniya et al 2014). With increased public awareness of Cr poisoning in both animals and humans, there has been a surge in the desire to develop regulatory guidelines and remediation technologies for Cr-contaminated soil and water ecosystems (Rahman and Singh 2019). The reduction of Cr (VI) to Cr (III) and subsequent adsorption as a method for managing Cr contamination in soils has been proposed as an effective method (Premalatha et al 2018). Understanding the bioavailability of Cr (VI) and Cr (III) in soils prompts research into their adsorption and desorption of chromium

(Kamaludeen et al 2003). Clay soil has enormous small pores in which more water is kept and might have promoted microbial activity in the clay soils and remediates the contaminated soils (Salwan Al-Maliki et al 2019). Organic matter in the soil may transform over a period of time. These transformations may have certain effect on the retention or adsorption of Cr in soil. Based on the nature and stability of organic amendments, they can influence metal solid solution phase partitioning and thus alter the bioavailability and environmental fate of metals. Hence, with these facts in view, this research was initiated to quantify the relative adsorption of Chromium by various organic amendments in contaminated soil.

The remediation of chromium contaminated soils is an important issue that helps sustain agriculture and reduces negative environmental impacts (Mahimaraja et al 2011) conducted laboratory experiments to examine the potential of biological wastes in remediating Cr contaminated soils. Their results revealed that 61% (in clay loam soils) and 75% (silt clay loam soils) reductions in the concentration of bioavailable fractions (soluble plus exchangeable) of Cr resulted from the application of coir pith. Sathya and Mahimairaja (2016) also conducted laboratory experiments using bioamendments for the remediation of Nickel. From these experiments, we concluded that the application of biological amendments, namely farmyard manure, composted poultry manure, pressmud compost and biochar, were found to be effective for reducing the bioavailable fractions of Cr, mainly through the formation of organic complexes, demonstrating their great potential in the bioremediation of Cr-contaminated soil. Therefore, in the current study, a bioremediation technology was developed by the addition of biological amendments and evaluated its potential in remediating the Cr contaminated soil, and the influence of soil pH, organic carbon (OC) content on bioavailable fractions of Cr in bio-amended soil was studied through a laboratory closed incubation experiment.

MATERIAL AND METHODS

Study area: The effect of different bio-amendments on the bioavailability of Cr and its fractions were investigated by performing a laboratory closed incubation experiment at the National Agro Foundation Research and Development Centre, Chennai, India (12º.98'84.01” N, 80º.22'26.4" E). The soil samples were air-dried for three days and sifted using a 2-mm sieve to attain equal particle size.

Selection of bioamendments: Bioamendments such as farmyard manure, composted poultry manure, pressmud compost, and biochar were chosen for this study. The bio-amendments were collected from Tamil Nadu Agricultural University Farm, Coimbatore (11°00'45.8"N 76°55'53.8"E). They are used as soil amendment to improve soil quality, fertility and increase soil carbon sequestration. In addition, the recalcitrant nature of bio-amendments increases their long-term potential value as a soil amending material (Liang et al 2021). Furthermore, incorporating bio-amendments into the soil can be used as a soil conditioner because it improves soil fertility due to its high organic carbon content and high nutrient and water sorptive capacity (Chan et al 2020). The selected bioamendments have favorable features, such as their large specific surface area, porous structure, surface functional groups, and high pH, allow them to be utilized as an adsorbent to immobilize heavy metals in soil (Rieuwerts 2007). Important characteristics of the bio-amendments were determined and presented in Table 1.

Incubation experiment: In the incubation experiment, soil was spiked with Potassium Dichromate ($K_2Cr_2O_7$) synthetic salt to achieve a final concentration of 500 mg Cr kg^{-1} and was mixed thoroughly. Then, five hundred grams of Cr salts spiked soil was weighed in a 2 kg plastic container and closed with a polyethylene cover containing small holes for aeration. Three replicates of each treatment were prepared and placed randomly and incubated in the laboratory at 25 ± 2ºC for 60 days. The moisture content of the soil samples were maintained at two different conditions in Field capacity moisture (FC) and Alternate wetting and drying condition (AWD). Then, after three days of equilibiration, selected bioamendments were added by following the treatment details;

Treatment Details

T_1 – Control, T_2- 500 mg kg^{-1} of Cr+ 12.5t ha^{-1} of farmyard manure, T_3- 500 mg kg^{-1} of Cr + 5t ha^{-1} of composted poultry

Table 1. Physico-chemical characteristics of bioamendments

Parameter	Unit	Farm yard manure	Composted poultry manure	Pressmud compost	Biochar
pH	-	7.25±0.009	6.23±0.07	6.27±0.13	7.86±0.19
EC	dS m^{-1}	3.08±0.02	2.35±0.003	2.28±0.03	3.19±0.06
Total nickel	mg kg^{-1}	16.01±0.39	16.26±0.25	13.50±0.29	18.07±0.23
Total chromium	mg kg^{-1}	BDL	0.47±0.001	0.33±0.007	BDL
Total cadmium	mg kg^{-1}	3.69±0.08	3.14±0.02	3.07±0.07	3.86±0.04

Note: BDL- Below Detectable Limit

manure, T_4- 500 mg kg^{-1} of Cr + 5t ha^{-1} of pressmud compost , T_5- 500 mg kg^{-1} of Cr + 5t ha^{-1} of biochar, M1- Field capacity moisture, M2- Alternte wetting and drying conditions

At the end of 0, 15, 30, 45, and 60 days of incubation, the samples were thoroughly mixed, and examined for pH and different fractions of Cr.

Speciation of chromium: Heavy metals transform based on their chemical valence state. As a result, a sequential extraction protocol was used to determine the relative proportions of different forms of Cr. A technique pronounced by Hughes and Noble (1991) was used to determine the species of retained chromium in the soil, and the calculation is depicted below.

Water-soluble fraction (Step1): One gram of air-dried soil sample was weighed in a 50ml polypropylene centrifuge tube and add 25ml of double-distilled water. It was shaken in an end- over-end shaker for 2h at 25 ± 2ºC. Then the samples were centrifuged (8000 rpm) for 10 minutes and filtered (Whatman No. 40). The amount of soluble Cr in the water extract was measured using an Atomic Absorption Spectrophotometer with an air-acetylene flame of VARIAN, AA240 (USEPA, 1979).

Exchangeable fraction (Step2): The amount of 25 ml of 0.5 M KNO_3 was added to the residue from phase 1 and shaken for 16h. As in phase 1, centrifugation, filtration, and calculation were carried out.

Organic fraction (Step 3): To the residue from step 2, 0.5M NaOH was added and shaken for 16h. The centrifugation, filtration is analysed in AAS for the chromium concentration, and calculation were carried out equation 1

Organic plus iron-oxide bound fraction (Step 4): To the residue from step 3, 0.05M Na_2EDTA was added and shaken for 6h. The centrifugation, filtration, and measurement

Residual fraction (Step 5): The soil residue from step 4 was transferred into a 100 ml conical flask utilizing small quantities of water and dried in an oven. 10ml of nitric acid (concentrated) was added and the contents were digested at 110ºC. After digestion, the contents were diluted and filtered using Whatman No.4 filter paper. Cr content in the filtrate was measured. Before and after the extraction, the tube and contents were weighed to determine the volume of entrapped solution and heavy metal transfer between extractants. The following equation was used to calculate the sum of Cr extracted by each extractant.

Cr extracted mg kg^{-1} = C x (E+M) - (C' x M) / soil weight

Where, C - Heavy metal concentration in the extraction solution, E - The extractants mass (g), M - Entrained solution mass (g) carried over from the previous extraction. C - Heavy metal concentration in the extraction solution of the previous step of the sequence.

RESULTS AND DISCUSSION

Characteristics of soil and bioamendments: The pH of the experimental soil was 7.30, with an EC of 0.542 dS m^{-1}. The following four bioamendments were chosen: Biochar, composted poultry manure, pressmud compost, and farmyard manure. The pH varied between 6.23 (composted poultry manure and 7.86 (biochar). The electrical conductivity (EC) was between 2.35 dS m^{-1} (composted poultry manureto 3.19 dS m^{-1} (biochar). The organic carbon content was 24.12% in farmyard manure, which is higher than others when compared to composted poultry manure ,pressmud compost , and biochar.

pH of bioamended soil: The pH of Cr contaminated soil was 7.82, which were significantly increased due to the incorporation of different amendments (Fig. 1). When the soil's pH increases, the soil's negative surface charge increases, resulting in increased adsorption of positively charged Cr. Initially, the pH of the experimental soil on the 0^{th} day without amendments was about 7.65 whereas, after adding organic amendments, pH varied between 7.69 to 7.82. After adding biochar, the soil pH had increased and it is mainly due to the alkaline nature of biochar and contribute to the stabilization of heavy metals (Wang et al 2019). The pH of the soil in the field capacity moisture condition (M1) was higher than the pH of the soil in the alternate wetting and drying condition (M2). The decrease in soil pH could be due to the production of organic acids during the decomposition of soil organic matter and the adding of organic amendments (Fatima et al 2021), while the increase in pH was most likely due to the production of NH_4 and the addition of base ions from bioamendments (Seenivasan et al 2015). Because of the activity of protons and ions, changes in the pH of the solution had an effect on the adsorption of metal ions (Alatabe and Kariem 2021).

Electrical conductivity of bio-amended soil: The initial electrical conductivity of the experimental soil was about 0.48 dS m^{-1}, further after the addition of different amendments the conductivity ranged between 0.35 and 0.54 dS m^{-1}. After 15 days, the EC increased slightly compared to the initial conductivity. However, Electrical conductivity (EC) started decreasing later till the 60^{th} day. The highest EC value (0.86 dS m^{-1}) was recorded in the composted poultry manure added soil, whereas the lowest (0.21 dS m^{-1}) was observed in soil that received pressmud compost at a rate of 5t ha^{-1}. Further, the electrical conductivity under field capacity conditions were slightly less than under alternate wetting drying conditions. Out of all amendments, biochar and pressmud compost exhibited the lowest electrical conductivity; this might be due to the adsorption of some cations and anions of amendments.

Soil organic carbon of bio-amended soil: Results from the laboratory closed incubation experiment have shown that the incorporation of bioamendments had remarkably enhanced the soil organic carbon (SOC). Initially, the SOC content ranged between 0.41% (T_1) and 0.68% (T_4). After 60 days of the incubation period, the organic carbon content ranged between 0.88% (T_5) to 1.18% (T_1). Hence, at the end of 60 days, the highest SOC (1.25%) was observed in biochar incorporated soil under alternate wetting and drying, whereas the lowest (0.21%) was observed in the control soil under field capacity moisture. It could be ascribed to the amount of the functional groups there in the biochar, larger specific surface area, and higher porosity of the soil, which paved the way for a higher rate of Cr adsorption (Sathya and Mahimairaja 2016). Similar results were also reported in the work of Shenbagavalli and Mahimairaja (2012) and the improvement in the organic carbon content due to the incorporation of organic amendments was also reported by Liu et al (2016) and Joshi et al (2017.) Out of all amendments, biochar has markedly increased the soil organic carbon than others Similartrend was observed by Lehmann (2007).,

Influence of bio-amendments on the bioavailability of Cr under two different moisture regimes: The bioavailability of chromium chemical fractions is divided into three categories: readily bioavailable, potentially bioavailable, and unavailable fractions, as well as the impact of bio-amendments in chromium contaminated soil. In both the field capacity moisture and alternate wetting and drying conditions, the higher concentration was observed on initial day and decreased at 60^{th} day of the incubation period. According to the classification, the readily available chromium in the analyzed soils decreased over time (Shahid et al 2017). The farmyard manure @ 12.5t ha^{-1} (T_2) showed a higher readily available fraction than all the other treatments in field capacity moisture conditions. Heavy metal binding in various fractions varies greatly depending on their bioavailability and chemical activity (Olaniran et al 2013). In both the conditions, the concentration of unavailable chromium fractions was higher at the beginning and at the later stages. It is feasible that the higher concentration of unavailable chromium fractions is due to a significantly less mobile state (Nawab et al 2016).

Water-soluble fraction: The water-soluble fraction was higher in soil under field capacity moisture conditions at the initial and final stages. There was an increasing trend in all the treatments towards the days from 0^{th} to 60^{th} day of the incubation period (Fig. 2). Initially, a high concentration of H_2O – Cr was observed under both moisture conditions, which ranged from 91.66 to 95.53 mg kg^{-1}. Application of different bioamendments markedly reduced the concentration of H_2O – Cr. During 60 days of incubation under field capacity moisture conditions, the H_2O–Cr concentrations were found to decrease up to 82.25 mg kg^{-1} with the application of farmyard manure at a rate of 12.5 t ha^{-1}. However, it was high in the soil during the incubation under alternate wetting and drying. Under field capacity moisture, the water-soluble Cr gradually decreased over time up to the 45^{th} day of incubation. Based on pH, total metal concentration, and organic matter content, the soluble concentration of Cr could be predicted (Davamani et al 2016). Hence, the reduction may be attributed to the effect of bioamendments in transforming H_2O-Cr to organic plus iron oxide from (Na_2EDTA - Cr) and residual form (HNO_3 - Cr), respectively. The production of insoluble chromium humic acid complexes may explain the decrease in the concentration of the water soluble fraction of Cr during incubation (Huang et al 2019).

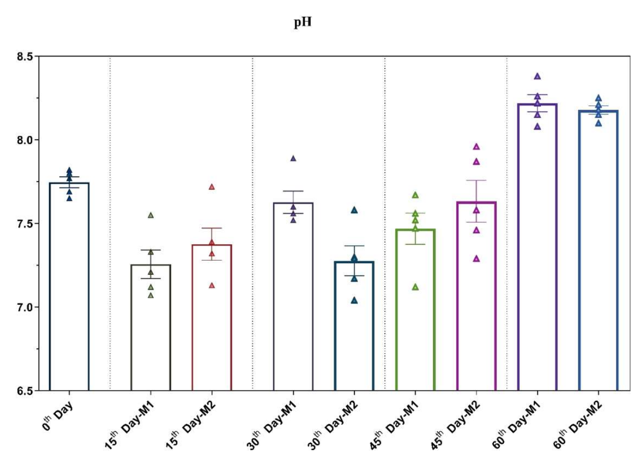

Fig. 1. Effect of bioamendments on soil pH of chromium contaminated soil under two different moisture conditions

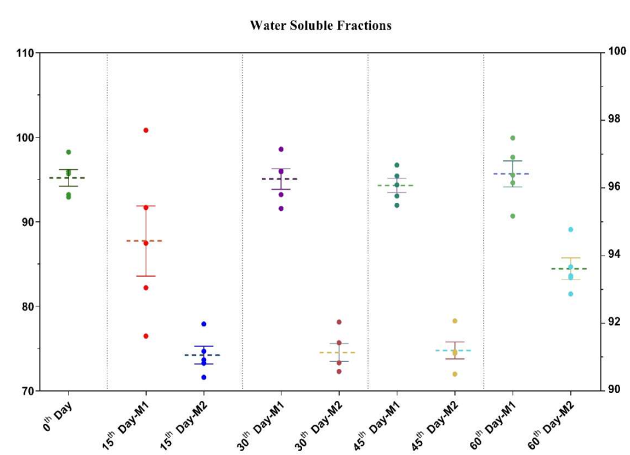

Fig. 2. Effect of bioamendments on water-soluble fractions of chromium contaminated soil under two different moisture conditions

Exchangeable fraction of chromium: The concentration of exchangeable chromium increased on the 15th day from the initial stage and then decreased at 30th and 45th days, which further increased at 60th day under field capacity moisture conditions (Fig. 3). The concentration of exchangeable Cr as extracted by using 0.5M KNO_3 ranged from 94.07 to 104.77 mg kg^{-1}. Both the moisture contents and various organic amendments had significant effect on exchangeable fraction of Cr. In general the concentration of exchangeable Cr was found decreased upto 30th day of incubation and thereafter it was found to increase at 60th day. Such effect was more pronounced in soil under alternate wetting and drying condition. The concentration of metals in this phase indicates the impact of metals on the environment (Sherene 2010). Both moisture and bioamendments significantly impacts the exchangeable fraction of Cr. It was found high in the pressmud compost amended soil and low in the control soil under alternate wetting and drying condition. The reduction in exchangeable Cr might be due to its adsorption on soil particles and its transformation to other species of Cr (Kotaś and Stasicka 2000). The adsorption of metals decreases as the pH of the soil decreases, increasing the available fraction (Zhang et al 2018). The metal transformation primarily influences soil type, moisture content, and incubation time in soil. The exchangeable fractions of fraction is a reliable indicator of the bioavailability of metals (Beesley et al 2011).

Organic fraction of chromium: There was a marked changes in the organic Cr content due to the application of bio-amendments (Fig. 4). The organic fraction of Cr was extracted by 0.5M NaOH and the concentration of NaOH-Cr decreased drastically from 137.54 mg kg^{-1} (control) to 76.38 mg kg^{-1} (bioamended soil). The organic fraction was higher in soil under alternate wetting and drying conditions than under field capacity moisture condition. In alternate wetting and drying conditions, the highest organic Cr (101.98 mg kg^{-1}) was obtained in the soil treated with pressmud compost and the lowest value (71.28 mg kg^{-1}) in the control soil after 60 days of incubation. The changes in organic Cr could also be attributed to changes in soil chemical properties and the chelating ability of organic matter present in the applied bioamendments (Cervera-Mata et al 2022). Complexation, adsorption, and precipitation, among other physicochemical reactions between metals, amendments and soils, are commonly decreased the metal availability in the different soil conditios and the experimental time (Adriano et al 2004). Different physico-chemical processes between metals and soils, such as complexation, adsorption, and precipitation, are generally attributed for the decrease in metal availability over time (Shahid et al 2017)

Organic plus iron oxide bound chromium: The concentration of metals in the organic plus iron oxide bound chromium indicates the impact of metals on the environment. Both moisture conditions and amendments significantly impact the organic plus iron oxide fraction of Cr (Fig. 5). Applying different bio-amendments resulted in significant changes in Cr's organic plus iron oxide fraction. In both under field capacity moisture and alternate wetting & drying, the concentration of organic plus iron oxide bound Ni was found decreased and increased alternatively over a period of time. The characteristics and nature of organic carbon in different bioamendments significantly impacted Cr biotransformation in soil, resulting in different concentrations of the amendments added to the soil. The complexation or chelation of Cr with organic materials is responsible for the change in the organic plus iron oxide bound fraction of Cr (Sellappa Gounder et al 2021). During the mineralization of organic amendments, the metal could precipitate as

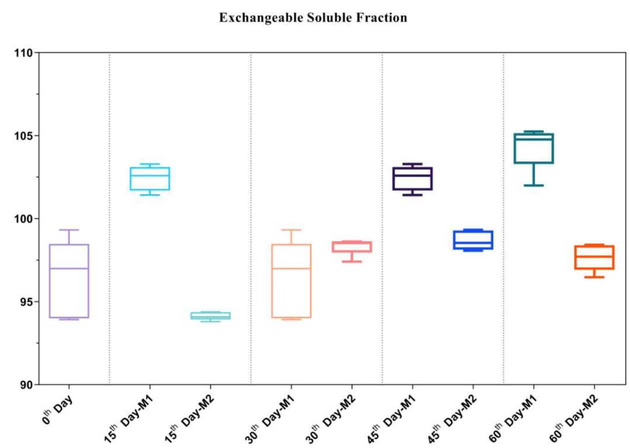

Fig. 3. Effect of bioamendments on exchangeable fraction of chromium contaminated soil under two different moisture conditions

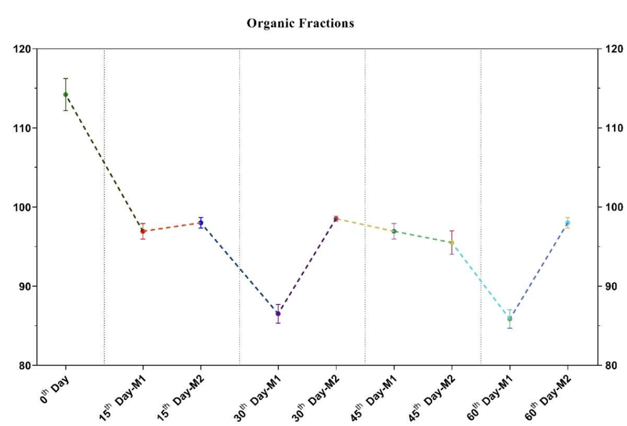

Fig. 4. Effect of bioamendments on organic fraction of chromium contaminated soil under two different moisture conditions

inorganic compounds. During the mineralization of bioamendments, the metal might precipitate as inorganic molecules (Lwin et al 2018). The complexation or chelation of Cr with organic matter is responsible for the variation in Cr's organic plus iron oxide bound fraction (Almås et al 2000). During the mineralization of organic amendments, the metal could precipitate as inorganic compounds (Walker et al 2003). The rate of Cr (VI) reduction was also affected by several factors, including pH, temperature, and the carbon and nutrient sources (Parameswari et al 2009, Megharaj et al 2003).

Residual fractions of chromium: The concentration of residual frations of Cr in the soil under field capacity moisture was significantly higher than in the soil under alternate wetting and drying conditions (Fig. 6). The significant increase in the residual Cr can be attributed to the sorption of Cr. Initially, the concentration was about 87.92mg kg^{-1}. However, after the 15^{th} day, the concentration increased compared to the intial stage and further increased up to the 60^{th} day. The residual fraction is a major carrier of metals in most ecological systems. The moisture conditions and organic amendments significantly affected the soil chemical properties. Under both moisture conditions, the residual Cr was found to increase gradually from the 0^{th} day to the 45^{th} day, and after that, it was found to decrease at the 60^{th} day of incubation. Under both moisture conditions, the residual Cr concentration was highest in the soil treated with biochar and lowest in the soil supplied with pressmud compost after 60 days of incubation. Biochar has been shown to adsorb and retain a higher level of heavy metals than other materials (Zhang et al 2013).

Furthermore, because it is the most prevalent speciation process, the solid phase of Cr accounts for most Cr in the soil (Sarkar et al 2019). Thus, biochar significantly reduced chromium fractions, which may be due to their high cations exchange capacity (CEC) and surface area, which facilitates Cr adsorption. In contrast, the other amendments increased Cr bioavailability by soluble organic matter fractions and organic acid production during decomposition (Amir et al 2005). Because it is the most dominant speciation process, the solid phase of Cr is associated with the largest fraction of Cr in soil. In addition, it has low mobility in the soil (Sherene 2010).

Pearson's correlation analysis of soil parameters on the initial day (0^{th} day) in both the conditions (M1): Pearson's correlation coefficient analyzes the relationship between different physicochemical properties and heavy metal concentrations. The soil pH is positively correlated with EC, SOC, organic Iron Oxide chromium, residual chromium and strongly positively correlated with exchangeable chromium. However, it has a strong negative relationship with water-soluble chromium and organic chromium. The correlation of pH has a good level of statistical significance (Fig. 7), with soil organic chromium fraction. The result was in agreement with previous studies of Chen et al (2015). Water-soluble chromium fractions are negatively correlated with pH and organic iron oxide chromium fractions but have a positive relationship with organic chromium fractions. Exchangeable chromium fraction is positively correlated with pH, and it has a negative relationship between organic and organic iron oxide chromium fractions. Since the neutral and alkaline soils have higher concentrations of clay minerals and oxides than acidic soils, Cr redistribution from readily available to potentially available is less in the available fraction (Shahid et al 2017). Organic iron oxide chromium fraction is positively correlated with pH, SOC and strongly negatively with water-soluble chromium fraction. Residual chromium fraction is negatively correlated with SOC and organic iron oxide chromium fractions. Neina (2019) observed negative

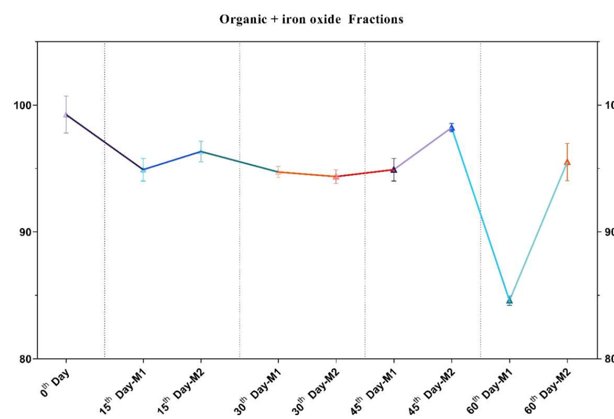

Fig. 5. Effect of bioamendments on organic plus iron oxide fraction of chromium contaminated soil under two different moisture conditions

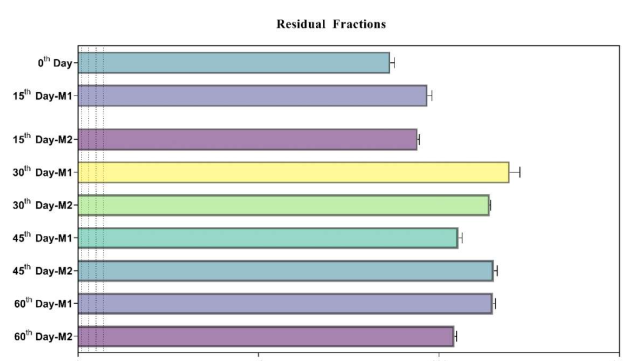

Fig. 6. Effect of bioamendments on residual fraction of chromium contaminated soil under two different moisture conditions

relationship between soil pH and metal ion availability and mobility in the soil solution.

Pearson's correlation analysis of soil parameters on the initial day (0th day) in both the conditions (M2): The soil pH is negatively correlated with the water-soluble chromium fraction and organic chromium fraction, and it has a positive relationship with the exchangeable chromium fraction. Water-soluble chromium and iron oxide bound chromium, on the other hand, showed a positive correlation. It is because there are more available and mobile Cr fractions (Barman et al 2020). The high pH value favoured the retention of additional metals on the soil surface in alkaline soil (Choppala et al 2018). Water-soluble chromium fraction is negatively correlated with pH, organic iron oxide chromium fractions. Exchangeable chromium fraction is positively correlated with pH and SOC. Organic chromium fraction is negatively correlated with pH, and exchangeable chromium fraction. The negative correlation might be due to the concentrations of non-available fractions increased.

In contrast, the concentrations of available fractions decreased, so Pearson's correlation analysis revealed a positive relationship between non-available fractions and pH and a negative relationship between organic chromium fraction and pH (Chen et al 2018). Organic iron oxide chromium fraction is negatively correlated with EC, water-soluble chromium fraction and residual chromium fraction. The strong link between exchangeable soil metals could indicate contamination at similar levels and from similar sources (Li et al 2009). Residual chromium fraction is negatively correlated with SOC and organic iron oxide Chromium fraction. In M2 moisture conditions, pH is highly negatively correlated with organic chromium fractions with high levels of significance and the same results were observed in M1 moisture conditions.

Pearson's correlation analysis of soil parameters on the final day (60th day) in both the conditions (M1): The soil pH is positively correlated with SOC and strongly negatively correlated with organic chromium fractions and iron oxide chromium fractions (Fig. 8). Low pH levels can increase the soil's water-soluble and organic Cr fractions (Król et al 2020). Water-soluble chromium fractions are negatively correlated with exchangeable chromium fractions. Water-soluble and exchangeable chromium metals in soil show a significant chemical fraction with a positive correlation between pH and EC (Yang et al 2019). The exchangeable chromium fraction has a negative relationship water-soluble chromium fraction. pH is negatively correlated with EC, water-soluble chromium fraction, and has a strong positive relationship with SOC. Though the parameters have a strong relationship, it is not statistically significant.

Pearson's correlation analysis of soil parameters on the final day (60th day) in both the conditions (M2): Soil organic carbon (SOC) has a strong positive relationship with pH and a strong negative relationship with the water-soluble chromium fraction. The pH and SOM concentration had a significant impact on the binding of heavy metals in various forms (Ettler et al 2007). The pH, SOC, and organic chromium fractions are negatively correlated with the water-soluble chromium fraction. The exchangeable chromium fraction is related to pH, EC, and SOC in a positive way. Organic chromium fraction is negatively correlated with pH,

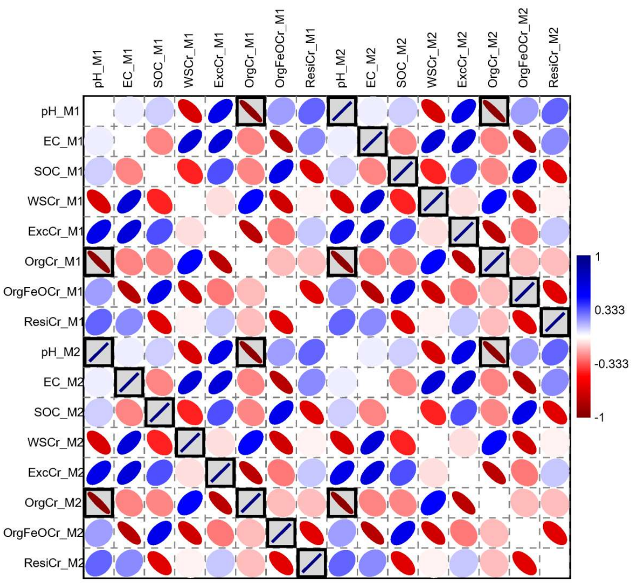

Fig. 7. Pearson's correlation analysis of soil parameters on the initial day (0th day) in both the conditions

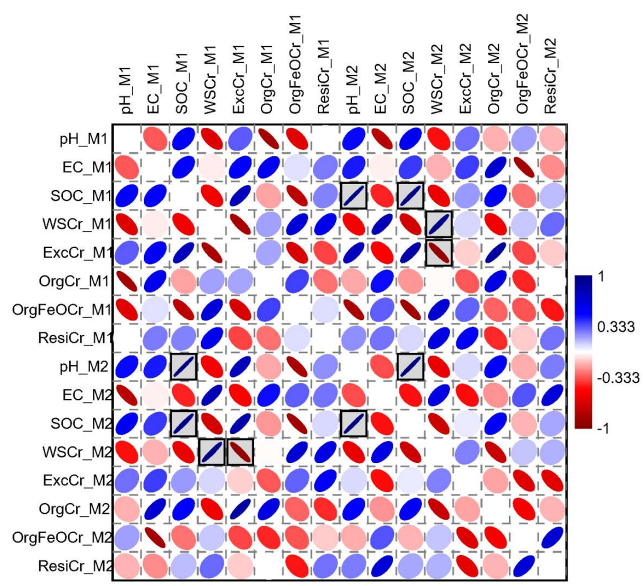

Fig. 8. Pearson's correlation analysis of soil parameters on the final day (60th day) in both the conditions

exchangeable chromium fraction. A significant negative correlation exists between chromium in the soil and chromium adsorption with amendments, indicating that metal removal from the soil is strongly linked to chromium adsorption with amendments (Ullah et al 2020). Organic iron oxide chromium fraction is negatively correlated with EC, water-soluble chromium fraction and residual chromium fraction. Soils with a negative correlation between pH and changes in the soil water-soluble and organic chromium fractions have a higher level of chromium (Shaheen and Rinklebe 2014). Residual chromium fraction is negatively correlated with the exchangeable chromium fraction. pH is highly positively correlated with SOC ..

CONCLUSION

Bioremediation is a more efficient method of removing metal contaminants and converting them to harmless substances and is efficient, eco-friendly and cost-effective strategies for remediation of Cr contaminated environment. The application of organic amendments to agricultural soils regularly improves their physical, chemical, and biological fertility. The organic amendments used for this study are cost savings and locally available products that farmers can use effectively to remediate chromium-contaminated soil. The organic acids producee during the decomposition of bioamendments reduced soil pH and increased the Cr bioavailability. The use of bioamendments resulted in 80 per cent reduction in the concentrations of bioavailable fractions such as water-soluble – Cr (H_2O – Cr) and exchangeable fractions (KNO_3–Cr) in contaminated soils under two different moisture conditions. Organic amendments have the potential to remediate Cr-contaminated soil based on Cr mobilization or immobilization. The soil pH and bioavailable fractions of Cr showed a positive correlation in our study. If the amendment increases Cr bioavailability, we can use phytoremediation technology. These contaminated lands must be remediated to maintain agricultural production and environmental health. As a result, using bioamendments to remediate chromium contaminated soils could provide a novel solution to the soil pollution problem.

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Paddy Stubble Burning in Punjab: An Architect of Breathing Woes

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Abstract: Crop residue burning (CRB) is a persistent issue in north India, every year it engulfs the whole of North India in its fumes. CRB results in severe negative aftermaths on both human health and the environment especially now when the Covid-19 pandemic is so rampant to cause respirational distress. The current study was being conducted to assess the state of crop residue burning in Punjab. The research was based on secondary data from the Punjab Remote Sensing Centre, which spans the years 2016 to 2020. During the *Kharif* season, the number of stubble-burning cases decreased from 81042 to 71081 (a decrease of about 13 percent) from 2016 to 2020. This dwindling trend in cases is a good sign for environmental conservation. There has been an increase of 25% in stubble burning during the Rabi season from 2016 to 2020, incidences of stubble burning have reached an all-time high in the last five years, even during the widespread Covid 19 outbreak and may be because of labour shortages during Covid-19. The farmers who had previously embraced good crop residue management methods may resort to burning fields in the coming rice harvesting season due to additional challenges which exacerbating the problem. The government should focus on subsidizing crop residue technologies and effective behavior change approaches to tackle the problem unanimously with the help of farmers themselves. The study recommends mandatory diversification of the cropping cycle on a minimum acreage basis, shift to early-maturing rice varieties as PAU suggested, and making paddy residue management technologies like happy seeder and super seeder widely available. Farmers should be incentivized accordingly for good agricultural practices rather than punished for burning.

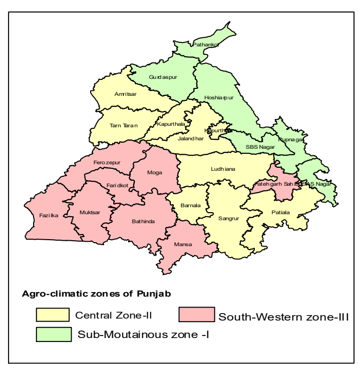
Keywords: Covid-19, Crop residue burning, *Kharif* and *rabi* season

Historically Punjab is an agrarian state and largest contributor of food grains to the central pool. Out of total operational holding, a significant chunk of whopping,i.e.,28 lakh hectares under wheat and paddy cultivation in the state. Of which a total of 47.2 lakh t of straw is generated every year. This included 25 lakh t of wheat straw and 22 lakh tones of paddy straw. Out of this 95 per cent of paddy straw and 25 per cent of wheat straw is burnt each year. The mechanized harvesting of these crops further adds to the quantity of residue. At the time of manual harvesting, the straw is chopped into small pieces and ploughed back into the soil to improve its content. Though a ban was imposed on stubble burning by the state government way back in 2005, the practice is still going on due non-implementation of the ban. The problem has been highlighted by the United States National Aeronautics and Space Administration (NASA),and the Supreme Court of India has also taken a serious note of it, but for two major reasons. Firstly, stubble burning is only responsible for a fraction of the overall pollution, and it occurs for less than a month. Secondly, it is less a matter of environmentally unfriendly farmers and more government inaction. This utterly predictable annual phenomenon is not manageable at the farmer level as the infrastructure to care for paddy residue is not commonly and economically available. On a positive note, this does seem to be changing. Farmers in Punjab (and, to a lesser extent Haryana) grow a significant share of India's cereals. There are many policy reasons for this, including the electricity pricing policy and the government's minimum support price scheme that favors cereals. This means that rice paddy farmers dominate Punjab's agriculture and they also grow wheat in the winter months. The time window between harvesting the paddy crop and planting the wheat crop is just 10 to 20 days in late October–November. Delay in sowing would risk compromising on the yield of the wheat crop, while planting the paddy crop earlier would entail suboptimal utilization of monsoon rains and consequently greater reliance on scarce groundwater. Therefore, the farmer cannot lengthen this time window and has to speedily dispose of the leftover residue by the combined harvesters before sowing the wheat crop. Burning has been the traditional go-to option for farmers in North India(especially in Punjab); it is easy and costless, unlike alternative means of disposal. While the agricultural residue could serve as an excellent fuel source for biomass power plants, these power plants are costly to set up and are few and small incapacities; they are currently capable of utilizing less than 5 per cent of the 20 million t of paddy residue generated annually (Gupta 2019). Baling is also not a farmer-friendly practice, but the transportation costs are high, and the open market price of bails of paddy residue is too low to be economically feasible.

Fortunately, there are solutions, and among them, a viable, affordable and scalable technological solution has become particularly attractive in the past several years. An innovative machine called the Happy Seeder cuts and lifts the rice straw and then leaves it as mulch over the field even as it plants the wheat seeds. Generally, it increases yields (Sidhu et al 2015), and profitability is higher than other disposal alternatives. These alternatives include other machines and the traditional practice of residue burning (Shyamsundar et al 2019). It is estimated that 35,000 Happy Seeders would be enough to cover the entire crop area responsible (Gupta 2019). Despite these advantages, the uptake has been somewhat limited. Barriers to the adoption of Happy Seeders include high upfront cost of purchase, high and variable cost of rental and lack of farmer awareness. The number of Happy Seeders manufactured was also unable to keep pace with increasing sales. These problems are finally being addressed: a substantial government subsidy is available for purchase, the state government is actively promoting Happy Seeders, and manufacturing facilities are being expanded. Thousands of Happy Seeders are now expected to join the agricultural workforce each year. Even biomass power plants may receive game-changing fresh investments to produce thousands of megawatts of electricity (IANS 2019). Farmer support for them had already been picking up, with some farmers even paying for the baling process and transportation, thus adding to the double whammy of cost and convenience (Krar 2018). Not all farmers could be expected to bear residue disposal costs altruistically. Many also mistakenly believe that burnt residue contains soil nutrients. Given that the cost of moving to alternatives is non-zero and that traditional practices are entrenched, the threat of legal enforcement may be needed as a motivating factor. Yet, it is insensitive to do that at present, when farmers realistically have no immediate alternative. This is justifiably making them angry (Khanna 2019). The Supreme Court's directive of providing farmers Rs. 100 ($1.5) per quintal of residue is insufficient for proper disposal. Nevertheless, it does seem that a combination of Happy Seeders and biomass power plants would solve the stubble burning problem in the next several years, at least in Punjab. The lessons learnt need to be implemented actively in India because many kinds of stubble are regularly burnt across the agricultural landscape. Agricultural waste burning is not benign, not in India and not elsewhere. Brazil, for example, suffers from the health consequences of post-harvest sugarcane fields set on fire (Rangel and Vogl 2016). Still, its contribution must be understood in context; a study found that burning all the agricultural wastes of the San Francisco Bay Area for one year would still emit less pollution than one day of traffic in the same area (Darley et al 2012). The Bay Area has far lesser vehicles than the National Capital Region of India. So, while residue burning could account for a significant portion of Delhi's pollution on certain days (Gandhiok 2018), the primary problems lie elsewhere. Instead of Delhi's reactive strategy of undertaking short-term emergency measures on pollution only after it crosses unbearable thresholds, there is a need for a predictive strategy as followed successfully in Beijing. However, the changing pattern of agriculture and usage of machines at the time of harvesting as less numbers of labourers, and many more reasons are associated with the problem of crop residue burning. Amid, Covid-19 pandemic raging around the world which is known to affect the lungs and cause respiratory distress, cases of wheat crop residue burning are not quashed in Punjab. Crop residue burning (CRB)is a solemn problem in north India, especially when the burning of stubble affects environmental pollution. The present scenario could be detrimental for Covid-19 patients with breathing problems. So, bearing in mind the seriousness of this problem, the present study was undertaken to check the status of crop residue burning in Punjab. Consequently, there is a need to study the current status of crop residue burning in the study area and scrutinize why farmers of this region burn crop residue.

MATERIALS AND METHODS

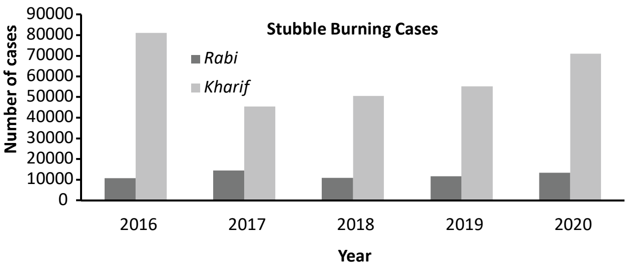
The study is based on secondary data collected from the authentic online portal of Punjab Remote Sensing Centre (PRSC) for collecting the data related to stubble burning case in Punjab state from the period 2016 to 2020. For concise study, the Punjab state is divided into agro-climatic zone to have the depth picture of burning cases in the state. The division of state shown in Punjab map made by using ArcGIS software and for analysis of data descriptive tools are used to achieve the objective.



Agroclimatic zone of Punjab state

RESULTS AND DISCUSSION

Stubble burning: There is large variability in the production of straw production, and their use which solely depend upon the crop grown, cropping intensity and productivity in a different region of India (Singh and Sidhu 2014). Cereal crops (rice, wheat, maize, millets) contribute 70 per cent of the total crop residue (352 Mt), comprising 34 per cent of rice and 22 per cent of wheat crops. The rice-wheat system accounts for nearly one-fourth of the total residue produced in India. The amount of straw is calculated by the difference of total residue and the amount used for various purposes. Traditionally the surplus amount of crop residue is burnt on farm by the farmers instead of using it for some other purpose. In India, it is estimated that nearly 84 to 141Mt per annum of surplus stubble left in which cereal crops contribute more than 50 per cent and also observed 82 Mt of surplus crop residue, nearly 70 Mts (44.5 Mt rice straws and 24.5 Mt wheat straws) are burnt annually. But in the case of Punjab, 28 lakh hectares under wheat and paddy cultivation in the state, 47.2 lakh t of straw are generated every year. This included 25 lakh t of wheat straw and 22 lakh t of paddy straw. Out of this, 95 per cent of paddy straw and 25 per cent of wheat straw is burnt each year. The mechanized harvesting of these crops has further added to the quantity of residue (Kaur 2017). The current study recorded that the number of stubble burning cases has declined from 81042 to 55210, i.e., nearly 32 per cent, during the years 2016 to 2019 in Kharif season. This declining trend of crop residue burning cases is a favorable indicator in order to protect the environment of state. It is also considered as the reward for untiring initiatives taken by the government and agricultural university of the state. At the same, the results of instability have been shown an increase of CRB cases during the study period in Rabi season. It is almost maximum as compared to the last five years in Punjab state and that too in the times of widespread Covid 19 pandemic. At present, burning wheat straw means creating an excess of particulate matter in the air, which is harmful to people with respiratory illness (especially with Covid 19). The study elucidates that the residue left after the harvesting the wheat crop is far less in quantity as compared to paddy, still the farmers are burning it.



Source: Punjab Remote Sensing Centre, Ludhiana, (GOP 2020)

Fig. 1. Number of stubble burning cases in Punjab during *Rabi* and *Kharif* season

This trend can intensify in the coming paddy harvest season when farmers have to arrange for the sowing of the next crop in a rush amid a labour shortage in the current scenario of reverse labour migration.

In Punjab, stubble burning from the yearly rice-paddy harvest is a timeworn practice that the farmers have been doing for many decades. It emits particulate matter (PM10 and PM2.5), which are the leading causes of smog, affecting visibility and the most significant contributor to global warming after CO_2, which aggravates the poor air quality in Punjab. Moreover, it also emits carbon monoxide (CO), volatile organic compounds (VOCs), ammonia (NH_3) which are precursors to ground-levelo zone layers and health problems for human beings. Many polices and research project has been framed to overcome this problem for past few years. Although, alternative technologies, practices have been launched time to time, yet farmers are reluctant to adopt that measure and still the rule of burning is persist (Gupta 2019). As per estimates, Punjab produces approximately 19-20 Mt of paddy straw and about 20 Mt of wheat straw in a year, in which about 85-90 per cent of this paddy straw is burnt in the field, and wheat straw is also being burnt during the harvesting of Rabi season (Singh et al2019)

Due to the above-listed reasons, stubble burning becomes the most significant problem during *Kharif* season in the Punjab state. The number of cases of stubble burning has been declining during the *Kharif* season. Still, the highest declining rate is be associated with Zone I (-32.01%), followed by Zone II (-14.02%) and Zone III (-8.30%).In the case of Zone I, the number of burning cases are recorded more in the case of SBS Nagar (82.73%), followed by Rupnagar (63.18%) and Pathankot, which is 60.71 per cent. The sub mountainous zone of Punjab (Gurdaspur, Hoshiarpur, SAS Nagar, SBS Nagar, Pathankot and Rupnagar) is dominated by wheat-maize rotation. Due to this reason, the zone comprises less sown area under paddy, which further leads to fewer problems of residue burning. In the case of Zone II of Punjab, which is dominated by wheat-paddy cropping pattern and relatively more responsible for residue burning as compared to another two zones but now the number of cases of stubble burning is decreased from 38279 in the year 2016 to 32913 in the year 2020due to various initiative provided by the government and concerned authorities. In case of Central zone or Zone II, the number of cases declined from year 2016 to 2020 is Jalandhar (52.43%), Ludhiana (47.89%) and Kapurthala (31.79%), while increasing trends were found in case of Amritsar (34.28%), and Tarn Taran, i.e. 23.87%. In Zone, i.e. South Western Zone of Punjab, the number of stubble burning cases declined but least compared to other Zones.

Fatehgarh sahib, Fazilika, Moga and Mukstar were the district that showed a declining trend in burning cases as compared to other districts in this Zone.

The wheat is the only crop that leads the farmers towards stubble burning during Rabi season, but wheat residue is not a big concern compared to paddy residue because it is used as dry fodder has good economic value. Farmers also earn money by selling it. That is why most of the wheat residue is used to make wheat straw in Punjab. Secondly, it does not take as much effort to clear the field as paddy field requires after making wheat straw. Even if this leftover residue is burned, it does not create as much pollution as paddy residue burning due to less quantity of residue and dry weather during harvesting. But still, stubble burning is a solemn problem in north India, especially when the burning of stubble affects environmental pollution .The number of stubble burning cases was increased in all the three zones i.e., Zone-I (10.98), Zone II (12.26%) and Zone III (47.10 %), which still needs more attention of concerned agencies (Table 3). In Zone I, only Rupnagar district showed a slightly lower case of burning compared to other districts. While in the case of Zone II i.e. central Zone of Punjab, Patiala and Tarn Taran districts had shown a decline in burning trend. In the case of Zone III, Fatehgarh Sahib had shown a 36.07% decline trend in stubble burning cases. So to avoid the problem of crop residue or stubble burning cases during Rabi season, different steps should be takento utilize the residue such as it can be used as fodder purpose, organic manure, power generation, mushroom cultivation, cattle shed construction, packaging, mat making and strawboard etc. Moreover, the

Table 1. Number of stubble burning cases in Punjab during *Kharif* season, 2016-2020

District	2016	2017	2018	2019	2020	% change from 2016 to 2020
Zone I						
Gurdaspur	1768	1185	1036	1497	1925	8.88
Hoshiarpur	709	378	175	316	399	-43.72
SAS Nagar	240	168	144	201	262	9.17
SBS Nagar	1100	547	256	279	190	-82.73
Pathankot	28	13	9	4	11	-60.71
Rupnagar	554	244	82	131	204	-63.18
Total	4399	2535	1702	2428	2991	-32.01
Zone II						
Amritsar	1788	999	1151	1510	2401	34.28
Jalandhar	3679	1543	1198	1627	1750	-52.43
Kapurthala	2369	1155	684	1422	1616	-31.79
Ludhiana	7697	3239	2481	2532	4011	-47.89
Patiala	4986	3829	3784	4212	5161	3.51
Sangrur	9556	6968	6862	7021	9357	-2.08
Tarn Taran	3619	2085	2420	3373	4483	23.87
Barnala	4585	2481	2735	3257	4134	-9.84
Total	38279	22299	21315	24954	32913	-14.02
Zone III						
Bathinda	7047	3693	5402	6036	6977	-0.99
Faridkot	3550	2277	2570	2545	3573	0.65
Fatehgarh Sahib	1862	1229	828	896	1338	-28.14
Fazilika	3063	1359	2181	1886	2080	-32.09
Firozpur	6036	3496	4924	5313	6616	9.61
Mansa	4405	3293	3596	3924	4564	3.61
Moga	7150	2200	3280	3267	5463	-23.59
Muktsar	5250	3003	4792	3961	4566	-13.03
Total	38363	20550	27573	27828	35177	-8.30

Source: Punjab Remote Sensing Centre, Ludhiana (GOP 2020)

Power and paper industries are now approaching to farmers for crop residue. Further, the stubble can also improve crop yield by 4–9% (Sood 2016) and is employed in biofuel generation (Singh et al 2016).

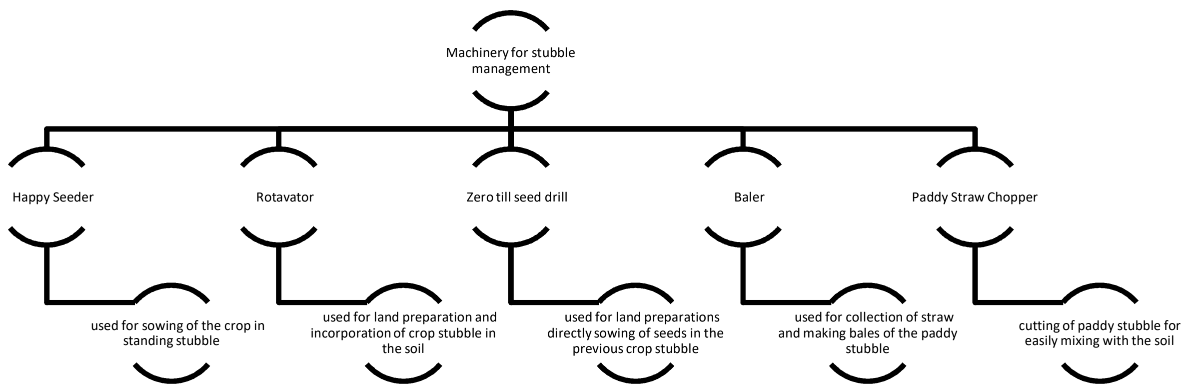
Reasons for crop residue burning (CRB): In Punjab, the major crop of them are paddy, wheat, cotton, maize, sugarcane, but the paddy is the dominant crop that leads to the problem of stubble burning. It might be due to straw left after the harvesting of wheat crop i.e. bhus a has an alternative use such as animal feeding and is also traded across districts. Moreover, the burning of wheat residue is unnecessary for the farmers because of the availability of technology and other alternative usage such as higher economic value as dry fodder. However, the residue left from rice cultivation is not used as fodder as it was non-palatable to animals due to its high silica content. Due to less economic value as animal feed and other general uses, farmers are forced to burn it on the field instead of incurring a high cost on collecting it. The further study also examined the various determinants that force farmers to burn paddy residue, i.e., use of a combine harvester, unavailability of paddy stubble machinery at a concessional rate in cooperative societies, and farmers producer organization. In addition to it, labour shortage at the time of harvesting and the costly process of cleaning the field after harvesting paddy crop are other vital determinants leading to crop residue burning cases in the study area. Another reason for CRB is the shortage of time (2-3 weeks) between harvesting paddy and sowing of wheat, which does not allow the farmers to perform the time-consuming operation of clearing the paddy straw from the

Table 2. Number of stubble burning cases in Punjab during *Rabi* season, 2016-2020

District	2016	2017	2018	2019	2020	% change from 2016 to 2020
Zone I						
Gurdaspur	896	1184	741	673	963	7.48
Hoshiarpur	364	541	340	263	434	19.23
SAS Nagar	29	92	28	93	36	24.14
SBS Nagar	160	274	150	172	193	20.63
Pathankot	132	217	121	111	138	4.55
Rupnagar	68	120	71	89	66	-2.94
Total	1649	2428	1451	1401	1830	10.98
Zone II						
Amritsar	949	1542	1027	1022	1147	20.86
Jalandhar	620	500	426	571	728	17.42
Kapurthala	469	495	442	441	536	14.29
Ludhiana	918	875	730	1035	1019	11.00
Patiala	412	456	530	518	407	-1.21
Sangrur	587	722	948	877	607	3.41
Tarn Taran	864	1753	770	875	851	-1.50
Barnala	261	434	417	479	408	56.32
Total	5080	6777	5290	5818	5703	12.26
Zone III						
Bathinda	577	831	772	797	1065	84.58
Faridkot	365	358	410	373	508	39.18
Fatehgarh Sahib	219	209	120	216	140	-36.07
Fazilika	401	405	322	532	560	39.65
Firozpur	856	1328	806	794	1059	23.71
Mansa	231	40	387	360	341	47.62
Moga	771	1151	760	724	1192	54.60
Muktsar	582	549	589	686	1022	75.60
Total	4002	4871	4166	4482	5887	47.10

Source: Punjab Remote Sensing Centre, Ludhiana (GOP 2020)

Reason	Reference
Shortage of labour and short window of time between paddy harvesting and paddy growing	Singh et al (2019)
High cost of paddy stubble management technology, non-availability of stubble management technology with co-operatives	Sandhu et al (2019)
Late-maturing basmati rice varieties	Iqbal et al (2002)
Lack of buyers, shortage of time for next crop, lack of assistance by the state government and labour shortage	Kaur (2017)
Discontinuing of its traditional uses (animal feed, fodder, fuel, roof thatching, packaging and composting)	Yadav et al (2017)



field. Moreover, the higher price of diesel, costly farm equipment, and machinery used in removing the field add an extra burden to the farmers. Whereas the wheat straw and fodder crops mostly meet the requirement of dry fodder for livestock. Further sowing of wheat by ploughing paddy stubble in the soil also leads to various problems. A high silicon dioxide content (SiO2) in paddy straw resists its decomposition when retained in the soil for the next crop. While observing the present situation of Punjab, shortage of labour (especially during Covid-19 times) could another added big cause. Labour shortages due to the reverse migration of labour amid the present pandemic will further inflate the process of ploughing crop residue in the field. There will be a dearth for available labour in this situation, and wages will rise from Rs 600-700 from Rs 400-500 presently.

Solutions to the burning problem: In 2014, the central government released the National Policy for Management of Crop residue. Since then, crop residue management has helped make the soil more fertile, resulting in savings of Rs 2,000/hectare from the farmer's manure cost. Farmers can also manage crop residues effectively by employing agricultural machines like:

The various government initiatives has been taken by both state and center government are as follow

- To overcome the problem of stubble burning, the government established custom hiring centers and undertook Information Education and Communication (IEC) activities. At the same time, the state government had released funds of Rs 269.38 crores in 2018-19 and Rs 273.80 crore in 2019-20 for the distribution of in-situ crop residue management machinery to the farmer's subsidy Anonymous (2018).
- The burning of crop residue was considered a legal offence under the Air Act of 1981, the Code of Criminal Procedure, 1973 and various appropriate Acts.
- National Green Tribunal (NGT) funds had released funds within the sanctioned budget for Sub Mission on Agricultural mechanization (SMAM).
- In order to create awareness about its effects on the environment and human health, the government of Punjab has launched three mobile apps developed by Punjab Remote Sensing Centre (PRSC). These are i-Khet Machine for facilitating farmers access to the agriculture machinery, e-PEHaL for monitoring tree plantation and e-Prevent to have prompt and accurate information about incidents of crop residue burning (Anonymous 2020).

Crop residue is a scorching topic at present and also situation of covid-19 pandemic adds oil to the fire, especially during paddy harvesting. There is no doubt that smoke from CRB affects people's health, road safety and the environment. This study concluded that the number of stubble burning cases had declined year to year in Punjab. But still, it is a matter of consideration that in light of current labour scarcities during covid- 19 the farmers who had earlier adopted good management practices of crop residue could also go for burning of crops in coming season of paddy harvesting due to added problems to their plate which will intensify the problem of

CRB plus add to the throbbing pain of Covid19patients.Labour shortages due to reverse migration of labour amid the present pandemic will further make ploughing crop residue in the field costly. There will be a shortage for available labour in this situation and wages are bound to rise to Rs 600-700 from Rs 400-500 presently. Therefore, there is a need for higher authorities to take early precautionary steps to control their menace in the coming season plus nudge the awareness among farmers to take anticipatory measures to monitor the burning of crop residue in coming 2020-21 season.

CONCLUSIONS

The study regarding the comparison between the years 2016 and 2020 reveals that there is a decrease in the burn area for all zones of Punjab state, respectively. These results are promising and show that remote sensing data may be used to estimate and detect stubble burning. Although stubble burning has decreased, the percentage decrease is significantly less. Hence it needs more policies and innovations to find a feasible solution. Make paddy residue management technologies widely available. A careful assessment of farm-level constraints, trade-offs, and viable business models is needed to widen the use of alternative machines. Shift to early-maturing rice varieties (such as those being developed by the Punjab Agricultural University) allow farmers more time to clear and prepare fields for sowing wheat. Raise farmer awareness through awareness campaigns to demonstrate better residue management practices, and rid farmers of misconceptions around practices and costs of alternative technologies. Punjab should break the wheat-rice rotation and diversify the cropping cycle in the medium and long term.

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Certain Morpho-biochemical Responses of Coriander (*Coriandrum sativum* L.) to Cement Kiln Dust Pollution

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Abstract: An attempt has been made to study the impact of cement kiln dust pollution on certain morphological and biochemical features of *Coriandrum sativum* plants grown in the experimental plot exposed to the simulated cement kiln dust pollution. The study of morphological features such as length of shoot and root, size of leaves, number of branches, leaves, flowers and fruits, and phytomass, root/shoot ratio, NPP reveals that there is reduction in the growth of *C. sativum* plants exposed to cement kiln dust pollution. An analysis of the epidermal features of the leaves of *C. sativum* plants exhibited decreased values of the most of the studied parameters in the plants exposed to cement kiln dust pollution. The declining trend, except for the total phenols, has also been observed in the majority of presently studied biochemical parameters of plants exposed to the cement kiln dust pollution. Besides, reduction in the levels of total phytomass and NPP of plants grown in the experimental plot substantiates the view that cement kiln dust pollution has influence on the growth and yield of *Coriandrum sativum.*

Keywords: Coriander, *Coriandrum sativum*, Cement kiln dust, Phytomass, Pollution, Yield

Global increase in urbanization has led to an upsurge in cement demand. The need for availability of raw materials and local demand has resulted in the establishment of more cement plants. The most exploited topic relating to cement production is its production of cement kiln dust emission, which result in stunted growth, leaf resetting, chlorosis, brown-gray necrosis and reduced long term yield. These pollutants affect the life and wellbeing of workers, children and people in close communities as well as the flora and fauna (Adeyanju and Okeke 2019). Cement dust is a well-known particulate pollutant of the vegetation near the cement manufacturing plants and cement kiln dust emanating from the cement factories is a mixture of elements, including high levels of fluoride, magnesium, lead, cadmium, nickel, zinc, copper, beryllium and other compounds (Uysal et al 2011). Cement kiln dust affects plant growth mostly by the formation of crusts on leaves, twigs and flowers (Chaurasia et al 2013). Particles of cement kiln dust were quite alkaline making soils neighboring cement exhibit elevated pH levels which in turn affect vegetation growth, decreasing rates of photosynthesis, respiration, transpiration and growth rate of plants (Fakhry and Migahid 2011). The pollutant particles can enter the soil as dry, humid or occult deposits and can undermine the physico-chemical properties. Hence contaminated soil can adversely affect plant survival and growth (Addo et al 2013). Cement kiln dust affected soils are said to be rich in calcium and potassium, but poor in nitrogen and phosphate (Shukla and Shukla 1996). Their deposits on plants interfere with the biosynthesis of chlorophyll and damage leaf cells, resulting in a reduction in photosynthesis (Shah et al 2020). An increase in the heavy metal levels, pH, electrical conductivity, and bulk density of the soil, while decreasing the water-holding capacity, as well as the moisture, organic carbon, and total nitrogen contents of the soil were observed due to Cement kiln dust (Lamare and Singh 2020). Cement dust is thought to be the most toxic environmental factor that physically blocks stomata and affects plant growth and development (Shah et al 2019). The cement particulate matter has a profound influence on the biochemical, morphological, and physiological responses of plants (Shah et al 2020). Pierce (1909, 1910), who studied the possible effect of cement dust on plants for the first time, observed that it is harmful to vegetation. Chaurasia et al (2013) is of the opinion that the harmful effects of cement kiln dust are due to the formation of crust in the presence of free moisture. Koperuncholan et al (2014) demonstrated that the cement kiln dust injures the leaf, but the degree of injury is related to the chemical composition of the dust and its size and deposition rate. However, there is a common belief that the particulate matter does not cause widespread plant injury. Contrary to this, information regarding the effects of particulate matter of cement kiln dust pollution on the growth, phytomass, net primary productivity (NPP) and yield of some economically important plants is available from the works of Lone (2010), Uysal et al (2011), Chaurasia et al (2013) and Shah et al 2020). A perusal of literature, however, reveals that attempts of this kind on vegetable yielding plants, particularly on green leafy vegetable and /or spice plants are very meager. Thus the present investigation has been undertaken with a view to assess the effect of cement kiln dust pollution on the morpho-biochemcial features of *Coriandrum sativum,* one of the important minor spices grown in India.

MATERIAL AND METHODS

The seeds of *Coriandrum sativum* were procured from the local market and seedlings were raised in the University Botanical Garden in a plot of 8-sq. m. The methods adopted to assess the morpho-biochemical and epidermal features of *Coriandurm sativum* were earlier described by Uma et al (1994) and Uma and Rao (1996), while phytomass was calculated from dry weight of plant sample. The primary productivity was determined based on the ratio between the phytomass and age of the plant (Kevt et al 1971). An analysis of elemental composition of soil from the control as well as experimental plots and also the cement kiln dust was done by using CAMECA Electron Probe Analyzer (Allen et al 1986). The pH and the physical properties of the soil in the control and experimental plots and cement kiln dust were analyzed as per the method described by Jackson (1962). All estimated results are the mean of three replicates. Data were examined with Duncan's multiple-range test (DMRT) for the evaluation of the significant difference between means ($p < 0.05$). SD is depicted using the average of the three replicates.

RESULTS AND DISCUSSION

The cement kiln dust polluted plants of coriander showed 14. 2% reduction in their shoot length, while 8.5% in their root length. The percent reduction in the number of branches (18), number of leaves (6.81), size of leaves (4.9), number of internodes (4.95%) and inter nodal distance (3. 58%)of polluted coriander plants than the plants grown in control. Further the cement kiln dust polluted plants of coriander had 20. 4% reduction in their net primary productivity (NPP) and reduced root/shoot (R/S) ratio to the level of 19% in comparison to that of control plants (Table 1). Decrease in the R/S ratio was also recorded in the cement kiln dust polluted plants of *Vigna mungo* and *Lycopersicon esculentum* L. were they reported to have increase in their R/S ratio (Iqbal et al 2020; Enespa and Dwivedi 2013). The plant growth and development form have a notable outcome on the root-shoot ratio (Askari et al 2017). This root-shoot ratio then shows the plant health conditions and sensitivity to stress (Agathokleous et al 2018).Phytomass in polluted coriander

Table 1. Morphological features of control and dusted plants of *Coriandrum sativum*

Age of the plant (days)		Shoot length (cms)	Root length (cms)	No. of Branches	No. of leaves	Size of leaves (cms)	No. of inter-nodes	Size of inter-nodes (cms)	No. of flowers	No. of fruits	Phyto-mass (g)	Root/shoot ratio	NPP (g/day)
20	C	8.62 ± 1.04^a	6.82 ± 1.37^a	-	8.35 ± 0.02^a	0.524 ± 0.001^a	1.53 ± 0.004^a	4.862 ± 0.13^a	-	-	0.791 ± 0.10^a	0.643 ± 0.01^a	0.032 ± 0.01^a
	D	7.18 ± 1.86^a	5.73 ± 0.13^a	-	6.98 ± 0.02^b	0.497 ± 0.002^b	1.24 ± 0.002^b	3.257 ± 0.03^b	-	-	0.798 ± 0.15^a	0.519 ± 0.01^b	0.025 ± 0.01^a
40	C	19.4 ± 1.38a	10.74 ± 0.14^a	4.15 ± 0.13^a	36.479 ± 1.35^a	1.638 ± 0.024^a	2.98 ± 0.024^a	18.649 ± 1.24^a	3.82 ± 0.14^a	13.8 ± 0.03^a	0.551 ± 0.01^a	1.824 ± 0.01^a	0.045 ± 0.03^a
	D	16.5 ± 1.14b	10.15 ± 1.09^a	3.25 ± 0.12^b	29.864 ± 2.55^b	1.142 ± 0.028^b	2.75 ± 0.031^b	17.536 ± 1.48^a	2.03 ± 0.19^b	9.52 ± 0.05^b	0.604 ± 0.02^b	0.986 ± 0.02^b	0.024 ± 0.01^a
60	C	53.2 ± 1.20^a	30.9 ± 1.03^a	8.43 ± 1.26^a	50.738 ± 2.65^a	1.985 ± 0.026^a	4.628 ± 0.149^a	24.695 ± 2.37^a	24.63 ± 12.57^a	10.521 ± 1.26^a	0.580 ± 0.01^a	2.031 ± 0.18^a	0.033 ± 0.01^a
	D	50.1 ± 1.02^b	29.4 ± 1.138^a	4.73 ± 1.18^b	47.395 ± 1.82^a	1.738 ± 0.025^b	3.856 ± 0.294^b	22.548 ± 1.76^a	19.285 ± 2.15^a	9.27 ± 1.12^a	0.588 ± 0.13^a	1.957 ± 0.03^a	0.032 ± 0.01^a
80	C	62.5 ± 2.18^a	39.6 ± 1.34^a	10.2 ± 1.25^a	68.497 ± 5.37^a	2.164 ± 0.035^a	4.935 ± 0.218^a	38.657 ± 1.12^a	58.932 ± 1.38^a	42.536 ± 5.78^a	0.633 ± 0.01^a	3.578 ± 0.08^a	0.044 ± 0.02^a
	D	56.8 ± 1.36^b	32.5 ± 1.28^b	7.46 ± 1.35^b	59.781 ± 4.65^b	2.018 ± 0.046^b	4.162 ± 0.253^b	36.734 ± 1.28^a	44.359 ± 1.26^b	40.15 ± 4.18^a	0.572 ± 0.01^b	2.139 ± 0.02^b	0.026 ± 0.01^a
100	C	64.9 ± 2.57^a	37.6 ± 2.04^a	14.8 ± 2.13^a	88.643 ± 10.25^a	2.287 ± 0.048^a	5.036 ± 0.284^a	44.581 ± 2.16^a	63.257 ± 1.42^a	79.536 ± 8.69^a	0.593 ± 0.02^b	4.893 ± 0.01^a	0.048 ± 0.01^a
	D	56.3 ± 2.57^b	35.9 ± 1.84^a	10.3 ± 1.81^b	80.786 ± 10.45^a	2.159 ± 0.026^b	4.928 ± 0.265^a	42.735 ± 2.47^a	51.49 ± 2.67^b	48.517 ± 10.74^b	0.633 ± 0.01^a	3.45 ± 0.02^b	0.034 ± 0.01^b
120	C	69.5 ± 1.38^a	36.9 ± 1.26^a	15.24 ± 1.08^a	92.863 ± 10.54^a	1.857 ± 0.034^a	4.832 ± 0.265^a	43.769 ± 1.50^a	29.348 ± 4.33^a	100.35 ± 12.49^a	0.568 ± 0.01^a	5.281 ± 0.16^a	0.044 ± 0.01^a
	D	59.6 ± 1.24^b	34.6 ± 1.48^b	12.49 ± 1.12^b	86.537 ± 12.69^a	1.765 ± 0.048^b	4.659 ± 0.276^a	41.586 ± 2.48^a	18.715 ± 1.29^b	99.486 ± 10.57^a	0.580 ± 0.15^a	4.273 ± 0.13^b	0.035 ± 0.01^a

C = Control; D= dusted; Values (mean ± SD) followed by dissimilar letters in each column are significantly different at $p \leq 0.05$

plants was reduced to just 2 % only (Table 1), which makes these plants to be considered as resistant in this regard, in comparison with a remarkable influence of cement kiln. Similar reduction in the phytomas was reported by Uysal et al (2011) in *Vicia faba* and Raajasubramanian et al (2011) in *Arachis hypogaea*. Increased concentration of cement dust pollutants causes visible injuries such as closure of leaf stomata, a marked reduction in growth and invisible injuries like progressive decline in the physiological process such as photosynthetic ability and respiration rate of leaves (Raajasubramanian et al 2011).

Fe occurs relatively less (8.51) in the cement kiln dust as compared to that of control soil (18.45) (Table 2). The deficiency of Fe, which is an essential activator for enzyme catalyzing reactions and is required by plants in high amounts, causes interveinal chlorosis as well as inhibition in protein synthesis. Thus lack of Fe may be a reason for some of the morpho-biochemical changes in Coriander. The reduction in plant growth in dusted plants was attributed to the fact that they interact with the environmental pollution stress, which in turn leads to a decreased photosynthesis in unit leaf area and / or enhanced leaf senescence (Nanos and Ilias 2007, Tripathi and Gautam 2007, Belmokhtar et al 2019). A significant variation has been found in the biochemical characters of dust polluted plants in comparison to that of control plants (Table 3). The reduction in the amount of chlorophyll 'b' was more in the dust polluted plants of *C.sativum.* However, this observation differs from the reports of Thambavani and Kumar (2011) who stated that chlorophyll 'a' content was more susceptible than chlorophyll 'b' content to pollutants in *Ficus religiosa* L. *Pongamia pinnata* L. and *Polyalthia longifolia* L.but he found that in *Azadirachta indica* L the chlorophyll 'a' content gets less degraded than

Table 2. Elemental analysis of control and cement kiln dust polluted soils and cement kiln dust (in atomic percentage) *

Elements detected	In control soil	In cement kiln dust polluted soil	In cement kiln dust alone
Mg	00.29	00.64	1.33
Al	08.15	09.06	06.45
Si	66.41	63.86	16.41
S	--	--	01.69
Cl	--	--	00.69
K	03.82	02.35	--
Ca	02.15	02.55	67. 74
Fe	18. 45	18.43	08.51
Ti	01.25	01.95	--

*Average of two replicates

Table 3. Biochemical parameters of control and cement kiln dust polluted plants of *Coriandrum satium* (mg/g)

Age of the plant (days)		Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophylls	Total sugars	Amino acids	Starch	Lipids	Total phenols	Total proteins
20	C	0.894±0.024^a	0.746±0.038^a	1.640±0.014^a	9.64±0.973^a	3.568±0.914^a	17.863±2.481^a	1.948±1.053^a	3.248±1.102^a	2.587±0.1026^a
	D	0.632±0.028^b	0.593±0.024^b	1.225±0.017^b	4.872±0.584^b	2.735±0.836^a	14.658±1.736^a	2.187±1.483^a	2.356±1.0124^a	2.139±0.2010^b
40	C	1.370±0.024^a	0.994±0.014^b	2.364±0.148^a	12.793±1.385^a	5.738±0.736^a	24.748±2.356^a	2.526±1.143^a	4.156±1.228^a	9.284±1.107^a
	D	1.256±0.014^b	1.043±0.014^a	2.299±0.120^a	10.865±1.054^a	3.645±0.124^b	21.369±2.562^a	2.148±1.316^a	3.457±0.742^a	7.139±1.024^b
60	C	1.725±0.104^a	1.274±0.148^a	2.999±0.137^a	7.635±2.013^a	6.483±0.146^b	37.314±2.586^a	4.782±1.431^a	5.248±1.109^a	16.743±1.128^a
	D	1.538±0.178^a	1.392±0.178^a	2.934±0.158^a	0.524±2.135^b	7.542±0.184^a	31.297±2.014^b	3.146±1.284^a	4.376±1.248^a	12.259±1.0246^b
80	C	1.643±0.589^a	1.289±0.816^a	2.932±0.153^a	35.978±3.452^a	7.349±1.504^a	59.637±2.142^a	5.348±1.04^a	6.583±0.732^a	24.586±2.124^a
	D	1.526±0.731^a	1.435±0.812^a	2.961±0.274^a	30.184±2.036^a	6.382±1.104^a	52.318±2.041^b	4.068±1.149^a	5.627±1.103^a	21.473±1.26^b
100	C	1.482±0.863^a	1.047±0.265^a	2.529±0.856^a	43.86±2.846^a	5.948±1.128^a	68.472±2.561^a	5.28±1.014^a	5.846±1.124^a	33.478±2.659^a
	D	1.364±0.582^a	1.258±0.628^a	2.622±0.568^a	59.128±2.236^b	4.356±1.034^a	63.249±2.178^b	4.351±1.034^a	4.853±1.275^a	31.482±2.375^a

C= Control; D= dusted; Values (mean ± SD) followed by dissimilar letters in each column are significantly different at $p \leq 0.05$

chlorophyll 'b' due to cement dust pollution. Further, a declining trend has also been noticed in the total chlorophyll content of Coriander plants exposed to cement kiln dust, which is in accordance with the several earlier published reports (Lepedus et al 2003, Thambavani and Kumar 2011, Giri et al 2013, Alavi 2017). Alavi et al (2014), who reported considerable loss in the total chlorophyll content of *Plantago lanceolata*, and attributed the loss of total chlorophyll in the dust polluted plants due to the absorption of a portion of cement kiln dust into leaf tissue and its consequent damage to the chloroplasts. Thus, one may infer that the cement kiln dust not only affects the synthesis of carbohydrates but also the whole cellular metabolism.

The quantitative analysis of bio-molecules of coriander plants from control as well as experimental plots revealed that there was reduction in the proteins to the extent of 51.6% in the cement dust polluted plants, while the amount of amino acids reduced to 3.19% only, but lipids, starch and sugars reduced to 17.7, 5.4, 25% respectively in the dust polluted plants of coriander (Table 3). The total phenol content in dusted plants of *C. sativum* was 17.6%. Shah et al (2020) observed the higher level of cement kiln dust pollution may considerably decrease the growth, metabolites and activities like photosynthesis and respiration. The reduction in protein content might be due to stressed conditions which enhanced the rate of protein denaturation and breakdown of existing protein to amino acid which ultimately causes reduction in protein content (Tripathi and Gautam 2007).

Epidermal features: The epidermal features of Coriander leaves exposed to cement kiln dust pollution exhibit decrease in the number of epidermal cells frequency (24%), stomatal frequency (11.4%), trichome frequency (1.5%), Epidermal cell size (8.59%), trichome size (3.2%) and stomatal pore size (9.3%). The stomatal index varied by 10.8% in dusted plants in comparison with that of plants grown in the control plot (Table 4).

Elemental analysis: When the soils from the control and experimental plots and cement kiln dust were analyzed separately for their elemental composition by using Energy Dispersive Analysis of X - rays (EDAX), soils in the control and experimental plots were found to contain Si as a major component with 66.41% in control and 63.83% in experimental plot, while Mg as a minor constituent with 0.29% in the control plot and 0.64 % in the experimental plot. In contrast, the cement kiln dust had Ca as a major element with 67.74% and Cl as a minor element with 0.68% (Table 2).

It is evident from the elemental analysis of soils in the control and polluted plots that 2.11% of calcium was present in the soil of the former plot, while the latter one had calcium to the tune of 3.06%, which may be due to the addition of

Table 4. Epidermal features of control and cement kiln dust polluted plants of *Coriandrum sativum*

Age of the plant (days)		Epidermal cell frequency	Stomatal frequency	Trichome frequency	Epidermal cell size (µm)	Guard cell size (µm)	Trichome size(µm)	Stomatal pore size (µm)	Stomatal index
20	C	32.561±1.439^{a}	9.31±0.125^{a}	0.492±0.015^{a}	2.063±0.142^{a}	0.623±0.014^{a}	2.375±0.164^{a}	0.426±0.051^{a}	22.23±1.852^{a}
	D	30.783±1.542^{a}	8.98±0.149^{b}	0.428±0.026^{b}	2.015±0.108^{a}	0.616±0.025^{a}	2.286±0.049^{a}	0.412±0.048^{a}	22.583±1.650^{a}
40	C	36.249±1.103^{a}	10.764±0.532^{a}	0.584±0.002^{a}	2.124±0.048^{a}	0.742±0.012^{a}	2.625±0.014^{a}	0.648± 0.012^{a}	22.895±1.124^{b}
	D	33.158±1.146^{b}	9.852±0.469^{b}	0.473±0.010^{b}	2.086±0.153^{a}	0.737±0.154^{a}	2.583±0.021^{a}	0.615±0.021^{b}	29.712±1.256^{a}
60	C	42.361±2.154^{a}	11.738±0.214^{a}	0.618±0.004^{a}	2.575±0.036^{a}	0.987±0.148^{a}	2.875±0.026^{a}	0.855±0.029^{a}	21.700±1.048^{b}
	D	39.514±1.268^{a}	10.356±0.125^{b}	0.603±0.002^{b}	2.186±0.028^{b}	0.965±0.246^{a}	2.694±0.012^{b}	0.278±0.016^{b}	26.208±1.536^{a}
80	C	47.825±1.078^{a}	12.964±0.518^{a}	0.659±0.024^{a}	2.575±0.012^{a}	1.062±0.318^{a}	3.025±0.016^{b}	1.015±0.024^{a}	21.326±1.843^{a}
	D	41.937±1.864^{b}	10.853±0.649^{b}	0.618±0.025^{b}	2.056±0.024^{b}	0.987±0.426^{a}	3.148±0.025^{a}	0.998±0.016^{a}	21.633±1.521^{a}
100	C	53.48±1.562^{a}	15.782±1.126^{a}	0.768±0.019^{b}	2.584±0.020^{a}	1.375±0.248^{a}	3.351±0.024^{a}	1.067±0.015^{a}	22.785±2.563^{a}
	D	46.568±1.476^{b}	15.246±0.153^{a}	0.872±0.028^{a}	2.165±0.012^{b}	1.125±0.206^{a}	3.268±0.015^{b}	0.987±0.014^{b}	24.664±2.221^{a}
120	C	59.759±1.368^{a}	18.679±1.266^{a}	0.793±0.024^{a}	2.625±0.136^{a}	1.268±0.539^{a}	3.468±0.012^{a}	1.195±0.013^{a}	23.813±1.649^{a}
	D	45.346±1.729^{b}	16.532±1.486^{a}	0.781±0.023^{a}	2.487±0.531^{a}	1.159±0.463^{a}	3.356±0.024^{b}	1.083±0.021^{b}	26. 712±1.348^{a}

C = Control; D= dusted; Values (mean ± SD) followed by dissimilar letters in each column are significantly different at $p \leq 0.05$

cement kiln dust to the latter one (Table 2). According to Lamare and Singh (2020) the deposition of dust onto the soil surface enriches the soil with Ca^{++} ions. Cement dusts contain calcium and when it comes in contact with phosphorus forms chelate resulting in reduction of phosphorus availability in the soils (Jain and Jain 2006). Besides, Adebiyi et al (2021) found variations in the other soil nutrient properties; carbon, nitrogen, phosphorus, potassium, sodium, calcium, magnesium, cation exchange capacity and organic matter arising from the effect of cement dust.

pH values and physical properties: pH of the soil ranges between 7.0 to 7.5 in the control plot and 8.5 to 9.2 in the dust polluted soil, the cement kiln dust was found to have the pH ranging between 10 to 11.5 (Table 5). According to Lamare and Singh (2020) due to deposition of cement dust on the soil near the cement plants, this caused a change in soil pH to the alkaline side. May be due to such a composition the cement dust kiln dust is found harmful to vegetation. Moreover, Rawat and Katiyar (2005) opined that the dust makes the soil alkaline and consequently reduces the microbial activity releasing less nitrogen. Abdel-Rahman and Ibrahim (2012) reported that cement dust accumulation caused an increase in pH of soil solution, salinity, calcium carbonate, electrical conductivity, total alkalinity and sulphate contents beside the disturbance of soil texture and that may eventually it may lead to reduce the yield.

Among the control and dust polluted soils of the present investigation, the dust polluted soil showed increase in the apparent density and absolute specific gravity, while the percentage pore space and maximum water holding capacity were found to decrease (Table 5). In view of the changes that occur in the physical and chemical properties of the soil due to cement kiln dust pollution, it is but natural that plants grown under such an environment get subjected to stress. In the present study, cement kiln dust is found to accumulate on both the surfaces of the leaves of plants exposed to cement kiln dust pollution and accumulation was found to be more on their adaxial surfaces. The settled dust in combination with mist or light rain forms a relatively thick crust on the upper surface. Chaurasia et al (2013) studied the effect of cement kiln dust on plants and observed the formation of crusts on leaves, twigs and flowers. The accumulation of cement kiln dust was more in the older plants. The crust is formed because some portion of the settling dust consists of the calcium silicates, which are typical of the clinker from which cement is made. When this dust is hydrated on the leaf surfaces, a gelatinous calcium silicate hydrate is formed, which later crystallizes and solidifies to a hard crust (Kabiru et al 2015).

Table 5. Physical priorities of control and cement kiln dust polluted soils*

Property	Control soil	Cement kiln dust polluted soil
Apparent density	01.09	01.26
Absolute specific gravity	02.95	03.64
Percentage pore space	70.18	51.73
Maximum water holding capacity	59.45	33.58

On the analysis of the physical properties of control and cement kiln dust polluted soils it was observed that that the percentage of pore size was more in the control soil (70.18) than that of the dust polluted soil (51.73). In contrast, the control soil had less apparent density (1.09) than that of dust polluted soils (1.26). Other physical properties of the soil in the control and experimental plots such as absolute specific gravity and maximum water holding capacity are given in Table 5.

CONCLUSIONS

Most of the morphological, epidermal and biochemical parameters of *Coriandrum sativum* elucidated under the present investigation got affected due to the cement kiln dust pollution, which eventually affects the growth and yield of the coriander crop.

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Estimation of Runoff Potential using Curve Number Method

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***Abstract*:** Runoff estimation is important for hydrological structure design. The SCS curve number (SCS-CN) approach is a popular technique for assessing rainfall-induced direct runoff. In this study, the runoff depth was calculated for the Hebburu micro-watershed in Tarikere Taluk, Chikkamagaluru district, Karnataka, using the Soil Conservation Service-Curve Number (SCS-CN) method. The Hebbur Micro-Watershed, which spans an area of 1038 ha, is situated between latitudes of 13º 46' 14.81" N to 13º 44' 23.95" N and longitudes of 75º 58' 24.38" E to 76º 0' 41.14" E. For the analysis, many parameters including information on the soil, rainfall, and land use were taken into account. Daily runoff was estimated between 2009-2018. Highest runoff was observed during 2014 (520 mm) followed by 2010 and 2009. During 2016 lowest runoff was generated in the watershed due to low rainfall in the year. Correlation coefficient between rainfall and runoff was found 97 per cent between 2009-2018. The results showed that the curve number approach, when combined with remote sensing and GIS technologies, can be effectively be used to estimate the runoff in an ungauged watershed.

***Keywords*:** Curve number, Runoff potential, Watershed, Remote sensing, Soil conservation service

A watershed is a region that drains to a single outlet. For proper watershed management, such as flood control and its management, irrigation and drainage network design, hydropower generation, etc., accurate runoff depth and volume estimation is an essential responsibility. Rainfall-generated runoff is influenced by many factors, including soil type, vegetation, and types of land use, in addition to the intensity, length, and distribution of rainfall. The current study uses the Natural Resource Conservation Service Curve Number (NRCS-CN) method to calculate the runoff depth (Rajbanshi 2016). There are various methods for modelling rainfall and runoff, including the Artificial Neural Network (ANN), the SCS Curve number model, the hydrograph, and others. (Askar 2014). SCS–CN technique is one of the simplest methods for rainfall runoff modelling. The curve number is based on the area's of hydrologic soil group, land use, treatment and hydrological conditions (Askar 2014). There are four hydrologic soil groups: A, B, C and D. Group A have high in-filtration rates and group D have low infiltration rates (Sahoo and Patra 2014). The Soil Conservation Service Curve Number (SCS-CN) method is widely used for predicting direct runoff volume for a given rainfall event (Soulis and Valiantzas 2012). The objective of the study was to estimate the runoff potential using curve number method. Estimation of the same is carried out to determine and forecast its effects. Estimation of direct rainfall-runoff is always efficient (Bansode et al 2014).

MATERIAL AND METHODS

Study area: The Hebbur micro-watershed of Ajjampura sub-watershed, Tarikere taluk, Chikkamagalore district has been selected for analysis of runoff using SCS-CN Method. Hebbur Micro-Watershed is located between 13º 46' 14.81" N to 13º 44' 23.95" N Latitude and 75º 58' 24.38" E to 76º 0' 41.14" E Longitude, covering an area of 1038 ha (Fig. 1). Area falls under semi-arid region with average annual rainfall of 874 mm. Apart from rainfall, tanks and bore wells are the source of water resources. Watershed area is covered mostly of black soils however it also contains smaller portion of red and sandy textured soil. The major crops grown in study area are maize, ragi, onion, ginger, potato and chilly during *Kharif,* whereas chick pea, jawar, safflower, wheat and horsegram during *Rabi* season. Major horticulture crops grown are arecanut, coconut, banana, mango and pomegranate.

Method: Topographic data from Survey of India (SOI) toposheet (57 C/2) of scale 1:50,000 was used to identify the study area. Daily rainfall data (2009-2018) from Ajjampura rain gauge station was collected from KSNDMC, Bangalore. The Indian Remote Sensing satellite with Linear Imaging Self Scanning sensors (IRS – LISS III) data of scale 1:50000 were collected from KSRSAC, Bengaluru to use land use/ land cover of the study area (Fig. 2).

The methodology adopted in assessing the runoff potential of the study area is explained in the following steps.

The first step is to determine the hydrologic soil group (HSG) of the particular soil. Soil data was obtained from Land

Use Inventory information under KWDP-II, Sujal-III Watershed Development project, for making appropriate hydrological soil classification A, B, C & D (Fig. 3). All soils are classified in one of four different categories-ranked A-D on the basis of their runoff potential (Sahoo and Patra 2014).

Class A soils mostly having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have high rate of water transmission. [Ex-deep sand, deep loess and aggregated silt]

Class B soils have moderately fine to moderately coarse textures and are considered to have moderate infiltration rates when completely wet [Ex– shallow loess, sandy loam, red loamy soil, red sandy loam and red sandy soil]

Class C soils have moderately fine to fine textures with slow infiltration rates.[Ex- clayey loam, shallow sandy loam, soils usually high in clay, mixed red and black soils]

Class D soils are primarily clay soils or soils with clay pan that have slow infiltration rates.[Ex-heavy plastic clays certain saline soils and deep black soils]

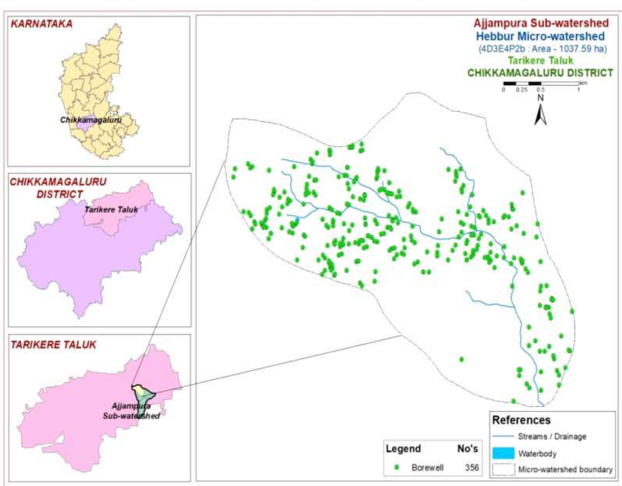

Fig. 1. Location map of the watershed

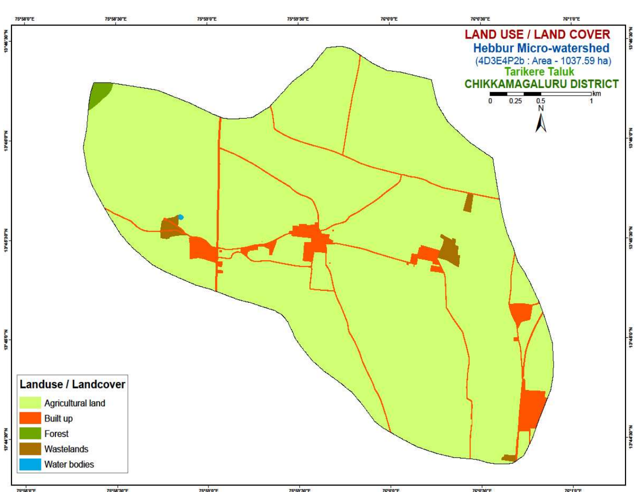

Fig. 2. Land use or land cover of the study area

Next step is to determine the five-day antecedent moisture condition of the particular soil from the daily precipitation record. It is an index for basin wetness. AMC (Antecedent Moisture Conditions) indicates the moisture content of soil at the beginning of the rainfall event under consideration. Three levels of AMC were documented by SCS are AMC I, AMC II and AMC III. The limits of these three AMC classes are based on rainfall magnitude of previous five days and season (dormant season and growing season). The values of curve number are determined based on the antecedent moisture conditions (Table 1).

The third step is to decide-on the basis of the land cover, the cultivation treatment, the hydrologic condition of the soil, and the hydrologic soil group of the particular soil-the actual runoff curve number to use in determining daily runoff from precipitation (SCS, 1972). SCS runoff CN for hydrologic soil cover complex under AMC II condition for the study area is given in Table 2. CN for AMC I and CN for AMC III were determined using equation (1) and (2).

CN for AMC I is calculated as: $CN_I = CN_{II}/(2.281 - 0.01281\ CN_{II})$...... (1)

CN for AMC III is calculated as: $CN_{III} = CN_{II}/(0.427 - 0.00573\ CN_{II})$...... (2)

Area weighted composite curve number for various conditions of land use and hydrologic soil conditions are computed as follows

$CN = (CN_1 \times A_1) + (CN_2 \times A_2) + \ldots \ldots + (CN_n \times A_n)/A$ ...... (3)

Where A1, A2, A3, ..., An represent land use areas of having CN values CN1, CN2, CN3,....., CNn respectively and A is the total area of the watershed.

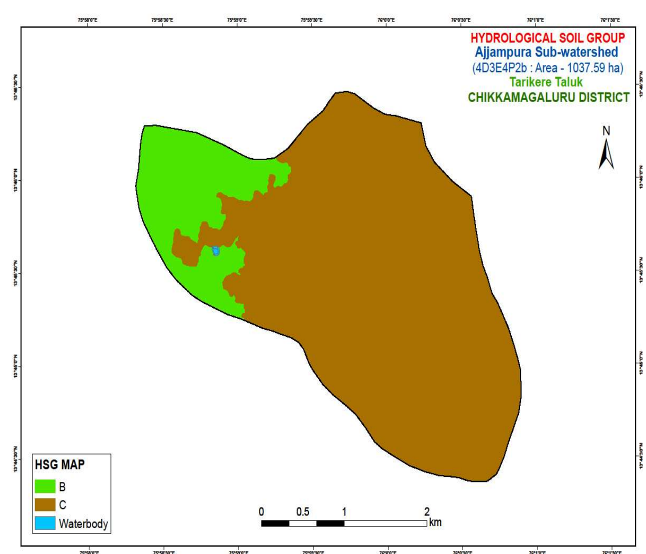

Fig. 3. HSG map of study area

Table 1. Antecedent moisture conditions for determining the value of CN

AMC type	Total rain in previous five days	
	Dormant season	Growing season
AMC-I: Soils are dry but not to wilting point. Satisfactory cultivation has taken place.	<13 mm	<36 mm
AMC-II: Average conditions	13-28 mm	36-53 mm
AMC-III: Sufficient rainfall has occurred within the immediate past 5 days. Saturated soil conditions prevail	>28 mm	>53 mm

Table 2. Curve number for HSG under AMC II conditions (Ahmad et al 2015)

Land use	Hydrological soil group			
	A	B	C	D
Agricultural land	76	86	90	93
Built up	49	69	79	84
Forest	26	40	58	61
Wastelands	71	80	85	88
Water bodies	97	97	97	97

Table 3. Sample of daily rainfall runoff computation of study area

Date	Rainfall (mm)	5 days cumulative rainfall (mm)	AMC condition	CN	S	Runoff (mm)
01-07-2009	0	11.5	1	78	71	0
02-07-2009	4	5	1	78	71	0
03-07-2009	9.5	14.5	2	89	31	0
04-07-2009	10.5	24	2	89	31	0
05-07-2009	4.5	28.5	3	95	13	0
06-07-2009	10.5	39	3	95	13	2
07-07-2009	2	37	3	95	13	0
08-07-2009	0.5	28	3	95	13	0
09-07-2009	3	20.5	2	89	31	0
10-07-2009	12.5	28.5	3	95	13	3
11-07-2009	0.5	18.5	2	89	31	0
12-07-2009	3.5	20	2	89	31	0
13-07-2009	3.5	23	2	89	31	0
14-07-2009	6.5	26.5	2	89	31	0
15-07-2009	32.5	46.5	3	95	13	19
16-07-2009	36.5	82.5	3	95	13	23
17-07-2009	19.5	98.5	3	95	13	8
18-07-2009	7.5	102.5	3	95	13	1
19-07-2009	7.5	103.5	3	95	13	1
20-07-2009	1	72	3	95	13	0
21-07-2009	1	36.5	3	95	13	0
22-07-2009	1	18	2	89	31	0
23-07-2009	1	11.5	1	78	71	0
24-07-2009	0	4	1	78	71	0
25-07-2009	0	3	1	78	71	0
26-07-2009	0	2	1	78	71	0
27-07-2009	1.5	2.5	1	78	71	0
28-07-2009	1	2.5	1	78	71	0
29-07-2009	2.5	5	1	78	71	0
30-07-2009	3.5	8.5	1	78	71	0
31-07-2009	0	8.5	1	78	71	0

Potential maximum retention is calculated using equation (4).

$$S = \left(\frac{24500}{CN}\right) - 254 \qquad (4)$$

Runoff is estimated using equation (5).

$$Q = \left(\frac{(P - \lambda S)^2}{(P - (1 - \lambda)S)}\right) \qquad (5)$$

For Indian conditions λ = 0.3

RESULTS AND DISCUSSION

The daily rainfall values were used as inputs to compute daily runoff. Using CN for AMC-II conditions, CN for AMC-I and AMC-III were calculated using equations (1)-(2). Using equation (3) weighted CN was calculated. Using equation (5) the daily runoff depth were computed. First daily rainfall runoff computation is shown in Table 4.

From the daily runoff, monthly and annual values can be derived. The annual runoff depths are computed for each rainfall event for the years 2009 - 2018 is shown in Table 5 and the relationship between rainfall-runoff is shown in Figure 4. Highest runoff was observed during 2014 which was about 42 percent of the annual rainfall followed by 2009 (39%) and 2010 (37%). Lowest was observed during 2016 due to low rainfall. Increase in runoff was observed with increase in rainfall in the year. Coefficient of determination for rainfall runoff was 0.94 for the watershed (Fig. 4).

Table 4. Runoff values (2009-2018)

Year	Rainfall (mm)	Runoff (mm)
2009	1051	404.74
2010	1167	440.08
2011	808	224.38
2012	513	152.60
2013	969	312.92
2014	1239	520.14
2015	1087	378.89
2016	542	107.08
2017	663	212.30
2018	1011	328.02

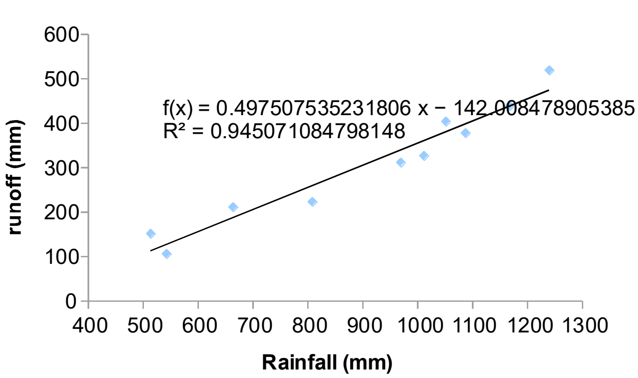

Fig. 4. Rainfall-runoff relationship

CONCLUSION

Daily runoff was estimated between 2009-2018. Highest runoff was observed during 2014 (520 mm) followed by 2010 and 2009. During 2016 lowest runoff was generated in the watershed due to low rainfall in the year. Correlation coefficient between rainfall and runoff was found 97 per cent between 2009-2018. This estimated runoff will be helpful for planning of the soil and water conservation structures in the watershed.

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Field Survey on Infestation of Iraqi Camels with Small Intestine Worms in Al-Qadisiyah Governorate

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Abstract: Camels are of great importance in all countries of the world and Arab countries, including Iraq. Therefore, conducted this study in Al-Qadisiyah governorate on camels that were brought to slaughter in the governorate's slaughterhouse include examination on 192 camels before slaughter and collected samples of their faeces. After slaughter, the small intestine was taken for laboratory examinations. The study was conducted for the period from August 1 , 2019 to August 31, 2020. There were 105 animals infected with parasites of the small intestine of males (43) and females(62). The highest infection was recorded in November which is the mild weather (1320 worms), while was 11 during August. The highest rate of parasite eggs was during the spring and autumn. The types of worms were recorded were *Moniezia expansa* and *Avitellina* spp. *Camelostrongylus mentullatus*, *Nematodirus helvitainus, Nematodirus spathiger, Nematodirus* spp., *Trichostrongylus* spp. The study recommends conducting studies on internal and external parasites of camels and to establish farms for breeding camels in Iraq to benefit from their meat and milk.

***Keywords*:** Field survey, Small intestine, Infected, Worms, Al-Qadisiyah Governorate, Iraqi camels

Camels play a major role in the lifestyle of many societies, especially those in semi-arid and arid regions in the Middle East and Arab regions (Al-Ani Falah Khalil 2010, Robert Irwin 2012). The Arabian camel has one a huge hump lives in the Arab world, Africa and the Indian subcontinent. As for the two-humped camel, it is endemic to Central Asia, where the winters are cold, as it is covered with a winter coat to protect it from the cold of winter, and its legs are short while the Arabian camel's legs are long to keep it away from the heat of the sand as much as possible (Al-Ani Falah Khalil 2010, Robert Irwin 2012). The camel considered as a ruminant animal, so its digestive system consists of three parts (Hamid Ali 2019) the rumen is the first part , where its contents occupy about 10-15% of the weight of the animal; in the lower part of the rumen there are pockets whose openings are surrounded by strong muscles (Bradford 2002) .Retina is the second part which is similar to that of other ruminants, except that its inner surface contains glandular bags that store about 2 liters of water. (Bradford 2002, Radostitis et al 2002). The third part (the tube room) corresponds to the convolution which the real stomach in other ruminants where the boundary between them disappears from the outside, and from the inside there are no leaves and replaced by folds with the spread of tubular-shaped glands that distinguish the leaf from the real stomach (Hamid Ali 2019). The length of the small intestine in camels is 40 m while the large intestine 19.5 m with a cecum. The spleen is curved and scarlet in color. The camels do not have a gallbladder vesicle. (Bradford 2002, Radostitis et al 2002). Although camels live in desert and environmental conditions that are not suitable for the reproduction and transmission of parasites (Radostitis et al 2002, Wernery and Kaaden 2002). There are no adequate studies in Iraq on the extent of camels' disease in general and their gastrointestinal diseases in particular. The current study is find out whether camels are generally infected with small intestine parasites, their types, infection in Qadisiyah Governorate and whether any effect of months, gender and age on infection.

MATERIAL AND METHODS

192 samples were collected from the complete digestive tracts. Then taking a part of the small intestine and samples of the faeces from camels that were slaughtered in AL-Qadisiyah governorate massacre from August 1, 2019 to August 31, 2020. The samples collected weekly with two visits per week. The ages of camels ranged between 1-18 years. The samples were divided into ten groups based on the age and gender of the animals (Table 1).

Clinical examination: Before slaughter-ing and collecting samples, the animals examined clinically for temperature, speed of pulse and respiration, skin and skin covering, lint shine, to note the integrity of the skin and the absence of external parasites. The animal is examined clinically after one of its front limbs are tied in order to sit and its head is tied to the side far from the examiner, often with the animal's back leg. Then the mucous membranes of the conjunctiva of the eye are examined, temperature, pulse rate and breathing are measured.

Collecting contents of the small intestine: The contents of the small intestine are emptied by opening it along its length and washing it well, then its contents are passed through a filter 90 mesh / inch and the contents are diluted to 4 liters, then a sample of 400 cm^3 is taken and placed in glass bottles after adding 10 cm^3 of formalin at a concentration of 10% until use.

Detection of eggs and counting their number in faeces: Faeces samples from the rectum were collected directly to calculate the number of eggs by McMaster method (Gordon and Whitlock 1939). By mixing well 3 grams of faeces with 42 cm^3 of water, then it is passed through a filter 60 mesh / inch. After that, a sample of the filtrate is taken with a volume of 15 cm^3 and placed in a clean test tube to be placed in a centrifuge 1500 cycle for two minutes, then the filtrate is poured to take the precipitate and mixed with a saturated solution of sodium chloride to reach the volume to 15 cm^3 .The tube is flipped several times to complete the process of good mixing, then fill in one of the two corridors of the modified McMaster by a Pasteur pipette with a size of 0.15 mm^3 to calculate the number of eggs and multiply the number of calculated eggs in (100) to obtain the number of eggs per gram.

Number of worms and their diagnosis: The contents of the small intestine were taken and placed in a glass dish and examined under an anatomical microscope in order to isolate the worms and calculate their numbers. Added one drop of lactophenol to clarify its parts and examine them under a compound microscope. It was adopted in the diagnosis of the species on males' description of (Dunn & Dunn 1978, Murray Levine 1982, Soulsby 1982).

To obtain the number of small intestinal worms, the number was multiplied by the dilution factor 10. The tapeworms, after isolating them from the contents of the small intestine, they were left in water for 1-7 hours were fixed in formal-saline for 24 hours after cutting them into small pieces and the head of the worm , small pieces of it were placed between two glass slices and the carmine dye was used (Carleton 1980), then it was examined under a compound microscope.

Statistical analysis: SPSS statistical analysis for windows operating system (version 16) (IBM SPSS Bootstrapping 24, 2016) was used.

Table 1. Total numbers and the groups of the camels according to the age and sex

Sex	Age / Year	Total number	Percent
She camel	1 – 3	10	5.20
Camel	1 – 3	30	15.62
She camel	4 – 7	26	13.54
Camel	4 – 7	25	10.02
She camel	8 – 11	15	7.81
Camel	8 – 11	18	9.37
She camel	12 – 15	13	6.77
Camel	12 – 15	12	6.25
She camel	16 – 18	32	16.66
Camel	16 – 18	11	5.72
Total		192	100

RESULTS AND DISCUSSION

After examining 192 samples of intestinal contents with the same number of faeces samples of camels that were slaughtered in the massacre in AL-Qadisiyah governorate for both sexes, here are 105 animals of camels infected with small intestine parasites, 54.7% and the number of healthy camels were 45.3%. The number of infected camels of males was 22.4% the number of females 32.3%, (Table 2). The percentage of 54.7% maybe high , but this does not mean that camels are sick, as the severity of the symptoms resulting from infection with intestinal worms depends on several factors, including the type of parasite, its number, the host's race and his way of life .The high percentage of infection may be attributed to not treating these animals with dewormers drugs and the higher rate of infection in females than males is that the slaughter of males at young ages higher because use females for reproduction, pregnancy and childbirth, which leads to a high rate of female infection (Swai et al 2011).The clinical examination of infected animals in characterized by an increase in respiratory and pulse rate, a rise in temperature, animals lethargy, loss of appetite, general weakness, roughness and lack of luster of lint (Table 3) which is similar to earlier observations (Radostitis et al 2002, Moallin 2009).

Table 2. Total numbers of healthy and infected camels with small intestinal worms for both sexes

Sex	Infected camels	%	Healthy camel	%	Total number	%
She camel	62	32.3	34	17.7	96	50
Camel	43	22.4	53	27.6	96	50
Total	105	54.68	87	45.3	192	100

The highest rate of worms was in the November (59.48 %) followed by in June (10.36%) While the lowest rate of worms recorded during August (0.49%) consistent with earlier study (Mohammed et al 2007, Nwosu et al 2007, Magzoub M 2000).

The species of worms in small intestine were *Cooperia spp. , Moniezia expansa, Avitellina spp., Camelostrongylus mentullatus, Nematodirus helvitainus, Nematodirus spathiger, Nematodirus spp., Trichostrongylus spp. Trichostrongylus colubriformis, Trichostrongylus probolarus*. These species were recorded by (Soulsby 1982, Radfar and Gowhari 2013.) The highest infection was by *Nematodirus helvitainus* (49.47 %). The lowest species recorded was *Moniezia expansa* (1.04%). The results of the examination of the eggs in faeces showed that the highest rate of eggs laid / gram of faeces per animal was during the spring and early summer season. The highest rate was 2450 during June, and the followed by April about 2100. The September and October also recorded high egg laid, (1000 and 1120), while the lowest average was during August and July (550 and 600) (Table 6). This indicates that in spring the number of eggs released was proportional to the number of worms present in the intestines of camels.

In desert areas, the number of eggs increases in order to reach the precipitated larvae and restore their effectiveness again during the spring. This was also observed by Dirie F & Abdurahman (2003). The increase in the numbers of eggs during the autumn months may be due to the increase in egg shedding by the huge number of worms present in the camels, which leads to pollution of the environment and the existence of appropriate conditions of appropriate temperature and humidity, so the number of infectious larvae increases and the possibility of increasing infection with camels, which is consistent with Ukashatu et al (2012) and Wafa (2015). The Figures 7, 8 shows the shape of the eggs of

Table 4. Infection of camels with small intestine worms during the month of the year (Per cent)

Months	Mean of intestinal worms / month	Mean±	SE
January	45	2.02±	8.1
February	33	1.48	12.6
March	30	1.35	8
April	230	10.36	42.9
May	85	3.83	21.7
June	55	2.47	17.8
July	1320	59.48	268
August	11	0.49	6.5
September	92	4.14	37.2
October	218	9.82	24.5
November	22	0.99	6.8
December	78	3.51	28.9
Total	2219	100	19.39

Table 5. Species of parasite in intestine in Iraqi camels

Species of parasite	Number of worms	Number of infected animals	Percent
Trichostrongylus spp	45	32	23.43
Trichostrongylus colubriformis	22	15	11.45
Trichostrongylus probolarus	2544	135	1.32
Nematodirus spp	38	23	19.79
Nematodirus helvitainus	95	38	49.47
Nematodirus spathiger	83	32	43.22
Camelostrongylus mentullatus	11	1	5.72
Avitellina spp	7	5	3.64
Moniezia expansa	2	2	1.04
Cooperia spp	9	6	4.68

Table 3. Clinical examination of infected camels for both sexes

Sex	Age / Year	Total number	%	Infected camels	%	Tem.C	Pulse /min.	Res. /min.
She camel	1-3	10	5.20	6	3.125	37.78	52.75	17
Camel	1-3	30	15.62	14	7.29	37.05	47.97	16.79
She camel	4-7	26	13.54	16	8.33	36.52	49.25	17
Camel	4-7	25	10.02	13	6.77	38	52.55	15.7
She camel	8-11	15	7.812	6	3.125	37.85	44.72	11.8
Camel	8-11	18	9.37	8	4.166	3698	49.09	12.98
She camel	12-15	13	6.77	6	3.125	37.12	47.18	13.81
Camel	12-15	12	6.25	8	4.166	36.8	45.93	13.64
She camel	16-18	32	16.66	23	11.97	37.3	64.42	14.5
Camel	16-18	11	5.729	5	2.60	37.1	51.65	14.95

Fig. 1. Shows in front of *Trichostrongylus spp*. (X100)

Fig. 2. Shows the back of the parasite *Trichostrongylus* spp. (X200)

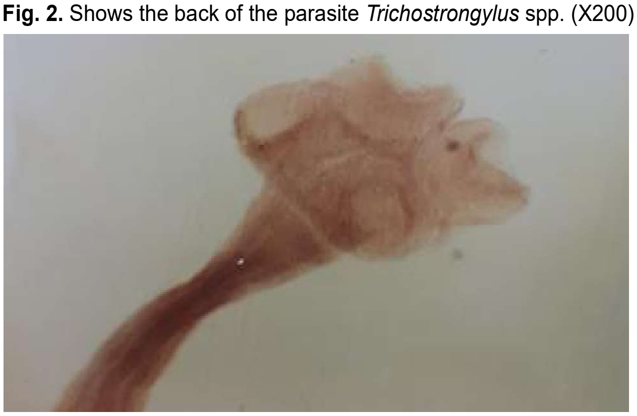

Fig. 3. Shows in front of *Moniezia expansa* (X40)

Fig. 4. The mature pieces of *Avitellina spp.* (X40)

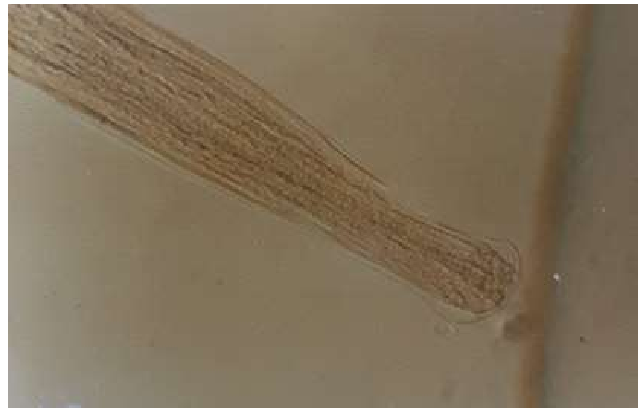

Fig. 5. Shows the in front of *Nematodirus spp.* (X200)

Fig. 6. Shows the back of the female *Nematodirus spp.*(X40)

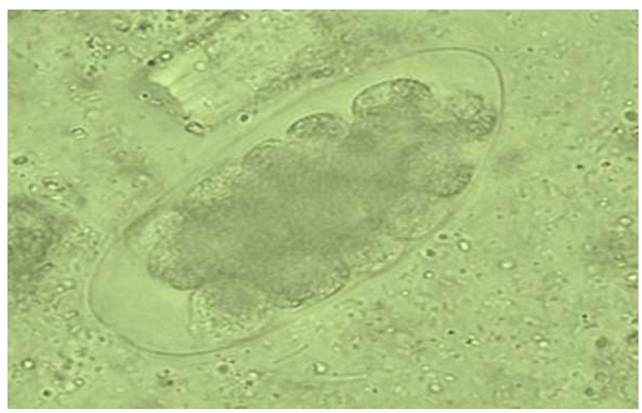

Fig. 7. Egg of *Trichostrongylus* spp. (X10)

Fig. 8. Shows the egg of *Nematodirus ssp.*(X10)

Table 6. Number of worm eggs excreted from the small intestine / gram of faeces during different month (Mean ± SE)

Months	Highest number of eggs excreted /gram of faeces/ animal	Rate of eggs excreted/ gram of faeces / animal	
January	800	650±	45.22
February	1100	800	90.45
March	1800	1400	120.6
April	2700	2100	180.9
May	2000	1700	75.37
June	2800	2450	105.52
July	900	600	90.45
August	700	550	45.22
September	1200	1000	60.30
October	1350	1120	69.30
November	1000	845	46.73
December	1100	900	60.30

some small intestine worms for e diagnostic (AL-taif 1974). The highest rate of eggs laid per gram of faeces per animal was during the spring and early months of summer (2450 during June) (Table 6).

CONCLUSION

Camels are infected with internal parasites, like other ruminants, they show signs of disease and weakness in cases of severe parasitic infection and failure to give anthelmintic drugs, which negatively affects the production of meat, milk and lint for camels, especially females, which are kept for long ages for reproduction. Therefore, research is required to preserve this wealth animal by limiting the unjust slaughter of weak or infected animals also formation of mobile veterinary teams by developing a preventive program to give anthelminthic and fortifying medicines to compensate for nutritional deficiency and strengthen immunity to reduce infection with diseases and parasitic diseases in particular.

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Effect of Maize Succession with Winter Crops on Growth and Productivity of Maize

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Abstract: The study was conducted to investigate the effects of winter crops succession on maize growth and productivity, at Salahaddin University, Erbil, Iraq, during fall and a winter season of 2016-2017. During both fall seasons, the field was completely planted with maize, afterwards, at winter season, three crops were selected namely canola, chickpea and wheat as well as a fallow plot in factorial randomized complete block design. The studied vegetative characters were plant height, ear height and stem diameter, while the productive characters were ear diameter, grain yield, 300-kernels weight of ear's base and biological weight. The highest plant height was after fallow and ear height and stem diameter after chickpea with 232.96, 90.87 and 2.46 cm respectively. The ear diameter and grain yield were maximum (2.69 cm, 13.46 t/ha) after chickpea. The 300-kernels weight of ear's base and biological weight were maximum in fallow after canola (93.88 and 491.43 g). The physiological characters, leaf area and leaf area index demonstrated the highest values after canola (6342.41 cm^2 and 3.38 respectively).

Keywords: Crop succession, Growth, Productivity, Maize, Winter crops

Maize is the most important cereals planted in Iraq. The cultivated area of maize is 781322 hectares, with a production of 2916928 tons (Iraqi Ministry of Planning 2017). In general, crop succession augments crop productivity and yield constancy (Helmers et al 2001). Crop successions with a greater participation of cereals exhibit a diminished yield balance of wheat versus to rotations involving legumes (Macholdt and Honermeier 2017). Boddey et al (2010) mentioned that leguminous crop which participates to the N addition by biological fixation plays crucial role in encouraging C accumulation in soil, which may be attributable to the diminished release of nitrogen waste on the surface, favouring maize root growth. This impact may affect even the height of plants can result in higher height of maize. Despite the fact that both plant species struggle for soil components, particularly N, for the reason that they demand N for their development. This competition influences legumes to fix nitrogen (N) from the air and amplify soil nutrients (Giller et al 2011). The association of both lowest soil tillage and crop succession ameliorates soil fertility and plant yield (de Cárcer et al 2019). Sadalla et al (2016) expressed that in fall season 2011, maize achieved significant variations for the traits namely ear height, 250-kernel weight and yield, but in fall season 2012, only ear height and length had significant variation. Arshed et al (2009) established that canola and field pea were greater advantageous than wheat as preceding crop for wheat yield three years of crop succession involving leguminous crops as wheat-faba bean and wheat-chickpea which had noticeable impact on wheat level.

Furthermore, a number of oilseed crop species developed in the winter, like radish, crambe and canola might be beneficial for manufacturing biofuels (Chammoun 2009). Additionally, a number of crop species release chemical compounds which normally excretes to the soil via the root structure, suppressing germination and/or development of other crop species. Leaf area (LA) is a decisive agent in various physiological and agricultural activities, especially with regard to development, photosynthesis, transpiration, water and nutrients consumption and yield (Pandey and Singh 2011, Gao et al 2012). Linear calculation and chart approach, K-coefficient for verification of leaf area for maize was estimated as 0.75 (). Leaf area index (LAI) and leaf inclination angle (LIA) distribution are two essential variables that differentiate foliage canopy composition, then perform a vital task in water, vapour and energy transfer between canopy and ambiance. They assist as major information of patterns that imitate photosynthesis, evapotranspiration (ET) and radiative reflectance (Fang 2015). Augmentation kernel production by the choice for best crop has been the basic point in innovative corn breeding. Consequently, leaf angle, a key factor of crop architecture, has been ameliorated to accommodate to the always-amplifying crop density in corn productivity significantly throughout the numerous decades ago (Ding et al 2015).

Leaf inclination angle (LIA) distribution itself is a crucial input criterion for radiative penetrate versions as the arrangement and inclination of leaves in canopy mutually with vegetation density and sunlight angle affect in what manner light is obstructed and cooperates amid leaf layers as it passes the crop canopy. In addition to it is essential for photosynthesis assessment. Crops can manage its morphological properties and leaf anatomical compositions beneath diverse light conditions (Fan et al 2018). Light straight influences the plant growth and productivity potential, high plants such as maize consume main portion of the light, while lower plants such as soybean take small quantity of light for photosynthesis and have trouble with shading from higher plants (Wang et al 2007, Wang et al 2013). Zhou et al (2019) pointed out that vegetative dry weight of corn magnified when subjected to interrupted light conditions significantly in comparison with continuous light conditions regardless of phosphorus furnish.

MATERIAL AND METHODS

The field experiment was performed at Grdarasha Research Station in 2016 and 2017 throughout three seasons (two fall seasons and a winter season). Three winter crops were selected: wheat (*Triticum aestivum* L.), canola (*Brassica napus* L.) and chickpea (*Cicer arietinum*) along with a fallow plot. In autumn seasons of 2016 and 2017 all blocks were cultivated to a homogeneous maize plant, the commercial corn hybrid ABGARO grown in 3m long lines dispersed at 75cm with 25cm between plants. Through the winter season of 2016-2017, the winter crops were planted in randomized complete block design with three replicates. Each replication comprised of four plots measured (3×3) m. For every plant type, all prescribed farming processes accomplished in terms of sowing date, crop density, fertilization and watering. After the harvesting of the plots were ploughed individually by hand to prevent soil concoction among plots for the purpose to be ready for the next growing season the same process was repeated after each season. Data of maize characters registered in both seasons and then the differences estimated as percentage between both fall seasons. The data analysed by employing IBM SPSS Statistics 22.0 software.

Studied Characters

Leaf area index (LAI): The leaf area index, the leaf area to field area ratio, commonly expressed as square meters per square meter, is a generally utilized biophysical property of foliage (Watson 1947).

$$LA = L * W * a$$

Where LA, L, W and a are leaf area, leaf length, leaf utmost width and a constant, sequentially. The value of the constant (a) is 0.75. When you estimate the overall leaf area of whole crops in a specified section, you can determine the leaf area index as the ratio of total leaf area to the total ground area accessible to the plants (Montgomery 1911). Irradiance

Table 2. Effects of winter crops succession on the vegetative characters of maize (2016-2017)

Season	Days to 50% tasselling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position	No. of nodes/ plant	Stem diameter (cm)
2016 (1)	57.83	56.75	213.65	92.65	7.59	15.05	2.35
2017 (2)	57.50	56.75	247.61	85.48	7.83	15.30	2.42
Percent difference	-0.57	0.00	15.90	-7.74	3.16	1.66	2.98
Treatment							
Canola-maize (A)	57.17 ^{a}	56.17 ^{a}	227.38 ^{b}	88.51 ^{ab}	7.75 ^{a}	14.78 ^{a}	2.11 ^{b}
Chickpea-maize (B)	57.33 ^{a}	57.33 ^{a}	229.85 ^{ab}	90.87 ^{a}	7.63 ^{a}	15.55 ^{a}	2.46 ^{a}
Fallow-maize (C)	58.17 ^{a}	56.83 ^{a}	232.96 ^{a}	86.26 ^{b}	7.37 ^{a}	15.42 ^{a}	2.39 ^{ab}
Wheat-maize (D)	58.00 ^{a}	56.67 ^{a}	224.34 ^{c}	83.61 ^{c}	8.10 ^{a}	14.95 ^{a}	2.28 ^{b}
Season × Treatment							
1×A	57.67 ^{a}	56.00 ^{a}	216.10 ^{bc}	96.40 ^{a}	7.47 ^{a}	14.80 ^{a}	2.32 ^{a}
1×B	56.67 ^{a}	57.00 ^{a}	219.47 ^{b}	97.53 ^{a}	7.23 ^{a}	15.33 ^{a}	2.39 ^{a}
1×C	58.33 ^{a}	57.00 ^{a}	215.47 ^{bc}	89.73 ^{ab}	7.33 ^{a}	15.47 ^{a}	2.32 ^{a}
1×D	58.67 ^{a}	57.00 ^{a}	203.57 ^{c}	86.93 ^{b}	8.33 ^{a}	14.60 ^{a}	2.37 ^{a}
2×A	56.67 ^{a}	56.33 ^{a}	244.67 ^{a}	84.62 ^{b}	8.03 ^{a}	14.77 ^{a}	2.31 ^{a}
2×B	58.00 ^{a}	57.67 ^{a}	244.22 ^{a}	84.20 ^{b}	8.03 ^{a}	15.77 ^{a}	2.53 ^{a}
2×C	58.00 ^{a}	56.67 ^{a}	250.45 ^{a}	86.79 ^{b}	7.40 ^{a}	15.37 ^{a}	2.30 ^{a}
2×D	57.33 ^{a}	56.33 ^{a}	251.11 ^{a}	86.29 ^{b}	7.87 ^{a}	15.30 ^{a}	2.53 ^{a}

was calculated to distinguish the light condition at various points at the apex of canopy by employment of (EXTECH light meter 401025). The sensor was situated horizontally 5 cm upon and below the canopy. Photosynthetically active radiation (PAR) acquiring on the apical layer of the foliage (I_o) and at the base of the canopy (I) was computed from every plot. Light transmission ratio (LTR) was determined .

$$LTR\ \% = \left(\frac{I}{Io}\right) \times 100$$

LI% = 100% - LTR%

Photosynthesis is heavily light reliant. The fraction of light arriving the soil via the plant and consumed for photosynthesis typically decreases exponentially with the leaf area index (L):

$I = Io\,e^{-KL}$ [J/m^2 s]

$$Or = \left(\frac{I}{Io}\right)e^{-KL}$$

$$OrIn = \left(\frac{I}{Io}\right) = -KL$$

$$K = \left\{In\left(\frac{I}{Uo}\right)\right\} / L$$

Where

I Light intensity on a specific depth in the canopy outline.

The radiation flux which attains the ground (PAR, J/m^2 s),

I_0 the incident radiation flux of photosynthetically active radiation (PAR, J/m^2 s),

K the radiation extinction coefficient (m^2 (ground)/m^2 (leaf)), and

L the leaf area index (*LAI*, m^2 (leaf)/m^2 (ground)).

Period of time to achieve 50% tasselling and silking were documented as the number of days required to attain 50% tasselling and silking from the time after sowing, on the basis of the emergence of tassels and silks in 50% of the plants in each plot.

RESULTS AND DISCUSSION

Most characters showed higher values during the second season than the first one. The winter crops effects on the vegetative characters of maize but there were no significant differences among the treatments for most of the characters except stem diameter, plant and ear height,. Sadalla et al (2016) referred this to the genetic characteristic of the used variety, meanwhile, characters plant height and ear height are extremely affected by soil components and environmental factors.

The plant height in second season was maximum (232.96 cm) after fallow (Fig. 1). This was due to that the soil didn't exploit at the preceding season and the nutrients didn't deplete, while the minimum value was of 224.34 cm after wheat as wheat is an exhaust crop for the soil nutrients and fertilizer and can also be attributed to the its allelopathic effect. Considering the interaction effects of the season and treatments, the maximum plant height gained from the interaction between the second season and wheat (251.11 cm) while 203.57 cm and was the minimum between the first season and wheat. These results magnify the great impact of the season interaction.

Ear height, comparing the two seasons, declined about by 7.74%. The ear height was after chickpea (90.87cm) and this agreed with Boddey et al(2010). The lowest was 83.61cm after wheat, highlighting the effect of the previous crop on the soil components, because chickpea is one of the leguminosae members and characterized by improving of soil nitrogen content crops. Similar findings were reported by Giller et al (2011). In terms of seasons influences on the ear height, 97.53 cm was the highest value obtained by the interaction between the first season and canola. The lowest ear height was exhibited by the interaction between second season and chickpea with 84.20 cm. The stem diameter was maximum after chickpea (2.46 cm) whereas 2.11 cm was the minimum observed after canola.

Apropos the effects of winter crops succession on the productive characters, each of ear diameter, grain yield, 300-kernels weight of ear's base and biological weight exhibited significant differences among the treatments (Table 3 and 4). For ear diameter, maize followed chickpea possessed the widest ear diameter with 2.69 cm while the smallest was 2.61 cm after fallow treatment. The maximum grain yield was harvested after fallow treatment (13.46 tons per hectare). This may be due to the area which was not utilize for a season consequently led to soil improvement and retain the nutrients. However, the lowest yield was at canola-maize succession (10.32 t/ha) because canola has a huge vegetative growth which eventually exhausted a great amount of soil nutrients. Pertaining 300-kernels weight of ear's base, the maximum was 98.88 g after canola crop, whereas the minimum was 89.83g produced after chickpea. These results are comparable to Arshed et al (2009). Relating to the biological weight, the highest weight was obtained at canola-maize succession which was 491.43g, simultaneously 436.82g was the lowest weight collected after chickpea, probably due to the species allelopathic effects (Fujii 2003).

With respect to the season × winters crop interaction, most of the yield components and physiological characters performed significant variations. For ear diameter, the highest value was 2.78 cm in interaction between second season and wheat, but the lowest interaction value was 2.48 cm exhibited between the first season and wheat. Regarding 300-kernels weight the maximum value noticed from the interaction between the second season and fallow treatment with 95.86g, in contrast 78.34g was the minimum value gained by the interaction between the first season and fallow treatment underlining the great impact of the season factor on the characters. Focusing on 300-kernels weight of the

Table 3. Effects of Succession on the productive characters of maize (2016-2017)

Season	Ear diameter (cm)	Grain yield (t/ha)	300-kernels Weight (g)	300-kernels weight of ear's base (g)	300-kernels weight of ear's centre (g)	300-kernels weight of ear's tip (g)	Biological weight (g)
2016 (1)	2.55	12.49	81.12	89.67	92.72	71.03	468.47
2017 (2)	2.76	13.64	91.82	98.49	96.98	79.99	472.27
% difference	8.24	9.21	13.19	9.84	4.59	12.61	0.81
Treatment							
Canola-maize (A)	2.69 ^{ab}	10.32 ^{b}	88.05 ^{a}	98.88 ^{a}	96.12 ^{a}	74.02 ^{a}	491.43 ^{a}
Chickpea-maize (B)	2.69 ^{a}	11.83 ^{ab}	86.19 ^{a}	89.83 ^{b}	93.88 ^{a}	77.76 ^{a}	436.85 ^{c}
Fallow-maize (C)	2.61 ^{b}	13.46 ^{a}	87.10 ^{a}	97.00 ^{ab}	93.89 ^{a}	77.62 ^{a}	478.10 ^{ab}
Wheat-maize (D)	2.63 ^{ab}	11.06 ^{b}	84.53 ^{a}	90.63 ^{b}	95.51 ^{a}	72.65 ^{a}	462.08 ^{b}
Season×Treatment							
1×A	2.61 ^{b}	12.48 ^{a}	80.43 ^{b}	93.13 ^{b}	89.61 ^{b}	68.27 ^{b}	475.83 ^{a}
1×B	2.62 ^{b}	12.54 ^{a}	83.24 ^{b}	88.03 ^{b}	93.16 ^{ab}	74.33 ^{ab}	470.80 ^{a}
1×C	2.50 ^{c}	12.64 ^{a}	78.34 ^{b}	86.89 ^{b}	92.88 ^{ab}	69.67 ^{b}	474.37 ^{a}
1×D	2.48 ^{c}	12.32 ^{a}	82.46 ^{b}	90.65 ^{b}	95.21 ^{ab}	71.86 ^{ab}	452.87 ^{a}
2×A	2.76 ^{a}	12.96 ^{a}	95.68 ^{a}	104.63 ^{a}	102.63 ^{a}	79.77 ^{ab}	487.03 ^{a}
2×B	2.76 ^{a}	13.52 ^{a}	89.14 ^{ab}	91.63 ^{b}	94.60 ^{ab}	81.20 ^{ab}	442.90 ^{a}
2×C	2.72 ^{ab}	14.28 ^{a}	95.86 ^{a}	107.10 ^{a}	94.90 ^{ab}	85.57 ^{a}	475.83 ^{a}
2×D	2.78 ^{a}	13.80 ^{a}	86.61 ^{ab}	90.60 ^{b}	95.80 ^{ab}	73.43 ^{ab}	483.30 ^{a}

Table 4. The effects of winter crops succession on the productive and physiological characters of maize (2016-2017)

Season	No. of rows/ ear	No. of kernels/ rows	Ear length cm	No. of ears/ plant	Leaf inclination angle	LA	LAI
2016 (1)	15.73	41.08	19.96	1.39	26.16	5710.18	3.05
2017 (2)	17.06	42.44	20.11	1.60	25.57	6060.51	3.23
Percent difference	8.46	3.31	0.75	15.11	-2.26	6.14	5.90
Treatment							
Canola-maize (A)	16.39 ^{a}	41.28 ^{a}	20.09 ^{a}	1.47 ^{a}	25.25 ^{a}	6342.41 ^{a}	3.38 ^{a}
Chickpea-maize (B)	16.19 ^{a}	41.17 ^{a}	19.56 ^{a}	1.55 ^{a}	26.22 ^{a}	5678.89 ^{b}	3.03 ^{b}
Fallow-maize (C)	16.67 ^{a}	41.72 ^{a}	20.38 ^{a}	1.50 ^{a}	25.62 ^{a}	5926.23 ^{ab}	3.16 ^{ab}
Wheat-maize (D)	16.33 ^{a}	42.89 ^{a}	20.09 ^{a}	1.47 ^{a}	26.42 ^{a}	5593.87 ^{b}	2.98 ^{b}
Season×Treatment							
1×A	16.33 ^{abc}	41.33 ^{a}	20.04 ^{a}	1.27 ^{c}	24.93 ^{a}	6053.53 ^{ab}	3.23 ^{ab}
1×B	15.27 ^{c}	40.00 ^{a}	19.28 ^{a}	1.57 ^{ab}	25.57 ^{a}	6158.07 ^{a}	3.29 ^{a}
1×C	16.00 ^{bc}	40.33 ^{a}	20.27 ^{a}	1.33 ^{bc}	26.87 ^{a}	5706.5 ^{abc}	3.04 ^{abc}
1×D	15.33 ^{c}	42.67 ^{a}	20.23 ^{a}	1.40 ^{bc}	27.27 ^{a}	4922.63 ^{c}	2.63 ^{c}
2×A	16.45 ^{abc}	41.22 ^{a}	20.13 ^{a}	1.67 ^{a}	25.57 ^{a}	6631.28 ^{a}	3.53 ^{a}
2×B	17.11 ^{ab}	42.33 ^{a}	19.85 ^{a}	1.53 ^{ab}	26.87 ^{a}	5199.71 ^{bc}	2.77 ^{bc}
2×C	17.33 ^{a}	43.11 ^{a}	20.49 ^{a}	1.67 ^{a}	24.37 ^{a}	6145.95 ^{a}	3.28 ^{a}
2×D	17.33 ^{a}	43.11 ^{a}	19.96 ^{a}	1.53 ^{ab}	25.57 ^{a}	6265.1 ^{a}	3.34 ^{a}

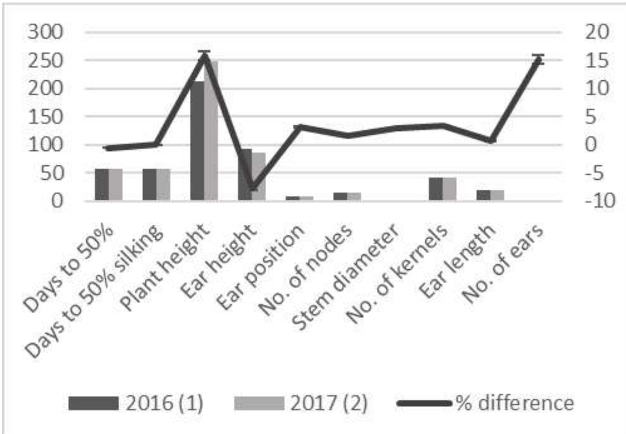

Fig. 1. Effects of winter crops succession on the vegetative characters of maize during 2016-2017

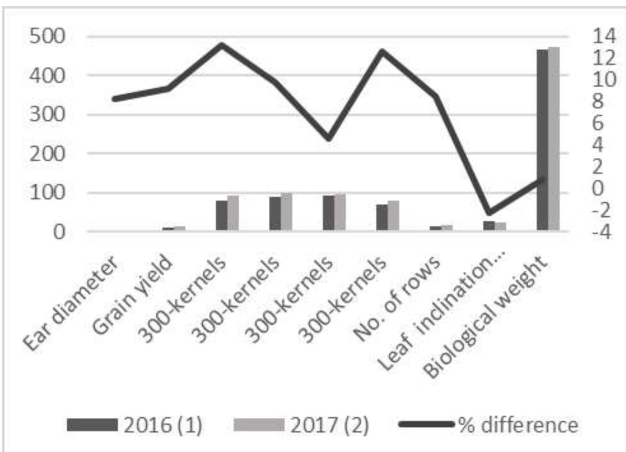

Fig. 2. Effects of succession on the productive characters of maize during 2016-2017

ear's base, centre and top, the maximum weight for each was 107.10, 102.63 and 85.57g observed in the interaction between the second season with fallow, second season with canola and second season with fallow respectively. The minimum value was 86.89g in interaction between the first season with fallow being 89.61 and 68.27g for the interaction between the first season and canola (Table 3). Relation between the seasons and treatments for some other productive and physiological characters, for number of rows per ear, 17.33 was the highest number gained from the interaction between the second season and both of fallow treatment and wheat. The lowest number of rows per ear was 15.27 exhibited by the interaction between the first season and chickpea. The number of ears per plant was maximum (1.67) for interactions between the second season and both of canola and fallow treatment, whereas the minimum was 1.27 accomplished by the interaction between the first season and canola.

LA and LAI characters, recorded highest value for the interaction between the first season and fallow was 5706.5 cm and 3.04 respectively, but the lowest LA and LAI was at the interaction between the first season and wheat which was 4922.63 cm and 2.63 in ascending order.

CONCLUSION

The study confirmed that succession of maize with winter crops had significant impacts on some growth, yield components and physiological characters of maize because the used winter crops showed significant differences in their allelopathic activities. Thus, the sequences of canola-maize and fallow-maize took advantage to perform the highest values for most characters among the rest of successions. The present study conclude that canola (*Brassica napus* L.) could be most suitable crop in succession followed by chickpeas. Additional investigations are required to find the most appropriate succession beneficial for maize characters improvement and enhance high productivity.

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