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Sustainable Agricultural Innovations for Resilient Agri-Food Systems

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Potential of Different Fruit-based Agroforestry Models for Improving Livelihood in Humid and Sub-Tropical Region of India

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Abstract: In developmental context of rural areas the major constraints lies is lack of family planning, concomitant population growth, extensive deforestation, fragmented land holdings and monocropping. Agroforestry practices helps improving productivity and reduce inputs, trying to mitigate the adverse effect of monocropping and deforestation. So, the scientific community intervenes to harness the positive effects of agroforestry land use systems and address global issues of land degradation, bio diversity conservation, agriculture sustainability and more recently the climate change and food security by providing good returns to the farmers. In this light a research was conducted at Regional Research Station (Bidhan Chandra Krishi Viswavidyalaya), Jhargram, West Bengal, India to find out suitable fruit-based agroforestry model which comprised silvi species gamhar *(Gmelina arborea)*, fruit crop mango (*Mangifera indica*) and five arable crops viz, cowpea, black gram, groundnut, okra and maize cultivated during Kharif and mustard in Rabi season. The all the growth characters of gamhar (*Gmelina arborea*), production of mango and soil health status were at higher side under agroforestry systems as compare to sole cropping. Gamhar + Mango + Groundnut – Mustard agroforestry model gave the highest returns in terms of income and yield of tree and intercrops i.e ₹8,46,420.62 $ha^{-1}yr^{-1}$ in Indian Rupee (INR).

Keywords*:* Fruit based Agroforestry, Livelihood, Productivity, Red and lateritic zone

According to FAO, India is the first country in the world to adopt the National Agroforestry Policy in 2014, under Ministry of Agriculture and Farmers Welfare with an objective is to expand tree plantation in combination with crops or livestock to improve overall productivity, reducing unemployment, generating additional source of income for marginal growers. This policy highlights that agro forestry could be implemented to meet the domestic and industrial requirements of the country for wood and its products. Around 31 percent of the Earth's land mass, constitute the total forest cover which accounts to an area of over 4 billion ha (FAO 2010). Mono cropping have been a failure to meet the demands of the people, and attaining sustainability for the future generations and is proved to be at rear side in generating additional income. Therefore, diversification of land use systems with agro forestry is a quintessential need for providing variety of products for meeting requirements of the people, insurance against risks caused by weather fluctuations, improving soil health and ensuring sustainable production with a futuristic approach. Agroforestry is the preferred land use management practice for improving livelihood security by increasing the total productivity per unit area of land, to meet the growing demands of the people for food, fruits, fuel wood, timber, fodder, bio-energy and other ecological services (Sarkar 2019a, Sarkar et al 2017c, Sarkar 2019b). Murmu et al (2016) focussed on diversification of agroforestry by selection of appropriate tree species, their quality planting material and remunerative crop combinations for reclaiming the degraded lands of India by increasing their productivity and economic returns by meeting the water and nutrient requirement of the crops, trees and controlling their insect, pest and diseases. Agroforestry systems provide good economic rates of return and also optimize livelihood solution for poor farmers, biodiversity conservation and environmental sustainability. The integration of trees with agricultural crop diversifies the income drive and enforces sustainability for increased social, economic and environmental benefits through agroforestry which is a dynamic, ecologically-based natural resources management system (Msuya and Kideghesho 2012). Agroforestry aims at promoting economical, social and environmental sustainable rural development (Leakey 2012). In India, agroforestry systems are classified as traditional and advanced agroforestry systems (Korwar et al, 2014).

Fruit-based agroforestry system integrates the cultivation of agronomic crops, vegetable crops, fruit trees and silvi component. The integration of forest trees provides all food, fuel, medicines, fodder, building materials and cash income (Fig. 1). Fruit crop-based multi-storied agroforestry models were the most effective in minimizing the risk of sole cropping in upland watersheds of Eastern India. Kumar (2020) opined that inter space between the fruit crops is utilized for growing short duration cash crops which not only sustain the orchardist during the non-fruiting months of the main crop but also add to the fertility of the soil by enhancing the soil health. Intercropping has greater advantages that increases production, fruit quality chemical composition of fruits and reduces the fruit drop. Rahman et al (2015) ascertained that mango based suitable Agri-horti-silvi cropping models have been standardized for rainfed uplands in the watersheds under sub-humid plateau regions of Eastern India. Mango is an important fruit crop to be included in the agro forestry system as the association is believed to optimize the yields, enhance soil fertility and soil moisture, ameliorates the soil, by adding biomass for long term build up of soil organic matter. Crop production on red and laterite soil under rainfed condition is low and unstable. *G. arborea* is one of the indigenous multipurpose tree species grown in eastern region of India and produces one of the best quality timbers. It is a medium to large-sized deciduous tree of up to 40m height, and grows best in areas with a mean annual rainfall from 800 to 2,500mm, and an annual average temperature of 15-36°C and prefers a heavy soil and damp situation. This plant grows best in loamy alluvial soils, but ranges from gravel to sand to clay. There is a recorded mean increment of annual diameter of 3cm. Wood and wood-pulp both account for use in furniture, bent-wood articles, boat-building, panelling, brushes, slate frames, figure and pattern making

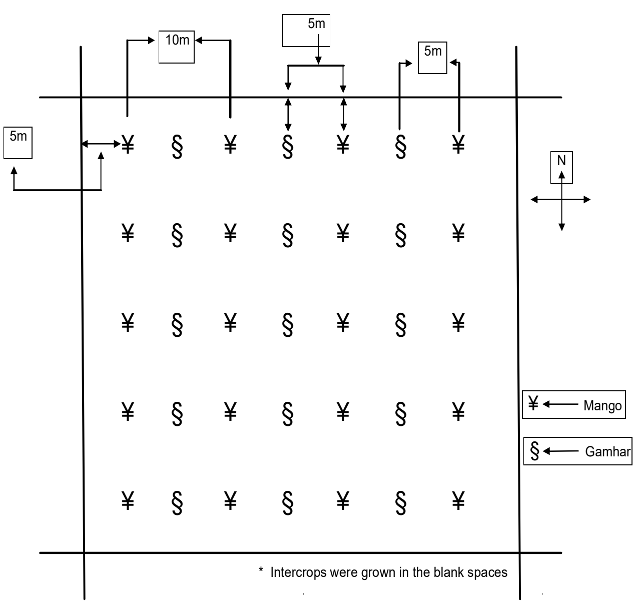

Fig. 1. Layout of experiment

as well as for wrapping, writing and printing papers. It is a well-suited agroforestry tree found in the red and laterite zone of West Bengal (Dhara 2019). Adoption of economically important tree species under agro forestry systems increases the productivity and narrows the gap between demand and supply of wood. (Murmu and Dhara 2022) Mango based agri–horticultural systems constitutes of three main components i.e., main crop, filler crop and inter crops which occupy three different tiers in space of the production system. The intercropping of rainfed arable crops is of immense importance for getting quick returns in the initial years. The integration of short duration arable crops like, pulses, vegetables, groundnut etc. with dry land horticultural fruit trees like, mango, guava etc. is proved to be the most profitable. With areas of 50% of western part of West Bengal being in rainfed condition encounters land degradation and as well as the climate is tropical and humid, hence for enhancement of livelihood a suitable mango-based agroforestry system is needed to be developed for this soil erosion prone zone, where in suitable intercrop integrated with mango-based agroforestry system will provide higher economic return and maintain the sustainability of the environment (Mondal and Dhara 2016).

Keeping in view the prima facia condition of red and laterite zones of West Bengal, a field experiment was undertaken to develop a suitable fruit-based agro-production system for rainfed red and laterite zone of West Bengal.

MATERIAL AND METHODS

Location of the study area: The present study was carried out at Regional Research Station (Red and Laterite Zone) of Bidhan Chandra Krishi Viswavidyalaya at Jhargram, West Bengal, India. The experimental site is located at $22^{0}30"$ N latitude and $87^{0}0"$ E longitude and at an elevation of 78.77 above mean sea level.

Climate and weather: The location of experiment is situated in humid sub-tropical climatic zone and characterized with short winter and long hot summer. The annual precipitation varies between 1100 and 1300mm, about 80% of which are usually precipitated during monsoon period (June-September). Maximum and minimum temperatures during the month of cropping period were found between 25.5-38.8 and 16.4-28.2°C respectively. The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature have been collecting from Regional Research Station (Red and Laterite Zone) of Bidhan Chandra Krishi Viswavidyalaya at Jhargram, West Bengal, India.

Soil: The experiment was carried out in upland situation where the soil are coarse texture and acidic (pH 5.5) and poor in organic matter available nitrogen, phosphorus, potassium and lime content and highly susceptible to erosion hazards.

Tree and plant material: Previously established mango (*Mangifera indicia*) trees were used as fruit tree component and Gamhar (*Gmelina arborea*) was used as tree component with six arable crops as intercrops viz. Groundnut (Var. TAG-24), Cowpea (Var. Pusa Barsati), Black gram (var. WBU 109), Maize (var. Kanchan-K-25) and Okra (var. Parvani Kranti).

Experimental design and treatment combination: The experiment initially started in August 2007, with one year old saplings of mango grafts cv. Amrapali (100Nos.) planted along with Gamhar *(Gmelina arborea)* seedlings of about 2months old at 10× 10m spacing. The tree component were planted in between two mango plants and a 5m spacing in between two mango rows and as boundary plantation of the experimental field. The plot size of experiment accompanied with intercrops was 20 × 20m for each treatment. Six arable crops viz. Cowpea (Var. Pusa Barsati), Black gram (var. WBU 109), Groundnut (Var. TAG-24), Okra (var. Parvani Kranti), Groundnut (Var. TAG-24) and Maize (var. Kanchan-K-25). were grown during kharif season (mid-June to Ist October) followed by mustard crop (var. B-9) in rabi season (October to March) of 2015-16 and 2016-17, which was cultivated by using residual soil moisture.

The experiment has been laid out in a randomized block design having 8 treatments (T_1: Gamhar + Mango + Cowpea; T_2: Gamhar + Mango + Black gram followed by Mustard; T_3: Gamhar + Mango + Groundnut followed by Mustard; T_4: Gamhar + Mango + Okra followed by Mustard; T_5: Gamhar + Mango + Maize followed by Mustard; T_6: Gamhar + Mango; T_7: Sole Gamhar; T_8: Sole Mango) with 3 replications. Inter crops were grown with standard agronomic package of practices. Different growth parameters of silvi species and fruit tree (height, DBH, Crown diameter and fruit yield) were recorded.

Land preparation: The experimental land with Gamhar and Mango plants were first ploughed in the month of April. The land preparation was carried out and experimental plots of 20 X 20m were laid out and intercrops were planted accordingly in the kharif season and mustard was grown in the residual moisture.

Application of fertilizer and manures: The recommended doses of cow dung/compost, Urea, SSP and MOP were applied. Full amount of well decomposed cow dung/compost and SSP were incorporated during the final land preparation. The nitrogenous fertilizers were applied in full doses. The recommended doses of fertilizers were applied in all the intercrops grown, as in case of leguminous crops least amount of nitrogenous fertilizer was applied.

Weeding and irrigation: Weeding was done three times in experimental plots to keep the plots weed free. The plots were irrigated by using watering can to supply sufficient soil moisture for the intercrops and mustard was allowed to grow in residual moisture.

Thinning or filling: Emergence of seedlings of intercrops was started after 15days from the date of sowing. Seedlings were thinned out for two to three times at 5days interval from first thinning.

Pest and disease control: No major diseases and pests were observed hence, insecticide and fungicide application was minimal.

Data analysis: Different growth attributes i.e., height, stem girth, crown diameter at breast height and volume yield was recorded.

The basal area of individual Gamhar tree was calculated by using following formula.

$$BA = \pi \times \frac{(DBH)^2}{4}$$

The volume yield calculation (for tree species) was done by quarter girth formula. The volume yield estimates were calculated by the given equation,

$$Y_{vol} = BA \times h_t \times 0.5$$

The commercial biomass of wood of Gamhar was estimated by the help of commercial volume yield and wood density.

Biomass = Volume yield (kg/m^3/ha/yr) × Wood density (kg/m^3)

Data on soil nutrient status had also been taken both prior to commencement of the experiment and after completion of two cycles of inter cropping for calculation of increase or decrease percentage of soil nutrients. The height and yield of mustard was recorded for all the treatments. The yield of mango and intercrops were recorded for all the treatments.

For economic evaluation of the system, the return from tree component, fruit component and the intercrops were calculated by recording the yield of mango and intercrops, along with wood production from different treatments. The return from the tree fruit and intercrops were estimated from the prevailing farm gate prices and were estimated in terms of (Rs/ha/yr). The economics of different treatment was worked out separately by taking into account the yields, existing price of various input and output separately. The investment on fertilizer, labour and power for performing different operations such as ploughing, weeding, irrigation, picking/harvesting (`ha^{-1}) were considered as per market price of Jhargram, West Bengal. The cost of cultivation was taken into account for calculating economics of treatments and to work out return hectare^{-1} (₹ha^{-1}) and benefit cost ratio.

Gross return: Gross returns were obtained by converting the harvest into monetary terms at the prevailing market rate during the course of studies for every treatment.

Net returns: Net return was obtained by subtracting cost of cultivation from gross return.

Net return (Rs ha^{-1}) = Gross return (Rs ha^{-1}) – Cost of cultivation (Rs ha^{-1})

Benefit cost ratio (B: C) : The benefit cost ratio was calculated on the basis of net return per unit cost of cultivation.

$$B: Cratio = \frac{\text{Net Returns (Rs h}^{-1})}{\text{Cost of Cultivation (Rs h}^{-1})}$$

The data gathered in each observation were statistically analyzed using SPSS version 20 software. The critical differences were calculated to assess the significance of treatment means wherever the 'F' test was found significant at 5% level of probability by means of ANOVA.

RESULTS AND DISCUSSION

Growth parameters of gamhar *(Gmelina arborea)*: The height of the Gamhar tree was recorded to be highest in both the years in treatment (T_3) where Gamhar was intercropped with Mango and Groundnut i.e., 5.78 and 6.67m in 2015 and 2016 respectively (Table 1). This was followed by (T_1) where Gamhar was intercropped with cowpea followed by T_2 (Gamhar + Mango + Black gram – Mustard) and T_5(Gamhar + Mango + Maize – Mustard) and the lowest height recorded in Sole Gamhar i.e., 4.33 and 4.41m in 2015 and 2016 respectively. The DBH and volume yield recorded of Gamhar inferred the same trend as height of the tree, the highest DBH was in T_3 4.71 and 4.89cm, followed by T_1 and T_2. The lowest DBH being recorded from sole Gamhar as 3.44 and 3.58cm respectively in both the years. The increasing age of plant resulted in increasing of growth attributes of the tree (Table 1). The estimates of volume yield of the trees were found to be highest in T_3 0.034 and 0.045 m^{3}ha^{-1}yr^{-1}, followed by T_1. The growth attributing characters were higher in Mango based Agro-production models as compared to sole crop, thus exhibiting a positive effect of mango-based intercropping on tree growth. The growing of legumes as intercrops entrapped positive effect on growth attributes of gamhar as well as on commercial wood biomass of the tree component. The effect of heredity and environment is directed towards growth in diameter and height of tree (Das et al 2017).

All the Mango-based agro forestry systems were significantly different from each other and were found to have increased height and DBH (Diameter at breast height) than the sole crop. The results are in conformity with the findings of Rathore et al (2013). The complementary effect of Mango-based agro-production accompanied with inter-cropping of groundnut on growth and timber volume yield of Silvi species was further elaborated by Das et al (2014) and Sharma et al (2017), where the growth attributes of silvi species (Gamhar) was higher in the mango-based agro forestry model than in sole cropping. The lowest volume yield was in sole crop as 0.015 and 0.016 m^{3}ha^{-1}yr^{-1} in 2015 and 2016. Swain (2014) opined that yield was higher in mango based agro forestry systems than the sole crop and were significantly different under rainfed situation, fruit tree-based framing system resulted in reduced risk. According to Saravanan (2012) and Fanish & Priya (2013), farmers who are facing problems in practicing unprofitable sole agriculture can raise *G. arborea*. Gamhar is extensively used for timber, industrial wood and fodder production and is grown both on government and private lands in north-east India.

Commercial biomass production & basal area of gamhar : The highest commercial wood mass is 13.73 kg/m^3/ha/yr recorded in the second year (2016) in treatment followed by treatment T_1 (Table 2). There is increase in wood mass in the successive years. The basal area of gamhar also followed

Table 1. Growth attributes of Gamhar tree grown in agroforestry and sole plantation

Mango-based AFS model	Height (m)		DBH (cm)		Volume yield (m^{3}ha^{-1}yr^{-1})	
	2015	2016	2015	2016	2015	2016
T_1:Gamhar + Mango + Cowpea	5.67	6.63	4.52	4.68	0.034	0.037
T_2:Gamhar + Mango + Black gram – Mustard	5.52	6.55	4.38	4.58	0.029	0.030
T_3:Gamhar + Mango + Groundnut – Mustard	5.78	6.67	4.71	4.89	0.034	0.045
T_4:Gamhar + Mango + Okra – Mustard	5.25	5.56	3.87	4.00	0.020	0.025
T_5:Gamhar + Mango + Maize –Mustard	5.46	5.87	4.22	4.34	0.022	0.031
T_6:Gamhar + Mango	4.84	4.90	3.68	3.84	0.019	0.021
T_7:Sole Gamhar	4.33	4.41	3.44	3.58	0.015	0.016
T_8:Sole Mango	-	-	-	-	-	-
CD (P=0.05)	0.57	0.40	0.42	0.36	0.006	0.005

the same trend as of the growth attributes of gamhar.

Growth attributes of mango under different agroforestry systems: The height, stem girth and crown diameter was found highest in T_3 (6.25 and 7.01m in 2015 and 2016 respectively), followed by T_1 and T_2(Table 3). The least height of mango was recorded in sole cropping of mango i.e., 4.55 and 5.04m in successive years respectively. The maximum stem girth recorded in T_3 was 68.46 and 79.85cm in 2015 and 2016 respectively, followed by T_1. The treatments T_2, $T_5$and T_4 ranked third, fourth and fifth for both height and stem girth. The sole crop of mango recorded lowest stem girth i.e., 48.24 and 53.29 cm in 2015 and 2016 respectively. The same trend was observed in crown diameter of the fruit crop. The crown diameter was highest in T_3 i.e., 5.62 and 6.65cm in both the years followed by T_1 and T_2. The lowest crown diameter 4.77 and 5.60cm was recorded in sole crop of mango. All the treatments were at par from each other.

Production (t/ha) of fruit (mango): The mango yield obtained from T_3 was highest among all treatments in the consecutive years i.e., 6.42 and 9.67t ha^{-1} in 2015 and 2016 respectively, followed by T_1 by T_2, T_4 and T_5respectively (Table 5). The production of mango was more when legume crops were intercropped with mango. The lowest mango yield was obtained in Sole mango crop in consecutive years i.e., 4.54 and 6.09t ha^{-1} in 2015 and 2016 respectively. The mango yield and production of intercrops increased in the year 2016 as compared to year 2015. The increase percent of yield of mango in different AFS models was maximum (50.67%) in T_3-(Gamhar + Mango + Groundnut – Mustard) (Table 5).

Height and yield of intercrops under different agroforestry systems: Yield of intercrops grown under different mango-based agroforestry systems were slightly increased in second year as compared to first year (Table 5). The height of the intercrops was increased by 3.77, 5.71, 11.50, 13.08 and 44.98% in cowpea, groundnut, okra and maize (Fig. 2). The yield of intercrops also increased comparably in 2016 than 2015. The highest increase of yield was recorded in groundnut i.e., 30.47%, followed by cowpea,

Table 2. Commercial biomass production & basal area of Gamhar

AFS model	Wood biomass of Gamhar (kg/m3/ha/yr)			Basal area of Gamhar (m2)		
	2015	2016	Increase (%)	2015	2016	Increase (%)
T_1	10.20	11.20	9.73	0.0117	0.0125	7.35
T_2	8.71	8.98	1.88	0.0109	0.0121	10.51
T_3	10.47	13.73	31.16	0.0126	0.0136	7.41
T_4	6.17	7.66	24.17	0.0083	0.0091	9.22
T_5	6.66	9.53	42.99	0.0101	0.0107	5.45
T_6	5.74	6.26	9.01	0.0078	0.0084	7.22
T_7	4.41	4.88	10.51	0.0067	0.0073	8.48
T_8	-	-	-	-	-	-
CD (p=0.05)	1.83	1.59	-	0.0021	0.0018	-

See Table 1 for treatment details

Table 3. Growth attributes of Mango tree grown in agroforestry and sole plantation

AFS model	Height (m)		Stem girth (cm)		Crown diameter (cm)	
	2015	2016	2015	2016	2015	2016
T_1	6.18	6.85	65.87	75.91	5.57	6.62
T_2	5.99	6.77	61.83	70.39	5.48	6.58
T_3	6.25	7.01	68.46	79.85	5.62	6.65
T_4	5.85	5.86	52.02	62.03	4.98	5.86
T_5	5.90	6.62	55.64	66.01	5.41	5.95
T_6	4.93	5.73	52.21	58.93	4.90	5.91
T_7	-	-	-	-	-	-
T_8	4.55	5.04	48.24	53.29	4.77	5.60
CD (p=0.05)	0.13	0.47	6.05	8.16	0.39	0.75

See Table 1 for treatment details

blackgram, okra and maize with increase of 10.65, 7.91, 3.71 and 0.96% respectively (Fig. 3). The increase in yield in second year was might be due to the addition of nutrients from crop residues from first year and micro flora activity in the rhizosphere. Kaur et al (2017) also observed profitable intercropping in mango plantation.

Height and production of mustard in different agroforestry models: The height of mustard increased in the successive year 2016. The highest height of mustard was recorded in T_5 (Gamhar + Mango + Maize – Mustard) (101.07 and 103.55m in 2015 and 2016 respectively), followed by T_3 (Fig. 4). The yield of mustard was maximum in T_5 (Gamhar +

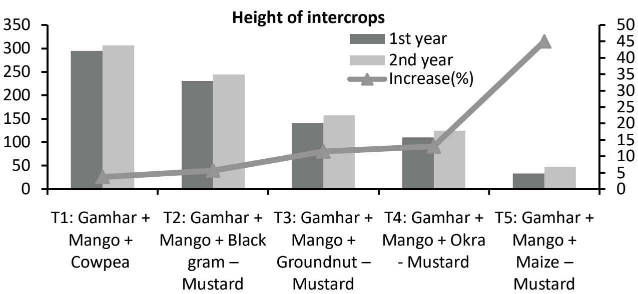

Fig. 2. Height of intercrops in consecutive years in different agroforestry models

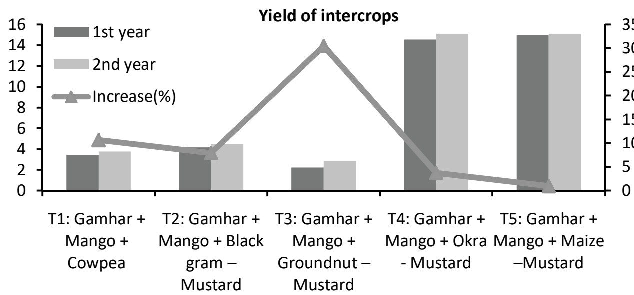

Fig. 3. Yield of intercrops and increase percentage in different agroforestry models

Table 4. Effect of different agroforestry models on soil health status

Treatment	Initial status of nutrient		Final status of nutrient		Increase (%)		Initial status of nutrient			Final status of nutrient			Increase (%)		
	pH	OC	pH	OC	pH	OC	N	P	K	N	P	K	N	P	K
T_1	5.5	0.37	5.7	0.48	3.64	29.73	164.1	17.8	174.1	228.45	24.6	208.32	39.21	38.20	19.66
T_2	5.5	0.36	5.7	0.45	3.64	25.00	169.09	17.5	170.09	231.67	24.13	200.34	37.01	37.89	17.78
T_3	5.4	0.35	5.6	0.43	3.70	22.86	167.37	17.8	177.37	227.32	24.02	207.34	35.82	34.94	16.90
T_4	5.3	0.36	5.5	0.44	3.77	22.22	162.5	19.8	172.5	218.23	26.32	199.32	34.30	32.93	15.55
T_5	5.3	0.33	5.5	0.39	3.77	18.18	173.05	15.1	183.05	224.35	19.21	207.55	29.64	27.22	13.38
T_6	5.1	0.34	5.3	0.39	3.92	14.71	148.2	11.8	158.2	181.34	14.67	182.13	22.36	24.32	15.13
T_7	5.1	0.31	5.3	0.35	3.92	12.90	144.2	11.7	154.2	166.23	14.06	176.34	15.28	20.17	14.36
T_8	5.1	0.29	5.1	0.32	0.00	10.34	140.2	11.7	150.2	158.34	13.9	165.34	12.94	18.80	10.08

See Table 1 for treatment details

Table 5. Economics returns obtained from different AFS models

AFS models	*Production of wood (m3/ha/year)	Yield of mango (t/ha)	Yield of mustard (t/ha)	Production of intercrops (t/ha)	Return from tree (Rs./ha/year)	Return from fruit crops (Mango) (Rs./ha/year)	Return from mustard crop (Rs./ha/year)	Return from intercrop (Rs./ha/year)	Gross returns (Rs./ha/year)	B:C Ratio
T_1	11.20	7.46	-	3.59	335862.69	223900	-	107750	667512.69	1.05
T_2	8.98	7.13	0.94	4.34	269484.08	213850	37600	86700.00	607634.08	1.03
T_3	13.73	8.05	1.01	2.55	412020.62	241400	40200	152800.00	846420.62	1.82
T_4	7.66	6.43	0.87	14.82	229851.88	192950	34600	50933.33	508335.22	0.96
T_5	9.53	6.67	1.16	4.78	285822.33	200100	46400	286800.00	819122.33	1.73
T_6	6.26	5.79	-	-	187814.84	173750	-	-	361564.84	0.81
T_7	4.88	-	-	-	146287.29	-	-	-	146287.29	0.17
T_8	-	5.31	-	-	-	159400	-	-	159400.00	0.59

See Table 1 for treatment details
(*Production of Wood = Volume Yield × No. of plants grown in One ha. Farm gate Price = Gamhar- (Rs 30000/m^3), Mango = Rs 30/kg, Mustard = Rs 40/kg, Pigeon Pea = Rs 50/kg, Black Gram =Rs 40/kg, Bottle Gourd = Rs 15/kg, Okra = Rs 20/kg, Maize = Rs 60/kg)

Mango +Maize – Mustard) in both the years i.e., 0.94 and 1.38t ha^{-1} respectively, followed by T_4, T_2 and T_4. The lower mustard yield was attributed to the residual moisture in which mustard was grown.

Soil health status: The soil nutrient analysis was carried out by measuring the initial nutrient status and end nutrient status after completion of the experiment (Table 4) represents the initial nutrient status and final nutrient status of the soil after completion of two years. After completion of two cycles of cropping, the results increase in percentage of organic carbon, N, P and K was highest in first treatment T_1(Gamhar + Mango + Cowpea) i.e., OC-29.73%, N-39.21%, P-38.20% and K-19.66%), followed by T_2, T_4, T_5 and T_6. The higher increase in soil nutrients is attributed by intercropping with leguminous crops like Cowpea and Black gram. The lower increase in the nutrient status was recorded in the sole cropping T_7 and T_8. The increase of soil pH was observed under all the different agroforestry system as compared with T_8. The findings are in conformity with the results of Misra (2011), Uthapa et al (2015) and Yadav et al, (2011) reported the complimentary effect of edition of different components along with agricultural crops for better utilization of natural resources.

Economic return from different Mango + Gamhar based agroforestry system model: Return from Gamhar were estimated in terms of Rs/ha/yr, by the help of estimation of commercial biomass in the final year of the experiment. The return from fruit tree, intercrops and mustard were calculated based on the mean yield and farm gate prices. T_3 (Gamhar + Mango + Groundnut – Mustard) agroforestry model gave the highest returns in terms of income and yield of tree and intercrops i.e., ₹8.46 lakh $ha^{-1}yr^{-1}$ in Indian Rupee (INR). This was followed by T_5 with total income gained as ₹8.19 lakh $ha^{-1}yr^{-1}$. T_1, T_2 and T_4 ranked third, fourth and fifth (Table 5). The sole cropping of mango and gamhar provides minimal income to the farmers, on the contrary the agro forestry models are enabled to enhance the livelihood of the farmers by combining the complementary effects of the agro-ecosystem. Murmu et al, (2017) also observed the trend of integration of crops with components of tree and fruit gave higher gross income than tree and fruit tree alone (Basanda et al, 2017). Tiwari and Baghel (2014) concluded that higher household income is expected to increase the risk-bearing capacity of smallholder farmers' decision making and the willingness to wait for the returns from long term investment such as trees. This is an incentive to agroforestry adoption and its subsequent impact on the living standards of rural farming households. Similarly, McGinty et al (2008) observed that the average annual income of farmers is important to adopt agroforestry. Sharma et al (2017) observed and the results corroborated that mango + gamhar + groundnut system was more remunerative followed by mango + gamhar + maize, when compared with maize mono-cropping under rainfed condition in West Bengal.

Farmers can increase their income by selling forest, agriculture and livestock products which leads to a sustainable life with improved livelihood. Chakraborty et al (2015) infers that farm size is significantly positively related to farmers' income. Hemrom and Nema (2015) reported that

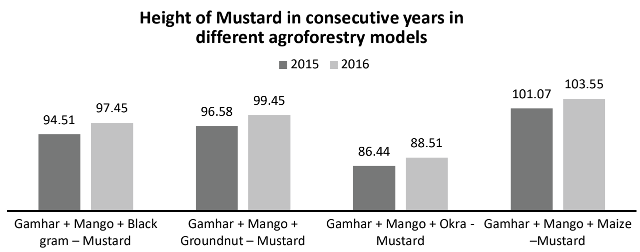

Fig. 4. Height of mustard in consecutive years in different agroforestry models

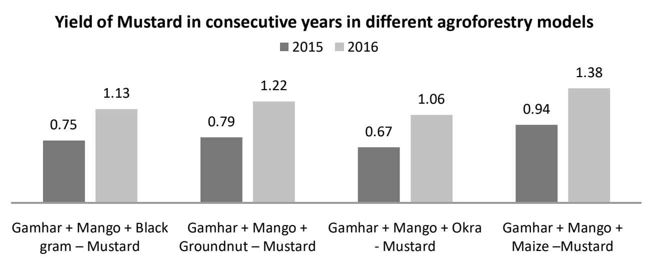

Fig. 5. Yield of mustard in consecutive years in different agroforestry models

Source: https://www.doi.org/10.36.106/gjra

Fig. 6. Maintaining soil health through agroforestry

the Agri-silvicuture system combines trees like *Shorea robusta*, *Tectona grandis, Acacia* spp, *Phoenix Sylvestris* etc and horticultural species like the fruit trees *Cocos nucifera*, *Caraya papaya*, *Musa acuminate*, *Mangifera indica*, *Anacardium ocidentale* and *Embellica officinalis*. *Artocarpu sheterophyllus*, *Azadirachta indica*, *Dalbergia sissoo*, *Gmelina arborea*, *Leucaena leucocephala*, *Melia azadarech*, *Syzygium cumini* and *Tectona grandis* are the tree species and the horticultural tree includes *Artocarpus heterophyllus*, *Litchi chinensis*, *Mangifera indica* and *Syzygium cumini* (Singh et al 2017, Singh and Oraon 2017, Lakra et al 2018). Farmers in the study area are having sufficient farming experience, but few farmers are having adequate knowledge in agroforestry. The contribution of the trees in the farming systems certainly diversifies the dimension by way of income and employment to the farm households besides fulfilling the requirement of wood. Income of households from the sale of agroforestry produce contributes only 2.41 percent to total annual income which indicative of enormous potential of improvement in existing agroforestry practices prevalent in the study area (Kumar et al 2018) Results indicate that agroforestry may not only be an optimal solution for poor farmers, species diversity conservation and environmental sustainability but may also have good economic rates of return.

CONCLUSION

All Mango-based agroforestry systems evaluated were profitable in respect to tree yield, fruit yield, yield of arable crops and soil health improvement compared to sole tree or sole fruit. Gamhar + Mango + Maize followed by Mustard and Gamhar + Mango + Groundnut followed by Mustard can be best models for the farmers to uptake for higher gross income and improvement of soil health leading towards sustainability and improvement of livelihood in rainfed and sub-tropical region of West Bengal. A relatively large percentage of the population lives under the poverty line and is affected by the countries degrading natural resources. The present research assesses the contribution of agroforestry to livelihoods in a tribal rural area of West Bengal. Agroforestry systems are a land management technique that implies a combination of forest trees with crops. The study has led to the conclusion that agroforestry may be considered as one of the major strategies for poverty reduction in rainfed and sub-tropical region of West Bengal, where there minimal scope of conservation of soil and forest, with subsistence requirement of food crop production. This study is a definitive example of how agroforestry systems with local crop, fruit and tree species components can restore the ecosystem services in degraded lands safe guarding farmers livelihood and income. Agroforestry systems not only increases food and fodder but also protects the existing environment and provides opportunities for unemployed and poor rural people. It is therefore, important that the policy makers, NGOs and Government Organizations should promote sustainable tropical agroforestry in developing environment-friendly and cost-effective technologies for poverty reduction in rainfed and sub-tropical region of West Bengal.

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CONTRIBUTION OF EACH AUTHOR

This work was carried out collectively by all the authors. The first author Suren Murmu designed the study, formulated the protocol, methodology, collected the data resources, formal analysis, investigation, visualization and wrote the first draft of manuscript. The second author Gayatri Kumari Padhi managed the analysis of the data, figures and the tables. The third author Paritosh Murmu and fourth author Debjit Roy managed the visualization, literature resources and reviewed the editing. Author Pratap Kumar Dhara supervised the complete experiment and approved the final manuscript. All authors had read and approved the final manuscript.

REFERENCES

Basanda GM, Dhara PK and Tarafdar PK 2017. Differential responses of arable crops with gamhar (*Gmelina arborea*) and mango (*Mangifera indica*) based agroforestry system in red and lateritic soils of West Bengal, India. *Indian Journal of Agricultural Research* **51**(1): 86-89.

Chakraborty M, Haider MZ and Rahaman M 2015. Socio-economic impact of cropland agroforestry: Evidence from Jessore District of Bangladesh. *International Journal of Research in Agriculture and Forestry* **2**(1): 11-20.

Das B, Dhakar MK, Sarkar PK, Kumar S, Nath V, Dey P, Singh AK and Bhatt BP 2017. Performance of mango (*Mangifera indica*) based agri-horticultural systems under rainfed plateau conditions of Eastern India. *Indian Journal of Agricultural Sciences* **87**(4): 521-527.

Das R, Dhara PK, Mandal AR and Dutta Ray SK 2014. Agri-Silvi-Fruit-Vegetable based agro production system-suitable models for sustainable land use and conservation in Red-Laterite and Semi-Arid Tracks. *Ecology, Environment and Conservation* **20**: S7-S13.

Dhara PK 2019. *Agroforestry Model: Gmelina and Eucalyptus based Agri-silvi-horticultural System.* Successful Agroforestry Models for different Agro-ecological regions of India. Central Agroforestry Research Institute (CAFRI) Jhansi, Uttar Pradesh, India: p 107-112.

Fanish SA and Priya RS 2013. Review on Benefits of agroforestry system. *International Journal of Education and Research* **1**(1): 1-12.

FAO 2010. *Global Forest Resources Assessment*. Food and Agriculture Organization of the United Nations, Rome, Forestry Paper: p 163.

Hemrom A and Nema S 2015. A study on traditional agroforestry practices existing at Bastar region of Chhattisgarh. *International Journal of Multidisciplinary Research and Development* **2**(3): 56-64.

ICAR-AICRPDA 2018*. Annual Reports of Central Research Institute for Dryland Agriculture*, Hyderabad, India: p 67.

Kaur N, Singh B and Gill RI S 2017. Productivity and profitability of intercrops under four tree species throughout their rotation in north-western India. *Indian Journal of Agronomy* **62**(2): 160-169.

Korwar GR, Prasad JVNS, Rao GR, Venkatesh G. Pratibha G and Venkateswarlu BJC 2014. Agroforestry as a strategy for livelihood security in the rainfed areas: Experience and expectations, pp.117-154. In: J.C. Dagar et al. (eds). *Agroforestry Systems in India: Livelihood Security & Ecosystem Services*. Advances in Agroforestry, 10. Springer Publisher, India.

Kumar A, Sah RB, Singh BK and Oraon PR 2018. Socio economic analysis of tribal farmers in the Gumla District of Jharkhand from existing agroforestry practices. *International Journal of Current Microbiology Applied Science* **7**(6): 595-604.

Kumar PN 2020. Effect of intercropping on fruit crops: A review. *International Journal of Current Microbiology and Applied Sciences* **9**(12): 745-755.

Lakra TS, Siddiqui MH, Chakraborty AK, Oraon PR and Malik MS 2018. Agroforestry practices followed in west Singhbhum District, Jharkhand. *Trends in Bioscience* **11**(4): 400-406.

Leakey RB 2012. *Multifunctional agriculture and opportunities for agroforestry: implications of IAASTD,* pp 203-214. In: Nair PK, Ramachandran and Garrity, Dennis (eds). *Agroforestry: the future of global land use*. Advances in Agroforestry, 9. Springer Publishers, New York, USA.

McGinty M, Swisher ME and Alavalapati J 2008. Agroforestry adoption and maintenance: self-efficacy, attitudes and socio-economic factors. *Agroforestry Systems* **73**: 99-108.

Misra PK 2011. Soil fertility management in agroforestry system. *International Journal of Biotechnology and Biochemistry* **7**(5): 637-644.

Mondal U and Dhara PK 2016. System for suitanable agriculture in New Alluvial Zone of West Bengal, India. *Journal of Research Innovation and Management Science* **2**(4): 26-37.

Msuya TS and Kideghesho JR 2012. Main streaming agroforestry policy in Tanzania legal framework. in: Martin Leckson Kaonga (eds). *Agroforestry for biodiversity and ecosystem services–science and practice.* In Tech Publishers, Shanghai, China.

Murmu S and Dhara PK 2022. Effective Food Safety and Land Use Management by Tribal Farmers through Agroforestry Practices, pp 303-308. In: Ghatak A, Vishwakarma Ramanuj, Prakash N and Kumar R (eds). *Crop Protection-driven Food Safety and Security*, Scientific Books Publisher, Delhi, India.

Murmu S, Chowdary KA, Roy D, Patra BC and Dhara PK 2017. Productivity and soil fertility status of mango-based agroforestry system in red and laterite zone of West Bengal. *Current Journal of Applied Science and Technology* **25**(3): 1-8.

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Murmu S, Dhara PK and Roy D 2016. Agroforestry: A sustainable agro-technique for red and laterite zone of West Bengal. *Journal of Agroecology and Natural Resource Management* **3**(3): 280-283.

Rahman SA, Foli S, Pavel MA, Mamun MA and Sunderland T 2015. Forest, trees and agroforestry: Better livelihoods and ecosystem services from multifunctional landscapes. *International Journal of Development and Sustainability* **4**(4): 479-491.

Rathore AC, Saroj PL, Lal H, Sharma NK, Jayaprakash J, Chaturvedi OP, Raizada A, Tomar JMS and Dogra P 2013. Performance of mango based agri-horticultural models under rainfed situation of Western Himalaya, India. *Agroforestry Systems* **87**: 1389-1404.

Saralch H and Singh SP 2013. Determining maturity indices for time of seed collection in *Gmelina arborea* under Punjab conditions. *International Journal of Farm Sciences* **3**(2): 90-94.

Saravanan S 2012. Constraints Faced by the farmers in adoption of *Gmelina arborea*: A case study in Tamil Nadu. *Indian Journal of Hill Farming* **25**(1): 13-16.

Sarkar PK 2019a. CO2FIX model: A tool for estimating carbon sequestration potential of any agroforestry system. *Agriculture & Food: e-Newsletter* **1**(3): 61-66.

Sarkar PK 2019b. Improving livelihood through agarwood (*Aquilaria malaccensis* Lam.) based agroforestry systems: An option. *Agriculture & Food: e-Newsletter* **1**(6): 139-147.

Sarkar PK, Das B and Bhatt BP 2017c. Bakain (*Melia azedarach* L.): a promising agroforestry species for improving livelihood to farmers of Eastern plateau and hill region of India. *The Bioscan* **12**(2): 1095-1100.

Sharma B, Tripathi SK, Dhara PK, Kumari P, Meena SK, Kumari R and Kumar A 2017. Comparative study of mango based agroforestry and mono-cropping system under rainfed condition of West Bengal. *International Journal of Plant & Soil Science* **15**(2): 1-7.

Singh BK, Oraon PR, Kumar A and Malik MS 2017. Traditional Agroforestry practices existing at Lohardaga District of Jharkhand. *Trends in Bioscience* **10**(23): 4651-4654.

Swain SC 2014. Performance and profitability study of different mango based intercropping systems in Easternghat high land zone of Odisha. *Journal of Crop and Weed* **10**(2): 170-178.

Tiwari R and Baghel BS 2014. Effect of intercropping on plant and soil of Dashehari mango orchard under low productive environments. *Asian Journal of Horticulture* **9**(2): 439-442.

Uthapa AR, Chavan SB and Handa AK 2015. Trees for soil amelioration: A review. *Global Journal for Research Analysis* **4**(6): 320-322

Verma P, Bijalwan A, Dobriyal MJR, Swamy SL and Thakur TK 2017. A paradigm shift in agroforestry practices in Uttar Pradesh. *Current Science* **112**(3): 509-516.

Yadav RS, Yadav BL, Chhipa BR, Dhyani SK and Munna R 2011. Soil biological properties under different tree based traditional agroforestry systems in a semi-arid region of Rajasthan, India. *Agroforestry System* **81**: 195-202.

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Intensification of Tree Cultivation in Cropland Based Agroforestry Systems- Role of Socio-economic Factors

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Abstract: Agroforestry is one of the sustainable land uses which have the potential of fulfilling the food as well tree based needs of the increasing population simultaneously from the same unit of the land. Intensification of agriculture through new high yielding cereal varieties, irrigation, pesticides and fertilisers has many concomitant environmental hazards. Thus emphasis has shifted on intensification of tree cultivation on cropland. The studies on factors affecting tree intensification on cropland are almost non-existent. Hence present study on role of socio-economic factors was undertaken in Mandi district of Himachal Pradesh. Multistage sampling was followed to select the households. The data were collected using a pre-structured schedule and personal interviews with the head of the household. Multistage sampling was used to select households. Tree intensification was defined in terms of the number of trees per hectare on the crop land of the farmers. The farmers were categorised into two groups: low intensity adopters (farmers with 1-78 trees/ha) and high intensity adopters (farmers with >78 trees/ha). The association between the dependent variable (low intensity adopters -farmers with 1-78 trees/ha) and high intensity adopters-farmers (>78 trees/ha) and different independent variables was found using Chi-square test of association. Logistic regression analysis was used to identify the key variables influencing tree intensification. The study shows that education level of the head of household, cropping intensity, household food sufficiency, household livestock holding, quantity of tree produce sold, livestock holding and level of restrictions on grazing after crop harvest significantly and positively influenced the intensification of tree cultivation. However, the farmers with large sized cropland holdings were less likely to go for tree intensification. Based on logistic regression model, more emphasis needs to be given to restrict on-farm grazing after crop harvest followed by encouraging linkage of tree products for better marketing so as to increasing the intensity of tree cultivation in cropland agroforestry systems. The influence of the size of cropland holding had also significant but negatively influence of tree intensification implies small holders are more likely to have more intensification than the larger. Therefore, specific efforts need to be made to encourage large holder to intensify tree cultivation. The study implies that socio-economic factors need to be considered while formulating tree intensification strategies.

Keywords: Households, Adopters, Diversification, Sustainable

By the year 2030, it is estimated that world population will be 8.5 billion leading to feed 800 million more people in the world compared to that of 2019 (UN 2019). This would increase the demand for food production to meet the needs of the increasing population. In addition will create more pressure on forests for tree products and possible diversion of forests for agriculture to produce more food leading to deforestation. In past, the intensification of agriculture in the form of the green revolution has resulted in an increase in food production from existing arable land through the use of new high yielding cereal varieties, irrigation, pesticides and fertilisers. Although it helped in meeting the food requirement of increased population, however, it resulted in environmental pollution, land degradation and decrease in basic productive capacity of the ecosystem. Thus productivity achieved during the green revolution could no longer be sustained. Thus the challenge became much bigger due to the decline in environmental resource base (soil erosion, water shortage, desertification, acid rain, global warming). Sustainable development strategies have gained importance after Brundtland's (1987) “Our Common Future” and were further affirmed by the World Summit on Sustainable Development (UN 2002). Agroforestry - a land use involving growing of trees with agricultural crops and/or livestock rearing, seems to hold the potential to solve the problems of rural development by fulfilling the needs of rural people for tree as well as food products through sustainable use of the land. Moreover, it has a capacity to divert pressure from existing forests and increase effective tree cover at local, regional and global level. Since few years agroforestry has also received impetus as strategy for climate change mitigation and adaptation. Agroforestry systems act as effective carbon sinks (IPCC 2000, Jose and Bardhan 2012). There has been an overall increase in area under agroforestry at the global level in 2000-2010 (Zomer et al 2014). The overall population in the world living in agroforestry landscape has increased from 746.7 million to 837.6 million during 2000-2010 (Zomer et al 2014). Thisimplies that more farmers have realized the importance of agroforestry and consequently adopted it. Now the emphasis is on intensification of tree component of agroforestry, rather crop components of Agroforestry, so that potential of trees to benefit crops, provide tree products, reduce deforestation and provide environmental benefits could be reaped to the maximum. There are many studies in various parts of the world to investigate the factors affecting agroforestry adoption. Many programmes and projects have been implemented in the various parts of the world to intensify the tree cultivation in agroforestry. Notwithstanding, there is meagrely any study to investigate the factors affecting intensification of tree cultivation in agroforestry, specifically the crop land agroforestry. Therefore, the study on the role of socio-economic factors on intensification of tree cultivation cropland agroforestry was under taken.

MATERIAL AND METHODS

The study was carried out in Mandi district of Himachal Pradesh. The data were collected using a pre-structured schedule and personal interviews with the head of the household. Multistage sampling was used to select households. Out of five forest divisions in the district, two forest division namely Joginder Nagar and Suket, were selected purposely as these contain both hilly and plain topography. A list of Joint Forest Management (JFM) programme and non-programme villages for each of hilly and plain areas was prepared with the help of divisional forestry staff of each selected forest division. Two villages from each subcategory (JFM programme and non-programme villages) for hilly and plain topography villages were chosen in each selected forest division using simple random sampling with replacement method. In this way, there were eight sample villages in each of selected forest divisions and 16 villages in total. A list of households in each of the selected villages was prepared by employing data collectors. One-thirds of households were taken as the sample from each selected village. Tree intensification was defined in terms of the number of trees per hectare on the crop land of the farmers. The median number of trees was 78. Thus the dependent variable (type of farmers) was categorised into: low intensity adopters (farmers with 1-78 trees/ha) and high intensity adopters (farmers with >78 trees/ha). The association between the dependent variable and different independent variables was found using Chi-square test of association at 0.001 level of significance. The following methods were used estimate different parameters:

Adult Male Equivalent = 1 Adult Male = 1.4 Adult Females = 2.5 Children (Jacob and Alles 1989).

$$\text{Food Sufficiency} = \frac{\text{Total quantity of grain produced (wheat and rice) from household land/year}}{\text{Total quantity of grain (wheat and rice) consumed by household/year}} \times 100$$

Adult Cattle Units: Adult Cattle Units (ACU) were worked out using Adult Cattle Unit equivalents used by Upadhyaya (1997):

Cow/bullock/horse/mule = 1.00 ACU

Buffalo = 1.30 ACU

Logistic regression model: In the current study many factors, each individually, motivate farmers for tree intensification on the cropland. However, which of the variables and how exactly these variables are important in motivating farmers for tree intensification when all the variables are taken into account simultaneously is not known. This requires knowledge of the key factors that motive farmers for tree intensification. Logistic regression modelling is an important tool in this regard which has been used widely in health sciences where the dependent variable was dichotomous or binary (Tabachnick and Fidel 1996). However, use of this technique in tree intensification in cropland agroforestry is almost non-existent and would be useful to planners and policy makers in devising the proper extension strategies to encourage farmers intensify the tree cultivation on cropland in the form of agroforestry.

Since the dependent variable for the present analysis: Low intensity adopters (farmers with 1-78 trees/ha) and high intensity adopters (farmers with >78 trees/ha) is binary and ordinary least square assumptions do not hold good in such cases and thus a logistic regression analysis was done. Since there was no previous study in agroforestry to help choose the variables for regression analysis, all independent variables which showed highly significant association with tree intensification were initially chosen as independent variables for logistic regression analysis. For exploratory purposes, the logistic regression analysis was done using the enter method. Some of the coefficients had high value but with very large standard errors. If the regression coefficients are large and their standard errors have very high value. This lowers the Wald statistics and therefore there are chances of increasing the type II error (accepting that effect is non-significant when it is significant) (Tabachnick and Fidel 1996). Therefore, instead of Wald statistics, the Forward Likelihood criterion was followed to select best predicting variables as the main aim was to select the best group of predictors. At each step the predictor which contributed most to prediction is added. For the entry of the predictors in the model the default value of 0.05 significance level was adopted. The standardised coefficients of the variables were found by estimating the standardised score for each variable in the model and running the model using these standardised scores. The significance of the constant in each model was determined on the basis of Wald statistics. The model is as specified below:

Logit is defined as natural log of odds and the model can be specified as:

$$Logit = Ln (P/1-P) = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + ---------- + \beta_kX_k = Z - 1$$

where

P is the probability of the outcome (Y = 1)

β_0 is the intercept term

β_1, β_2, β_3, and β_k are the coefficients associated with independent variables

X_1, X_2, X_3 and X_k are the predictors in the equation

Logit is linear function of independent variables. The probability can also express as:

$$P = P(Y = 1) = \frac{1}{1 + e^{-logit}} = \frac{1}{1 + e^{-(\beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + ---------- + \beta_kX_k)}}$$

$$\text{Similarly } P(Y_i = 0) = 1 - P_i = \frac{1}{1 + e^{(\beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + --------- + \beta_kX_k)}}$$

(Greenhouse et al 1995)

In the present study, P is the probability (Y> 78 trees/ha) and 1- P is probability of (Y=1-78 trees/ha). The logistic regression analysis was carried out using binary logistic regression technique in SPSS 22.0 software. For the validation of the model, model Chi-square and Hosmer and Lame show goodness-of-fit and cases correctly classified were taken into account. The Nagelkerke's R^2 was used as measure of determination of variation caused by predictors. The importance of various factors (predictors) in the model was judged on the basis of standardised regression coefficients.

The variables used, their abbreviations and coding for logistic regression analysis are given in Table 1.

RESULTS AND DISCUSSION

Effect of individual factors: There was no association between tree intensification and age of head of household, family type and size of the family (Table 2).

However, the education level of the head of the household significantly influenced the tree intensification (Table 2). The proportion of the high intensity adopters increased from 33.3% in illiterate class to 51.4, 61.4 and 74.3% in class 1-5, 6-10 and ≥ 11, respectively (Table 2). The association between tree intensification and number of government employees, primary occupation of household head, land tenure, number of family members working on farm was also non-significant (Table 3). The influence on the area of crop land owned on tree intensification was significantly (Table 4). Surprisingly the proportion high intensity adopters decreased from 90.3% in marginal farmers to 52.2, 45.8, 47.3 and 38.5% in small, semi-medium, medium and large farmers respectively (Table 4). Welker et al. (2016) also reported a decrease in density of trees with increase in farm size in Kenya.

Crop diversification did not have any association with tree intensification (Table 5). But cropping intensity was also found to have significant association with cropland tree intensification (Table 5). High intensity adopters showed a general increasing trend with crop diversification. The proportion of high intensity adopters increased from 20.8% on cropland with low cropping intensity to 24.4 51.4 and 62.4% on cropland with medium, high and very high cropping intensity. The household food self-sufficiency also had significant association with tree intensification). The proportion of high intensity adopters increased from low food self-sufficiency households to high food self-sufficiency. However, the households with no food self-sufficiency had 100% high intensity adopters. It implies crop intensifiers were also intensifiers of tree cultivation. Further, according to the theory of livelihood strategy food security is an important household livelihood objective. Therefore food deficient households minimised the risk to their food security either by not adopting agroforestry or limiting its extent to avoid reduction in crop yield owing to presence of trees.

The off-farm income did not have any association with tree intensification (Table 6). However, the sale of tree produce had significant association with tree intensification. The proportion of high intensity adopters were higher (66.2%) in households who sold tree produce than who did not sell (40.3%). The level of restrictions on grazing after crop also significantly influence

Table 1. Variable used, their abbreviations and coding for regression analysis

Name of variable	Abbreviation	Coding
Education level of head of household	Edulevel	0=Illiterate, 1=1-5 years, 2=6-10 years, 3=11 years and above
Cropping intensity (%)	Crpint	1=<150, 2=150-170, 3=170-195, 4=195 and higher
Household food sufficiency	Hfss	0=Nil, 1=Low, 2= Medium, 3= High
Household livestock holding (ACUs)	Hlsh	0= No cattle, 1=0.3-2.0, 2=2.0-4.0, 3=4 and above
Quanity of tree produce sold	Qtps	0= Do not sell, 1= Sell
Level of restriction on grazing on cropland after harvest	Resgraz	0= No restriction, 1= Restricted grazing, 3= No grazing
Area under cropland	Acropland	1= Marginal, 2= Small, 3= Semi-medium, 4= Medium, 5= Large

Table 2. Association between tree intensification and age of head of household, family type and size of family

Count % of Row % of Col	Age (Years)		
	Young (23-40)	Middle aged (40-60)	Old (60 or above)
Low Intensity adopters	30	75	65
	17.6	44.1	38.2
	0.4	30.4	
High intensity adopters	40	86	45
	23.4	50.3	26.3
	57.1	53.4	40.9
Total	70	161	110
% of Row	20.5	47.2	32.3

Chi-square= 5.814, D.F.= 2, p< 0.055, CFLF (Cells with frequency less than five)= 0

Association between tree intensification and family type

Count % of Row % of Col	Family type	
	Nuclear	Joint
Low Intensity adopters	98	72
	57.6	42.4
	45.0	58.5
High intensity adopters	120	51
	70.2	29.8
	55.0	41.5
Total	218	123
% of Row	63.9	36.1

Chi-square= 5.803, D.F.= 1, p<0.016, CFLF= 0

Association between tree intensification and size of the family

Count % of Row % of Col	Family size		
	Small (1-3 members)	Medium (4-7 members)	Large (8 members and above)
Low Intensity adopters	36	107	207
	21.2	62.9	15.9
	40.0	51.0	65.9
High intensity adopters	54	103	14
	31.6	60.2	8.2
	60.0	49.0	34.1
Total	90	210	41
% of Row	26.4	61.6	12.0

Chi-square= 7.795, D.F.= 2, p< 0.020, CFLF= 0

Association between tree intensification and education level of head of household

Count % of Row % of Col	Education level (Years of formal education)			
	0 (Illiterate)	1-5	6-10	11 and above
Low Intensity adopters	86	34	41	9
	50.6	20.0	24.1	5.3
	66.7	48.6	38.3	25.7
High intensity adopters	43	36	66	26
	25.1	21.1	38.6	15.2
	33.3	51.4	61.7	74.3
Total	129	70	107	35
% of Row	37.8	20.5	31.4	10.3

Chi-square= 28.486, D.F.= 3, p< 0.0001, CFLF= 0 tree intensification in cropland agroforestry. The proportion of high intensity adopters increased from 13.6% on cropland with free grazing after crop harvest to 44.4 and 78.7% in those with restricted and no grazing respectively. This is in contrast to study in the Philippines where grazing had a positive influence on tree growing (*Samanea saman*) through dissemination of indigestible seeds through animal waste (Pasicolon et al 1997). The intensification with restriction of grazing in the

Table 3. Association between tree intensification and number of government employees, primary occupation of household head, land tenure and number of family members working on farm

Count % of Row % of Col	Number of government employees	
	Do not possess	Possess
Low Intensity adopters	121 71.2 53.1	49 28.8 43.4
High intensity adopters	107 62.6 46.9	64 37.4 56.6
Total % of Row	228 66.9	113 33.1

Chi-square= 2.848, D.F.=1, p<0.091, CFLF= 0

Association between tree intensification and primary occupation of household head

Count % of Row % of Col	Primary occupation	
	Agriculture	Non-agricultural
Low Intensity adopters	100 58.8 58.5	70 41.2 41.2
High intensity adopters	71 41.5 41.5	100 58.5 58.5
Total % of Row	171 50.1	170 49.9

Chi-square=10.209, D.F.=1, p<0.001, CFLF= 0

Association between tree intensification and land tenure

Count % of Row % of Col	Land tenure	
	Share cropping	Self Cropping
Low Intensity adopters	18 10.6 54.5	152 89.4 49.4
High intensity adopters	15 8.8 45.5	156 91.2 50.6
Total % of Row	33 9.7	308 90.3

Chi-square=0.322 D.F.=1, p<0.571, CFLF= 0

Association between tree intensification and number of family members working on the farm

Count % of Row % of Col	Number of family members working on the farm (AME)		
	1-1.5	1.5-3.0	3.0 and above
Low Intensity adopters	25 14.7 32.9	94 55.3 53.4	51 30.0 57.3
High intensity adopters	51 29.8 67.1	82 48.0 46.6	38 22.2 42.7
Total % of Row	76 22.3	176 51.6	89 26.1

Chi-square=11.609, D.F.=2 , p<0.003, CFLF= 0

Table 4. Association between tree intensification and area of agricultural land owned

Count	Agricultural land owned (ha)				
	0.008-0.125 Marginal	0.126-0.250 Small	0.251-0.500 Semi-medium	0.501-1.00 Medium	1.01 and above Large
Low Intensity adopters	3 1.8 9.7	33 19.4 47.8	45 26.5 54.2	49 28.8 52.7	40 23.5 61.5
High intensity adopters	28 16.4 90.3	36 21.1 52.2	38 22.2 45.8	44 25.7 47.3	25 14.6 38.5
Total % of Row	31 9.1	69 20.2	83 24.3	93 27.3	65 19.1

Chi-square=24.610 , D.F.=4, p< 0.0001, CFLF= 0

Table 5. Association between tree intensification and crop diversification, cropping intensity and food sufficiency

Association between tree intensification and crop diversification

Count % of Row % of Col	Crop diversification (Number of crops grown/year)		
	2-4	5-6	7 and above
Low Intensity adopters	76 44.7 50.7	77 45.3 56.2	17 10.0 31.5
High intensity adopters	74 43.3 49.3	60 35.1 43.8	37 21.6 68.5
Total % of Row	150 44.0	137 40.2	54 15.8

Chi-square=9.541 D.F.=2 , p<0.008 CFLF= 0

Association between tree intensification and cropping intensity

Count % of Row % of Col	Cropping intensity (%)			
	<150 Low	150-170 Medium	170-195 High	195 and higher Very high
Low Intensity adopters	42 24.7 79.2	31 18.2 75.6	18 10.6 48.6	79 46.5 37.6
High intensity adopters	11 6.4 20.8	10 5.8 24.4	19 11.1 51.4	131 76.6 62.4
Total % of Row	53 15.5	41 12.0	37 10.9	210 61.6

Chi-square=41.789, D.F.=3, p<0.0001, CFLF= 0

Association between tree intensification and food self sufficiency

Count % of Row % of Col	Food self-sufficienc\y (%)			
	Nil	1-50 Low	51-100 Medium	100 or above High
Low Intensity adopters	0 0 0	46 27.1 63.9	44 25.9 62.0	80 47.1 41.2
High intensity adopters	4 2.3 100.0	26 15.2 36.1	27 15.8 38.0	114 66.7 58.8
Total % of Row	4 1.2	72 21.1	71 20.8	194 56.9

Chi-square=19.582, D.F.=3, p<0.0001, CFLF= 0 current study might be due to better germination and protection of tree seedlings on cropland with restricted or no grazing.

The livestock holding also significantly influenced the proportion of high intensity adopters (Table 7). This might be attributed to farmers with higher lives stock holding might

Table 6. Association between tree intensification and on-farm income

Association between tree intensification and off-farm income

Count % of Row % of Col	Off-farm income (Rs/year)			
	≤15000	15001-30000	30001-60000	≥60001
Low Intensity adopters	22 12.9 62.9	55 32.4 62.5	45 26.5 48.9	48 28.2 38.1
High intensity adopters	13 7.6 37.1	33 19.3 37.5	47 27.5 51.1	78 45.6 61.9
Total % of Row	35 10.3	88 25.8	92 27.0	126 37.0

Chi-square=14,998, D.F.=3, p<0.002, CFLF= 0

Association between tree intensification and sale of tree produce

Count % of Row % of Col	Sale of tree produce	
	Do not sell	Sell
Low Intensity adopters	126 74.1 59.7	44 25.9 33.8
High intensity adopters	85 49.7 40.3	86 50.3 66.2
Total % of Row	211 61.9	130 38.1

Chi-square=21.533 D.F.=1, p<0.0001, CFLF= 0

Table 7. Association between tree intensification, live stock holding and level of restriction on grazing after crop harvest

Count % of Row % of Col	Livestock holding (Adult Cattle Units-ACUs)			
	No cattle	0.3-2.0	2.0-4	4 and above
Low Intensity adopters	14 8.2 35.9	32 18.8 36.4	40 23.5 49.4	84 49.4 63.2
High intensity adopters	25 14.6 64.1	56 32.7 63.6	41 24.0 50.6	49 28.7 36.8
Total % of Row	39 11.4	88 25.8	81 23.8	133 39.0

Chi-square=18.868, D.F.=3, p<0.001, CFLF= 0

Association between tree intensification and level of restriction on grazing after crop harvest

Count % of Row % of Col	Restriction on grazing after crop harvest		
	No restriction (Free grazing)	Restricted grazing	No grazing
Low Intensity adopters	76 44.7 86.4	65 38.2 55.6	29 17.1 21.3
High intensity adopters	12 7.0 13.6	52 30.4 44.4	107 62.6 78.7
Total % of Row	88 25.8	117 34.3	136 39.9

Chi-square=92.723, D.F.=2 , p<0.0001, CFLF= 0

Table 8. Summary of variables and their significance

Step	Variable In:	Coefficients (β)	EXP (β)	Improvement in -2LL (Chi-square)	df	Significance of change (p)	Standardised coefficients
1	Resgraz	1.466	4.330	100.887	1	< 0.0001	1.171
2	Acropland	-0.666	.514	22.255	1	< 0.0001	-0.824
3	Qfps	0.963	2.620	11.145	1	< 0.0001	0.468
4	Edulevel	0.328	1.388	5.975	1	< 0.0001	0.341
	Constant	-1.739			1	< 0.098	

Table 9. Model summary

Statistic	Value	df	p
Initial –2LL	472.723	-	-
Model –2LL	332.461	-	-
Model Chi-square	140.162	4	<0.0001
Hosmer and Lameshow Chi-square	7.932	8	0.440
Nagelkerke R^2	0.449		
N	341		

have intensified tree cultivation to fulfil the demand of the fodder. The level of restriction on on-farm grazing after crop harvest also had significant association with tree intensification. The proportion of high intensity adopters increased from 13.6% in households with no restriction on grazing to 44.4% in households with restricted grazing and finally to 78.7% in households with no grazing on their cropland.

Logistic regression model: The iteration terminated at stage 4. Table 8 presents the model summary. The model is:

Logit = Z = -1.739+ 1.466Resgraz- 0.666Acropland + 0.963 Qfps + 0.328 Edu level

The model was significant (Model Chi-square= 332.461, p< 0.0001, Table 9) which means that model as a whole was significant in predicting the dependent variable compared to model without any variable (also known as intercept model). The Homer and Lameshow Chi-square was non-significant (Table 9). This means that there was no significant difference between the observed and predicted frequencies of two categories of the dependent variable. Therefore the model provides a good fit in estimating the probabilities of the dependent variable. The Step Chi-square (improvement in -2LL) shows that all the variables in the model were individually significant in predicting the dependent variable (Table 8).

Based on the standardised regression coefficients, restriction on grazing (Resgraz) was the most important variable in estimating the probability of adopting high intensity tree cultivation followed by cropland area (Acropland), quantity of tree produce sold (qtps) and education level of household head (Edulevel) respectively. With one unit increase in restriction on grazing (resgraz), quanity of tree produce sold (qtps) and education level of household head (edulevel), the odds of high intensity adoption increased by a factor 4.333, 2.620 and 1.388 respectively, however, with the increase in area under cropland the odds in favour of high intensity adoption decreased by a factor 0.666 (Table 8).

CONCLUSIONS

Out of the studies factors, six factorsnamely education level of the head of household, cropping intensity, household food sufficiency, household livestock holding, quantity of forest produce sold and level of restrictions on grazing after crop harvest significantly and positively influenced the intensification of tree cultivation. Based on logistic regression model, more emphasis needs to be given to restrict on-farm grazing after crop harvest followed by encouraging linkage of tree products for better marketing so as to increasing the intensity of tree cultivation in cropland agroforestry systems. Model also implies a need to encourage households to obtain better education for improving tree intensification on cropland. The influence of the size of cropland holding had also significant but negatively influence of tree intensification implies small holders are likely to have more intensification than the larger. Therefore, specific efforts need to be made to encourage large holder to intensify tree cultivation. The study implies that socio-economic factors needs to be considered while formulating tree intensification strategies.

REFERENCES

Brundtland GH 1987. *Our Common Future*. Oxford University Press for the World Commission on Environment and Development, Oxford.

Greenhouse JB, Bromberg JA and Fromm D 1995. An introduction to logistic regression with an application to the analysis of language recovery following a stroke. *Journal of Communication Disorders* **28**: 229-246.

IPCC 2000. *Special Report on Land Use, Land Use Change and Forestry*. Summary for Policy Makers. Geneva, Switzerland.

Jacob VJ and Alles WS 1989. *The Kandyab gardens of Sri Lanka*, pp. 181-195. In: Nair PKR (ed). *Agroforestry in the Tropics*. Kluwer Academic Publishers in Co-operation with ICRAF, Dordrecht, The Netherlands.

Jose S and Bardhan S 2012. Agroforestry for biomass production and carbon sequestration: An overview. *Agroforestry Systems* **86**: 105-111.

Myers N 1999. The next green revolution: its environmental underpinnings. *Current Science*. (http://www.iisc.ernet.in/~currsci/feb25/articles16.htm)

Pasicolon, PN, de Haes HA and Sujise PE 1997. Farm forestry: an alternative to government driven reforestation in the Philippines. *Forest Ecology and Management* **99**: 261-274.

Raintree JB 1991. *Socioeconomic Attributes of Trees and Tree Planting Practices*. FAO, Rome.

Sood KK and Mitchell CP 2009. Identifying important biophysical and social determinants of on-farm tree growing in subsistence-based traditional agroforestry systems. *Agroforestry Systems* **75**: 175-187.

UN (United Nations) 2019. *World Population Prospectus 2019-Highlights*. Population Division. Department of Economic and Social Affairs, United Nations, New York.

Upadhyaya K 1997. *Diagnostic Survey of Agroforestry Systems in Balh Valley, Himachal Pradesh*. M.Sc. Thesis (Unpublished). Dr. Y.S. Parmar University of Horticulture and Forestry, Solan, India.

Welker E, Vargas IR, Lama L, Hansen LV, Milenovic, M 2016. *What are the Ecological, Economic and Cultural Effects of Agroforestry Practices on Small Farms, Given the Trend of Land Fragmentation*? Interdisciplinary Land Use and Natural Resources Management, University of Copenhagen, Denmark.

Zomer RJ, Trubucco A, Coe A, Place F, van Noordwijk M and Xu JC2014. *Trees on Farms: An Update and Re-analysis of Agroforestry's Global Extent and Socio-ecological Characteristic*. Working Paper **179**. World Agroforestry Centre, Southeast Asia Regional Programme, Bogor, Indonesia.

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Socio- economic Factors Determining Extraction of Non-timber Forest Products in the Jammu Region of Jammu and Kashmir

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Abstract: Non-timber forest products (NTFPs) from natural forests provide significant benefits to forest dwellers. This study was conducted in the Jammu Region of Jammu and Kashmir, India assuming that the extraction of NTFPs by forest dwellers is related to income, age, type of family, education, land holding occupation and distance from the forest. The 150 NTFP collectors and 150 non- collectors from three forest divisions of Jammu region were interviewed. There was significant difference between the NTFP collectors and non- collectors in case of socio-personal variables of age, farming experience, type of house, number of MGNERGA card holders, type of ration card, formal education, literacy rate and sex ratio. The binary regression model was used to identify factors that affect the participation of households in collection of NTFPs. Independent variables, age of respondent, education of respondent, type of house, occupation, and irrigated land holding negatively and significantly affected the dependent variable. The extension contact, source of information, off farm income, literacy index and family size positively and significantly affected the NTFP extraction.

Keywords: Non-timber forest products, Collection, Socio- economic factors, Income

Non-Timber Forest Products (NTFPs) refer to a wide array of economic or subsistence materials that come from forests, excluding timber. These are also termed as non-wood, minor and secondary forest products. They include a wide range of edibles and non-edibles such as fruits, seeds, leaves, nuts, bush meat, roots, tubers, fibres, resins, latex, sticks, ropes, and construction materials like bamboos and rattans and a host of others. All these are an important source of livelihoods for the rural populations all over the world. Households often rely on resources available in the vicinity of forest, such as wood for cooking, heating, and construction (Naughton-Treves et al 2007) or forage for livestock. World Bank (2004) reported that the number of forest-dependent people globally to be 1.6 billion. Dependence of forest dwellers on forest resources differs greatly among individuals in terms of tribe, caste, class, and among and within communities and households by sex and age (Babulo et al 2009). Older people may possess superior knowledge than younger community members about medicinal plants, their uses and may collect more medicinal plants and wild foods (Ndagalasi et al 2007). The higher education provides opportunities for better jobs and reduces the households dependency on NTFPs, hence they are less interested in collecting NTFPs. (Adhikari et al 2004). Ravi et al (2006) studied the role of NTFPs in the life and economy of the tribal community living in and around the protected forests of H.D. Kote region. The presence of an additional individual in the household increases the household probability of collecting NTFPs. Household members can also provide labour that may help in collecting NTFPs. The contribution of forests to local livelihoods and to the national economy is significant but largely undocumented. In this research addressed socio economic factors affect the participation of households in collection of NTFPs.

MATERIAL AND METHODS

The present study was conducted in forest area of Jammu region of Jammu and Kashmir (33.2778° N, 75.3412° E). Multistage sampling plan was followed for drawl of ultimate sampling units. The East circle from Jammu region was purposively selected as it covers all the three agro- climatic zones namely subtropical, intermediate and temperate, thus it represents the whole Jammu division. Three forest divisions; Basholi, Ramnagar and Udhampur were selected from East circle by employing random selection procedure without replacement. From each randomly selected forest division, one forest range having maximum NTFPs availability was selected. The available collectors were contacted with the snow ball sampling procedure. Thus from each selected forest range 50 collectors and 50 non-collectors were selected and interviewed, thereby making a total sample size of 150 collectors and 150 non- collectors.

Data were collected from the sampled respondent on the pre-tested interview schedule by contacting personally on their fields or at their homes. Analysis of collected data was performed using SPSS 16.0 (statistical package for social sciences) software.

RESULTS AND DISCUSSION

The average age of collectors was 40.58 years (Table 1). Majority of collectors (49%) belong to age group 36-54 years followed by 41 per cent in 18-36 years age group and 10 per cent in 54-86 years age group. In non- collectors, the average age was 48.19 years. Majority of non- collectors (45%) belong to age group 36-54 years followed by 30 per cent (54-86 years and 18-36 age group) 30 and 25 per cent. The difference in the mean age of the collectors and non-collectors was significant. The average farming experience of collectors and non-collectors was 22.62 and 27.80 years and was significant. The average NTFP collection experience of collectors was 17.19 years. As far as the type of house is concerned majority of the respondents including both collectors and non- collectors had *kacha* house and this may be due to the low annual income of respondents from different sources of income In case of collectors, 67 per cent had kisan credit card whereas 60 per cent of non- collectors had kisan credit card. There was no significant difference in collectors and non- collectors in case of kisan credit card. Therefore, two growers were matching on this parameter. The 71 per cent of collectors had PHH ration card while 29 per cent had NPHH ration card. The difference in collectors and non- collectors in case of type of ration card was significant. Type of family was categorized into nuclear and joint family, 60 per cent of the collectors lived in nuclear family, where rest lived in joint family. In non- collectors, majority 70 per cent of the respondents lived in nuclear family and 30 per cent of the respondents lived in nuclear family. The difference in the type of family of the collectors and non-collectors was not significant. Kumari et al (2021) reported in their study that about 32 percent of farming families lived in nuclear type.

There was a significant difference in the literacy rate of families of collectors than non-collectors. This might be due to the fact that NTFP collection activity is labour intensive activity (Hegde and Enters 2000) and thus the collectors less focus on education. However, literacy index varied from 2.35 to 1.82 among both the categories, with an overall index of 1.89. This highlighted that literacy rate was higher, however the level of education was poor as indicated by low literacy index. Similarly, Gupta et al (2019) observed 84.00 per cent

Table 1. Descriptive statistics regarding socio personal status of the respondent

Parameter	Collectors (n=150)	Non- collectors (n=150)	Difference (Percentage)	Statistics (*p*-value)
Mean age (years)	40.58±12.14	48.19±14.62	7.61	t= 4.231* (0.001)
Age group[1] (% farmers)				
18-36 years	41	25	16	z= 2.406* (0.020)
36-54 years	49	45	4	z= 0.567 (0.568)
54-86 years	10	30	10	z= 1.633 (0.103)
Average farming experience (years)	22.62±11.38	27.80±14.22	5.18	t= 3.603** (0.001)
Average NTFP collection experience	17.19±7.53	--		
Type of house (% farmers)				
Kacha	75	41	34	z= 4.871**
Semi-Pacca	25	35	10	z= 1.543 (0.123)
Pacca	0	24	24	z= 5.222**
Kisan Credit card holders (% farmers)	67	60	7	z= 1.028 (0.303)
MGNERGA card holders (% farmers)	95	75	20	z= 3.961**
Ration card holders (% farmers)				
PHH	71	51	20	z= 2.899**
NPHH	29	49		
Family type (% households)				
Joint	40	30	10	z= 1.480 (0.138)
Nuclear	60	70		

[1]Categorization was done through Singh Cube root method
*Significant at p≤0.05, **Significant at p≤0.01

respondents had level of education in between primary to higher secondary.

With respect to farm size of both the groups the average land holding was0.55 ha which is equal to erstwhile J&K state landholding i.e. 0.59 ha (Agriculture Census, 2015). Although the landholding was identical but the non-collectors were having other sources of income also like government service, labour, private sector (Table 3).

The occupational status of the collectors eleven per cent were solely dependent on NTFP income for their livelihood and only one per cent households of the non- collectors had agriculture as sole source of income for the household which suggests that dependency upon agriculture as the only source of income is decreasing as observed by earlier workers (Peshin et al 2014 and Nanda et al 2019). In addition to agriculture and NTFP collection 70 per cent of the collectors were labourers whereas only 28 per cent of the non- collectors were labourers. That the 13 per cent of the non- collectors were involved in government service or retired from government service and none of the collectors had served or serving in government service. This may be due to the continuation of ancestral traditional occupation of agriculture and NTFP collection and vice versa. There is less scope of employment in service sector as their education level is not high to get employment.With regards to extension contact 100 percent of the collectors contact Forest Department regarding NTFP activities (Table 5).

Categorization was done on the basis of level of source of utilization and observed that about half of the non-collectors (49%) fall in low source utilization category (0-5 sources) followed by 39 and 13 per cent, under medium (6-7 sources) and high source utilization (above 7 sources) categories, respectively.

The collectors' average annual households' income was Rs. 173650. In non- collectors, the average annual households' income was Rs. 246040with significant difference. The collectors' average off- farm annual household income was Rs. 110440and in non- collectors Rs.

Table 2. Educational status of respondents' household

Parameter	Collectors (n= 150)	Non- collectors (n= 150)	Difference	Statistics (*p*-value)
Mean education	6.07±3.66	7.33±4.29	1.26	t= 2.928** (0.003)
Education level (% respondents)				
Illiterate	19	18	1	z= 0.182 (0.857)
Below primary	7	1	6	z= 2.165* (0.030)
Primary	30	13	17	z= 2.926** (0.003)
Middle	26	34	8	z= 1.234 (0.218)
Matriculation	12	20	8	z= 1.543 (0.123)
10+2	5	7	2	z= 0.595 (0.548)
Graduation and above	1	7	6	z= 2.165* (0.030)
Literacy rate (Percent)	71.72	91.26	19.54	z= 3.460** (0.001)
Literacy Index	1.89 (Primary)	2.63 (Middle)	0.74	

*Significant at p≤0.05, **Significant at p≤0.01

Table 3. Distribution of respondents on the basis of their farm size

Parameter	Collectors (n= 150)	Non- collectors (n= 150)	Difference (Percentage)	Statistics (*p*-value)
Average operational farm size (ha)	0.55±0.54	0.52±0.38	0.03	t= 0.658 (0.511)
Categorization of farm size (% farmers)[1]				
Marginal (<1 ha)	86	80	5	z= 0.952 (0.342)
Small (1-2 ha)	12	18	6	z= 1.188 (0.234)
Semi- medium (2-4 ha)	1	1	0	--
Medium (4-10 ha)	1	1	0	--
Large (>10 ha)	0	0	0	--
Average irrigated area (ha)	0.02±0.08	0.05±0.12	0.03	t= 1.604 (0.109)
Average unirrigated area (ha)	0.52±0.53	0.46±0.31	0.06	t= 1.037 (0.301)

[1]Categorization of the farm size as per MOA (2011)

241480 with significant difference. Collectors' average on-farm annual household income was Rs. 31773. In case of non- collectors, the average annual on- farm households' income was Rs. 19292.6but with no significant difference in both groups on this parameter. The collectors' average annual households' NTFP income was Rs. 58584.4.

Decision to collect NTFPs depends upon so many factors such as age of respondent, education of respondent, type of house, occupation, and size of land holding, extension contact, source of information, off farm income, literacy index and family size etc. In the present study, age of respondent negatively and significantly affected thedecision to collect

Table 4. Occupational status of respondents

Parameter	Collectors (n= 150)	Non- collectors (n= 150)	Different	Statistics (*p*-value)
Respondents solely dependent on NTFP income (% farmers)	11	--		
Respondents solely dependent on farming	0	16		
Respondents having other sources of income	89	84	5	z= 1.035 (0.303)
Retired for government service	0	6	6	z= 2.487* (0.013)
Government service	0	10	10	z= 3.244** (0.001)
Labour	71	28	42	z= 5.941** (0.001)
Private	9	8	1	z= 0.254 (0.803)
Shop	9	32	22	z= 3.889** (0.001)

*Significant at p≤0.05, **Significant at p≤0.01

Table 5. Extension contact of sampled households

Extension contact#	Collectors (n= 150)	Non- collectors (n= 150)	Different	Statistics (*p*-value)
State Agriculture University	1	0	1	z= 0.582 (0.562)
Forest Department	100	83	17	z= 4.310**(0.001)
Department of Agriculture	99	100	1	z= 0.582 (0.562)

#Multiple responses
**Significant at p≤0.01

Table 6. Source of information of NTFP collectors

Source of information#	Collectors (n= 150)	Non- collectors (n= 150)	Difference	Statistics (*p*-value)
NTFP contractor	100	19	81	z= 11.667** (0.001)
Agriculture Input dealer	100	100	0	--
Progressive farmer	99	99	0	
Friends/ relatives	100	100	0	
Radio	1	11	10	z= 2.977** (0.002)
Television	17	19	2	z= 0.368 (0.711)
Newspaper	1	13	12	z= 3.325** (0.001)
Training	2	1	1	z= 0.582 (0.562)
Group meeting	100	100	0	--
Field visits	1	1	0	--
Demonstration	10	26	16	z= 1.262 (0.207)
Kisan mela	95	75	20	z= 3.961** (0.001)
Level of source of utilization* (% farmers)				
Low utilization (0-5 sources)	3	49	46	z= 7.415** (0.001)
Medium utilization (6-7 sources)	194	39	55	z= 8.239** (0.001)
High utilization (Above 7 sources)	3	13	10	z= 2.606** (0.010)

#Multiple responses
*Categorization was done by Mean± Standard deviation
**Significant at p≤0.01

Table 7. Source of income of sampled households (Rs/annum)

Parameter	Collectors (n= 150)	Non- collectors (n= 150)	Difference	Statistics (p-value)
Average annual household income	173650± 120575	246040± 288848.7	72390	t= 2.832** (0.005)
Average annual off farm income	110440±110438	241480± 288994.9	1031040	t= 5.187** (0.001)
Average annual on farm income	31773± 19486.4	19292.6± 20534.98	12480.4	t= 0.045 (0.963)
Average annual NTFP income	58584.4±49705.7	--		

**Significant at p≤0.01

Table 8. Socioeconomic variables determining participation of households in NTFP collection (Binary Logistic Regression)

Dependent variable	Independent variables	Coefficient (ß)	S.E.	Wald	*p*-value	Model summary
Participation in collection of NTFPs	Constant	-7.663	2.624	8.527	0.003	Nagelkerke R^2=.0.675 -2 Log likelihood= 204.022 χ^2=211.867 *p* =0.001
	Age (X1)	-0.096	0.022	18.185	0.001	
	Education (X2)	-0.296	0.080	13.697	0.001	
	Extension contact (X8)	3.676	1.181	9.690	0.002	
	Source of information (X10)	1.314	0.221	35.225	0.001	
	Off farm income (X14)	0.000	0.000	8.847	0.003	
	Type of house (X16)	-2.067	0.383	29.153	0.001	
	Literacy index (X17)	0.572	0.264	4.696	0.030	
	Primary Occupation (X9)	-1.294	0.654	3.911	0.048	
	Family size (X3)	0.252	0.121	4.365	0.037	
	Landholding (X6)	0.143	0.470	0.092	0.762	
	Irrigated landholding (X7)	-4.567	1.833	6.205	0.013	
	On farm income (X13)	0.000	0.000	0.466	0.495	
	Family type (X4)	0.817	0.524	2.431	0.119	

NTFPs which means only young people were involved in collection of NTFPs and may be due to the reason that collection area was far away from the home and had tough terrains and difficult for aged person to widely move in forest areas.NTFPs are important for poor households, for young age group persons in the area of study possible reasons for that they can improve their incomes through NTFPs selling. However, Rodrigez (2007) found that adult household heads were more likely to collect NTFPs in India. Many other researchers (Hedge et al 1996, Hedge and Enters 2000, Shone and Caviglia-Harris 2006) observed positive association between age and decision to collect NTFPs. Second factor was the education of respondent which negatively and significantly affected thedecision to collect NTFPs. Likewise literacy index of household also negatively and significantly affected thedecision to collect NTFPs. This indicate that due to low education level peasants did not get any employment in government or private sector so they were more involved in collection of NTFPs. Baldewa (2011) also observed that the majority of respondents who were involved in collection of NTFP, had low level of education.

Size of land holding and main occupation negatively ands ignificantly affected the decision to go for collection of NTFPs which indicate only those respondents who had less landholding size were involved in collection of NTFPs. Other factors which significantly affected the decision of NTFP collection were extension contact and source of information. NTFP collectors had more extension contacts and sources of information. This might be due to the fact that for the purpose of marketing of NTFPs collectors had to make more contacts in social system to access new information regarding new market avenues, selling price of NTFPs etc. NTFP collection significantly affected was larger family size because collection of NTFPs is labour intensive activity and more man power is required in different activities after collection like washing, processing, storage and marketing.

CONCLUSION

The study indicated that considerable socio- economic variables affecting collection of NTFPs in the selected forest divisions of Jammu region. Age of respondent, education of respondent, type of house, occupation, and irrigated land holding negatively and significantly affected the participation of households in collection of NTFPs. The extension contact, source of information, off farm income, literacy index and family size positively and significantly affected the dependent variable.

REFERENCES

Adhikari B, Di Falco S and Lovett JC 2004. Household characteristics and forest dependency: Evidence from common property forest management in Nepal. *Ecological Economics* **48**: 245-257.

Agriculture Census 2015. *All India Report on Number and Area of Operational Holdings.* Agriculture Census Division Department of Agriculture, Co-Operation and Farmers Welfare Ministry of Agriculture and Farmers Welfare Government of India.

Babulo B, Muys B, Nega F, Tollens E, Nyssen J, Deckers J and Mathijs E 2009. The economic contribution of forest resource use to rural livelihoods in Tigray, Northern Ethiopia. *Forest policy and Economics* **11**(2): 109-117.

Baldewa SP 2011. *A research on impact analysis of NTFP and proposed model of lac development under the project sustainable agri-based livelihood enhancement, Charama, Kanker, Chhattisgarh.* Tata Administrative Service (TAS), Mumbai.

Food and Agriculture Organisation (FAO) 1995. *Non Wood Forest Products for Rural Income and Sustainable Forestry.* Rome: FAO NWFPs 7.

Gupta R, Singh K, Bhadauria Pand Jadoun YS 2019. Extension contact and extension participation of livestock farmers in Jalandhar District of Punjab: A benchmark analysis. *Indian Journal of Extension Education* **55**(3): 83-87.

Hedge R and Enters T 2000. Forest products and household economy: A case study from Mudumalai Wildlife Sanctuary, Southern India. *Environmental Conservation* **27**: 250-259.

Hedge R, Suryaprakash S, Achoth L and Brawa KS 1996. Extraction of non-timber forest products in the forest of Biligiri Rangan Hills, India. Contribution to rural income. *Economic Botany* **50**: 243-251.

Hegde R and Enters T 2000. Forest products and household economy: A case study from Mudumalai Wildlife Sanctuary, Southern India. *Environmental conservation* **27**(3): 250-259.

Kumari V, Chander S and Sharma S 2022. Knowledge and adoption of drip irrigation in citrus crops among farmers of Western Haryana. *Indian Journal of Extension Education* **58**(1): 151-156.

Nanda R, Peshin R, Singh AK, Sharma LK and Bagal YS 2019. Factors affecting the non-farm diversification among farm households in Jammu and Kashmir. *Agricultural Economics Research Review* **32**(1): 125-132.

Naughton-Treves B, Chapman C and Kammenc DM 2007. Burning biodiversity: Woody biomass use by commercial and subsistence groups in Western Uganda's forests. *Biological Conservation* **134**: 232-241.

Ndagalasi HR, Bitariho Gand Dovie DBK 2007. Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. *Biological Conservation* **134**: 242-250.

Neumann RP 1998. *Imposing wilderness: Struggles over livelihood and nature preservation in Africa*. Vol. 4. Univ of California Press

Peshin R, Sharma LK, Sharma R, Gupta V, Dwivedi SK and Nanda R 2014. *Impact of Government Intervention in Procurement of Wheat and Factors Affecting Wheat Productivity*. State Agriculture Management and Extension Training Institute Jammu and Division of Agricultural Extension Education, SKUAST, Jammu, J&K, India.

Rodrigez FZ 2007. Socio - economic determinants of Non-Timber Forest Products Collection. A case study among indigenous people in Karnataka, India. Universit at Autònoma de Barcelona, Spain.

Shone BM and Caviglia-Harris JL 2006. Quantifying and comparing the value of non-timber forest products in the Amazon. *Ecological Economics* **58**: 249-267.

World Bank 2001. *Tanzania forest conservation and development project.* Project appraisal document. World Bank, Washington D.C.

World Bank 2004. *Sustaining Forests: A development strategy*. World Bank Publication, Washington.

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Floristic Diversity of *Santalum album* L. Populations in Mid Hill Zone of Himachal Pradesh

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Abstract: The ecological study of a species is an essential requirement for its long -term survival in a particular area. Keeping in view the socioeconomic importance of the Indian sandalwood and existence of few natural populations to restricted sites in mid hill zone of Himachal Pradesh, India, the study on phytosociology and natural regeneration status of *Santalum album* L. was carried out in five locations of district Kangra. In every natural population, ten quadrats of 10 m × 10 m (100 m^2) size determined by species area curve method were randomly laid to study this tree species. In each quadrat, a sub-quadrat of 5 m × 5 m (25 m^2) and 2 m × 2 m (4 m^2) for size for shrubs and regeneration study were selected, respectively. Studies showed the dominance of *Santalum album* L. tree species in all the five natural populations. Among shrubs, *Lantana camara* L. was observed growing in close association with *Santalum album* L. whereas, natural regeneration of this species in all the studied natural populations was limited due to the lack of good mother trees and human interference to a greater extent.

Keywords: *Santalum album*, Floristic diversity, Natural regeneration, *Lantana camara*

Santalum album L. commonly referred as sandalwood is widely accepted valuable tree belongs to family Santalaceae. This family consists of 29 genera and 400 species, out of which 19 species are specific to genus *Santalum* (Teixeira de Silva et al 2016). This genus (*Santalum*) is distributed across South and Southeast Asia, Oceania and Australia (Harbaugh and Baldwin 2007, Page et al 2020). *S. album* L. is native to the tropical belt of peninsular India, Eastern Indonesia and Northern Australia (Venkatesa 1980). It is indigenous to India covering an area of 9600 Km^2 (Gairola et al 2007), mostly (90%) grown in states like Karnataka and Tamil Nadu (Kumar et al 2012, Kausar et al 2014 and Rocha et al 2017). In Himachal Pradesh, Sandalwood cultivated in some areas of district Bilaspur and Kangra mainly at Jawala Ji region. Sandalwood is an evergreen, hemi root parasite tree which can parasitize over 300 species ranging from grass to another sandalwood species (Ananthapadmanabha et al 1984, Nagaveni and Vijayalakshmi 2007, Rocha et al 2017). Hosts of this tree are different, both in nursery and plantation stages. *Cajamus cajan* and *Casuarina equisetifolia* are recorded as the best host plants during nursery and plantation stages, respectively (Doddabasawa and Chittapur 2021). Sandalwood tree is mainly exploited for its heartwood which yields the renowned East Indian Sandalwood oil, valued for its sweet fragrant, persistent, spicy, warm, woody note, tenacious aroma and fixative property (Krishnappa 1972). Growing sandalwood tree under natural conditions can produce an increment of one kg of heartwood/ year and a girth of one cm/ year (Rai 1990). The timber of Sandalwood is the world's second most expensive timber (Kumar et al 2012).

The existence of sandalwood populations in some particular areas of Kangra and Bilaspur districts of Himachal Pradesh was results of introduction. In late 1940s, Sandalwood trees were first introduced in Jawalamukhi area of district Kangra by an army officer during World War II (Dutt 2000). Later on, sandalwood trees got naturalized but could not spread beyond these confined sites besides the fact that, the entire sub-tropical sub montane hill zone has well suited soil and climate requirements of this tree species. The ecological study of this species is an essential requirement for its long-term survival in a particular area. In this lane the survey was accomplished on phytosociological and natural regeneration status of Sandalwood in five locations of district Kangra, Himachal Pradesh with objectives of studying the distribution pattern, natural regeneration status, ecological status and woody plant association of this tree species.

MATERIAL AND METHODS

Study area: The study was conducted in five natural populations (Banoh, Khariya, Amb Khatta, Selra and Jawala

Ji) of *Santalum album* L. distributed in district Kangra, Himachal Pradesh. The area located between latitudes 31° 41' 00" and 32° 28' 05"; and longitudes 75° 35' 34" and 77° 04' 46" presents an intricate mosaic of mountain ranges, hills and valleys. It is primarily a hilly district, with altitudes ranging from 350 m amsl to 4880 m amsl in the hills of Dauladhar. Six types of soils are observed in the district including Histosols (snow field, peaty and saline peaty), Ultisols (Brown red and yellow), Alfisols (Sub Mountain), Ardisols (Grey Brown) and Entisols (Younger alluvium). The climate varies from sub-tropical to sub-humid. Winter extends from December to February and summer extends from March to June while July to September are the rainy months. The average annual rainfall of the district is 1751 mm, out of which 83% occurs during June to September. Snow fall is received in the higher reaches of Dhauladhar ranges. The minimum and maximum temperature at Dharamshala varies from 2.9°C in January to 32.9°C in May.

Phytosociological Studies of Natural Populations

Community analysis: The status of plant diversity and regeneration in natural populations of the study area, community analysis was carried out during rainy season, 2020-2021. In every natural population, ten quadrats (10 m × 10 m) determined by species area curve method were randomly laid to study tree species. In each quadrat, a sub-quadrat of 5 m × 5 m and 2 m × 2 m size for shrubs and regeneration study were selected, respectively. The vegetation data was quantitatively analyzed for density (D), per cent frequency (%) and abundance (A). Relative frequency (RF), relative density (RD) and relative basal area (RBA) were determined following methods proposed by Phillips (1959), while Importance Value Index (IVI) was calculated by following Curtis (1959). Indices of similarity and dissimilarity were calculated by using formulae of Mishra (1989) and Sorensen (1948). Species Richness was estimated as per the method named Margalef's index of richness' (D_{mg}) as per Magurran (1988), Diversity as per Shannon-Wiener (1963) and Index of Diversity were estimated as per Simpson (1949).

Natural regeneration study of natural populations: The adequacy of regeneration of *Santalum album* L. within its natural population was judged on the basis of number of established plants in a unit area. According to Chacko (1965), desired number of established plants is 2500/ ha and the quadrate is considered fully stocked when it contains one established plant. Observations on regeneration were made in a quadrat size of 2 × 2 m.

RESULTS AND DISCUSSION

Natural population of *Santalum album* L : The major tree species that represent the natural populations of *Santalum album* L. in district Kangra are *Acacia catechu, Albizia chinensis*, *Albizia lebbeck, Grewia optiva, Leucaena leucocepahla* and *Dalbergia Sissoo*. These species occur mixed with other important/ associated species in the natural populations (Table 1-5). A range of 6-9 tree species and 2-3 shrub species were predominant in all five locations of district Kangra. The maximum number of tree species out of total species were d in Jawala Ji whereas, minimum number of species in Banoh. Maximum values for parameters like density, abundance, basal area, per cent frequency and IVI (Importance Value Index) were observed in *Santalum album* L. in four out of five locations namely, Banoh, Khariya, Selra

Table 1. Floristic diversity of trees and shrubs in Banoh

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/ (cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	90	1.13	0.18	80.00	17.31	25.81	13.92	57.04
Albizia chinensis	60	1.00	0.25	60.00	11.54	19.35	18.83	49.72
Cassia fistula	40	1.33	0.04	30.00	7.69	9.68	3.44	20.81
Ficus religiosa	20	1.00	0.39	20.00	3.85	6.45	28.95	39.24
Santalum album	300	3.00	0.42	100.00	57.69	32.26	31.41	121.36
Syzygium cumini	10	1.00	0.04	10.00	1.92	3.23	3.46	8.61
Total	520	8.46	1.36	310.00	100	100	100	300
Shrubs								
Lantana camara	330	3.30	44.53	100.00	51.56	47.62	56.5	155.64
Murraya koenigii	220	2.75	18.56	80.00	34.38	38.10	23.5	96.00
Rubus ellipticus	90	3.00	15.78	30.00	14.06	14.29	20.0	48.36
Total	640	9.05	78.87	210.00	100.00	100.00	100.0	300

and Jawala Ji. High values of these parameters attributed to the dominance of one species over the other species in their respective habitat. *Santalum album* found to dominant species. In general, *Santalum album* had older crop in their habitat. Minimum values for these parameters were observed for tree species named *Syzygium cumini* in Banoh, Khariya, Amb Katta and Selra. For Jawala Ji, *Ziziphus jujuba* recorded minimum value. This implies that *Syzygium cumini* and *Ziziphus jujuba* are also grow in association with *Santalum album* L. in one or other natural populations. *Santalum album* L. was dominant tree species in all the locations surveyed expect for Amb Katta. *Acacia catechu* (Banoh and Khariya), *Dalbergia sissoo* (Selra and Jawala Ji) and *Santalum album* (Amb Katta) was recorded as co-dominant tree species in natural populations of *S. album.*

Among shrub species, maximum number of shrubs

Table 2. Floristic diversity of trees and shrubs in Khariya

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/(cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	70	1.40	0.13	50.00	12.96	15.63	10.26	38.85
Acacia nilotica	20	1.00	0.06	20.00	3.70	6.25	5.29	15.25
Albizia lebback	50	1.25	0.18	40.00	9.26	12.50	14.15	35.91
Grewia optiva	40	1.33	0.08	30.00	7.41	9.38	6.88	23.66
Mallotus phillipinensis	30	1.50	0.03	20.00	5.56	6.25	2.34	14.15
Mangifera Indica	30	1.00	0.21	30.00	5.56	9.38	16.72	31.65
Santalum album	270	2.70	0.36	100.00	50.00	31.25	28.87	110.12
Syzygium cuminii	10	1.00	0.04	10.00	1.85	3.13	3.19	8.16
Terminalia chebula	20	1.00	0.15	20.00	3.70	6.25	12.29	22.25
Total	540	12.18	1.28	320.00	100	100	100	300
Shrubs								
Lantana camara	340	3.40	50.10	100.00	46.58	43.48	66.1	156.11
Murraya koenigii	280	3.11	16.46	90.00	38.36	39.13	21.7	99.19
Ziziphus mauritiana	110	2.75	9.29	40.00	15.07	17.39	12.2	44.71
Total	730	9.26	75.85	230.00	100.00	100.00	100.0	300

Table 3. Floristic diversity of trees and shrubs in Amb Katta

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/(cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	240	2.40	0.38	100.00	40.68	30.30	37.39	108.37
Bombax ceiba	20	2.00	0.07	10.00	3.39	3.03	7.08	13.50
Leucaena leucocephla	40	1.00	0.03	40.00	6.78	12.12	3.08	21.98
Mallotus phillipinensis	20	1.00	0.01	20.00	3.39	6.06	1.59	11.04
Mangifera Indica	20	1.00	0.16	20.00	3.39	6.06	15.66	25.11
Melia azedarach	20	1.00	0.06	20.00	3.39	6.06	5.95	15.40
Santalum album	210	2.10	0.21	100.00	35.59	30.30	20.73	86.63
Syzygium cuminii	20	1.00	0.08	20.00	3.39	6.06	8.52	17.97
Total	590	11.50	1.03	330.00	100	100	100	300
Shrubs								
Carrisa opaca	110	2.75	14.34	40.00	14.86	18.18	14.3	47.36
Lantana camara	410	4.10	71.47	100.00	55.41	45.45	71.3	172.20
Murraya koenigii	220	2.75	14.37	80.00	29.73	36.36	14.3	80.44
Total	740	9.60	100.18	220.00	100	100	100	300

(three) was recorded in locations like Banoh, Khariya, Amb Katta and Jawala Ji (Tables 1-5). The highest or density, abundance, basal area, per cent frequency and IVI was for shrub species *Lantana camara* L. in all the five locations surveyed. *Lantana camara* and *Murraya koenigii* were observed as dominant and co-dominant shrubs species, respectively in all the five locations. Shrub *Lantana camara* grown in close association with *S. album*. The high density of shrubs may be explained on an account of more space ad tree cover allowing more shrubs to grow on the surface floor. Sharma and Thakur (2015) have reported density value ranging from 270-316 trees per hectare and shrub density of 3440-5120 for different natural populations of *T. chebula* in district Kangra. The high basal area denotes the presence of higher number of matures trees and shrubs in natural populations.

Vegetation indices of trees and shrubs: Population wise descending order of tree species diversity was Khairya,

Table 4. Floristic diversity of trees and shrubs in Selra

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/(cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	70	1.75	0.13	40.00	12.73	12.12	11.05	35.90
Dalbergia sissoo	80	1.14	0.25	70.00	14.55	21.21	21.58	57.34
Ficus carica	40	1.00	0.08	40.00	7.27	12.12	7.08	26.47
Mallotus phillipinensis	50	1.67	0.03	30.00	9.09	9.09	3.13	21.31
Mangifera Indica	30	1.00	0.21	30.00	5.45	9.09	18.46	33.01
Morus alba	10	1.00	0.01	10.00	1.82	3.03	1.61	6.46
Santalum album	260	2.60	0.38	100.00	47.27	30.30	32.14	109.72
Syzygium cuminii	10	1.00	0.05	10.00	1.82	3.03	4.94	9.79
Total	550	11.16	1.18	330.00	100	100	100	300
Shrubs								
Lantana camara	410	4.10	61.77	100.00	57.75	50.00	74.8	182.52
Murraya koenigii	300	3.00	20.84	100.00	42.25	50.00	25.2	117.48
Total	710	7.10	82.61	200.00	100	100	100	300

Table 5. Floristic diversity of trees and shrubs in Jawala Ji

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/(cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	30	1.50	0.05	20.00	5.17	6.06	3.91	15.14
Albizia chinesis	50	1.00	0.16	50.00	8.62	15.15	10.99	34.77
Dalbergia sissoo	80	1.60	0.24	50.00	13.79	15.15	16.02	44.97
Eucalyptus spp.	10	1.00	0.10	10.00	1.72	3.03	6.82	11.57
Ficus carica	30	1.00	0.05	30.00	5.17	9.09	3.32	17.59
Santalum album	290	2.90	0.46	100.00	50.00	30.30	30.19	110.49
Tectona grandis	50	1.67	0.18	30.00	8.62	9.09	12.41	30.12
Toona ciliata	30	1.00	0.22	30.00	5.17	9.09	14.90	29.16
Ziziphus jujuba	10	1.00	0.02	10.00	1.72	3.03	1.44	6.19
Total	580	11.67	1.52	330.00	100	100	100	300
Shrubs								
Carrisa opaca	120	2.40	25.86	50.00	14.81	20.00	22.0	56.84
Lantana camara	390	3.90	64.76	100.00	48.15	40.00	55.2	143.31
Murraya koenigii	300	3.00	26.77	100.00	37.04	40.00	22.8	99.84
Total	810	9.30	117.39	250.00	100.00	100.00	100.0	300.00

Table 6. Vegetation indices of trees and shrubs under natural populations of *Santalum album* L.

Population	Vegetation index							
	Shannon – Wiener Index(H)		Simpson's dominance (cd)		Species richness (d)		Equitability (e)	
	Trees	Shrubs	Trees	Shrubs	Trees	Shrubs	Trees	Shrubs
Banoh	1.26	0.98	0.25	0.40	0.80	0.48	0.70	0.89
Khairiya	1.66	1.00	0.19	0.40	1.27	0.30	0.76	0.91
Amb Katta	1.48	0.97	0.24	0.43	1.10	0.30	0.71	0.88
Selra	1.60	0.68	0.21	0.52	1.11	0.15	0.77	0.98
Jawala Ji	1.64	1.00	0.20	0.37	1.41	0.30	0.71	0.91

Table 7. Regeneration studies of *Santalum album* L. in its natural populations

Location	Recruits /ha	Un-established /ha	Established /ha	Establishment index (I_1)	Stocking index (I_2)	Established stocking per cent	Regeneration success percentage
Banoh	175.00	125.00	50.00	0.18	0.03	1.91	3.25
Khairiya	125.00	75.00	50.00	0.20	0.03	2.09	2.75
Amb katta	75.00	75.00	25.00	0.10	0.02	1.00	1.75
Selra	125.00	75.00	50.00	0.25	0.03	2.13	2.75
Jawala Ji	75.00	75.00	75.00	0.33	0.04	3.33	3.75

Jawala Ji, Selra, Amb Katta and Banoh (Table 6). Species diversity of shrubs ranged from 0.68 to 1.00, maximum in Selra and minimum in Khairya and Jawala Ji. The high diversity can be attributed to low disturbance, habitat conditions and species characteristics (Zegeye et al 2006). Among all the locations surveyed maximum values for tree species dominance and tree species richness were recorded for Banoh and Selra, respectively whereas, in case of shrubs highest values for dominance and richness were observed for Jawala Ji and Banoh, respectively. The population wise equitability in tree and shrub species was recorded high in Selra (Table 6).

Natural regeneration: In all the natural populations surveyed, Banoh registered maximum number of recruits and un-established regeneration. Jawala Ji recorded maximum for established regenerations, establishment index, stocking, established stocking per cent and regeneration success per cent which was due to the presence of good mother tree and less human disturbance such as grazing, walking over and other human activities, etc., which led to the growth of good flourished seedlings of sandalwood. The rest of the locations were disturbed by human activities. Another reason for presence of good seedlings was the slope of this location as sandalwood needs sloppy areas for good drainage due to which it flourishes well (Padmanabha 2003). These findings are supported by Hanumantha et al (2012). Guleria (2008) observed that sandalwood regeneration is better in the presence of host plants association. These results are supported by findings of Sharma and Thakur (2016) and Singh (2020), where absence of natural regeneration of Harar in its natural populations due to the disturbance in the natural population sites by the humans and other factors which restrict the flourishing of seedling in its natural habitat.

CONCLUSION

The mature and over mature trees of *S. album* L. in limited number were observed growing in selected natural populations. Natural regeneration of S. *album* was negligible in these populations which confirm the urgency of supplementation of natural regeneration with the help of artificial regeneration. The major associated tree species of S. album were *Acacia catechu, Albizia chinensis, Albizia lebbeck, Grewia optiva, Leucaena leucocepahla and Dalbergia Sissoo*, while, *Lantana camara* L. and *Murraya koenigii* were major associated shrub species.

REFERENCES

Ananthapadmanabha HS, Rangaswamy CR, Sarma CR, Nagaveni HC, Jain SH, Venkatesan KR and Krishnappa HP 1984. Host requirement of sandal (*Santalum album* L.) *Indian Forester* **110**: 264-68.

Chacko VJ 1965. *A manual of sampling techniques for forest surveys*. Manager Publication, Delhi. p172.

Curtis JT 1959. *The vegetation of Wisconsin. An Ordination of Plant Communities*, University Wisconsin Press, Madison Wisconsin, p 657.

Doddabasawa and Chittapur BM 2021. Sandalwood plantations-points to ponder. *Current Science* **120**: 1184-1191.

Dutt S 2000. *Present status, nursery and plantation technology of sandalwood (Santalum album L.) in low hills of Himachal*

Pradesh. Ph.D. Thesis. Department of Silviculture and Agroforestry Dr. YSP University of Horticulture and Forestry, Solan.

Gairola S, Aggarwal P and Ravikumar GS 2007. Status of production and marketing of sandalwood (*Santalum album* L.). In: Proceedings of the National Seminar *on Conservation, Improvement, Cultivation and Management of Sanda*l, Bengaluru, 12-13 December, pp1-8.

Guleria V 2008. Analysis of plant, host and management relationships for sandalwood (*Santalum album*) cultivation in new subtropical locality of hill region of Indian Himalayas. *Indian Forester* **139**: 53-57.

Hanumantha M, Gunaga RP, Patil RS and Biradar S 2012. Natural regeneration in *Santalum album* Linn: A case study from campus of Forest Training Institute, Gungargatti, Dharwad, Karnataka. *Indian Forester* **138**: 386-389.

Harbaugh DT and Baldwin BG 2007. Phylogeny and biogeography of the sandalwoods (*Santalum*, Santalaceae): Repeated dispersals throughout the Pacific. *American Journal Botany* **94**: 1028-1040.

Kausar H, Jahan S, Ahmed N, Aslam K, Ahmed M and Ahmed S 2014. Perspective and recent studies of sandal safed (*Santalum album* Linn.): A review. *Journal of Pharmacy and Pharmaceutical Sciences* **3**: 2133-2145.

Krishnappa HP 1972. Sandal tree, a dollar earning parasite. *My Forest* **8**: 1-5.

Kumar A, Geeta J and Mohan Ram HY 2012. Sandalwood: History, uses and present status and the future. *Current Science* **103**: 1408-1416.

Magurran RA 1988. *Ecological diversity and its measurement.* University Press, Cambridge, p 179.

Mishra KC 1989. *Manual of Plant Ecology* (3rd edn.). Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, p 193.

Nagaveni HC and Vijayalakshmi G 2007. Differential response in the haustorial formation and growth of sandalwood plants (*Santalum album* L.) with respect different hosts. In: National Seminar on *Conservation, Improvement, Cultivation and Management of Sandal*, Institute of Wood Science and Technology, Bengaluru, December 12-13, 2007, 137-142.

Padmanabha HSA 2003. Information memorandum on investment opportunity of Indian Sandalwood. <http://www.quintis.com> Accessed 15 February 2021.

Page T, Jeffrey GK, Macdonella P, Hettiarachchi D, Boyce MC, Latab A, Oad L and Romee G 2020. Morphological and heartwood variation of *Santalum macgregorii* in Papua New Guinea *Australian Forestry* **83**(4): 195-207.

Phillips BA 1959. Methods of Vegetation study. Heavy Holt and Co. Inc., U. S.A.

Rai SN 1990. Status and cultivation of sandalwood in India. In: Hamilton L, Conrad, Eugene C (technical coordinators) Proceedings of the symposium on *Sandalwood in the Pacific*; April 9-11, 1990; Honolulu, Hawaii. Gen. Tech. Rep. PSW-GTR-122. Berkeley, CA: Pacific southwest Research Station, Forest Service, US Department of Agriculture **122**: 66-71

Rocha D, Ashokan PK, Santoshkumar AV, Anoop EV and Sureshkumar P 2017. Anatomy and functional status of haustoria in field grown sandalwood tree (*Santalum album* L.). *Current Science* **113**: 130-133.

Shannon CE and Wiener W 1963. *The mathematical theory of communication*. University Illinois Press, Urbana, USA, p117.

Sharma D and Thakur S 2015. Ecological variation among population of *Terminalia chebula* Retz. in district Kangra, Himachal Pradesh. *International Journal of Bio-Resource and Stress Management* **6**(6): 754-758.

Sharma D and Thakur S 2016. Ecological variation among population of *Terminalia chebula* Retz. in Sirmour and Una districts, Himachal Pradesh. *International Journal of Farm Science* **6**(1): 140-147.

Simpson EH 1949. *Measurement of diversity*. *Nature* **163**: 688.

Singh S 2020*. Regeneration and production potential of Harar* (*Terminalia chebula* Retz.). Ph.D. thesis. Department of Silviculture and Agroforestry, YSP University of Horticulture and Forestry, Solan, India.

Sorenson T 1948. A method of establishing groups of equal amplitude in a plant society based on similarity of species content. *Dan. Vidensk Selsk* **5**: 1-34.

Teixeira da Silva JA, Kher MM, Soner D, Page T, Zhang X, Nataraj M and Ma G 2016. Sandalwood: Basic biology, tissue culture and genetic transformation. *Planta* **243**: 847-887.

Venkatesa KR 1980. *A fresh look at the management of sandal*. In Proceedings of Second Forestry Conference, FRI and Colleges, Dehradun. pp. 1101-1108.

Zegeye H, Teketay D and Kelbessa E 2006. Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, south-central Ethiopia. *Flora* **201**: 483-498.

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Variation in Tree Biomass and Carbon Stock of *Pinus roxburghii* Sarg. along an Altitudinal Gradient in Jammu-J&K, India

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Abstract: The current study was carried out in the *Pinus roxburghii* forest of Billawar forest range in Kathua district of Jammu to estimate the tree biomass, carbon stock and soil organic carbon (SOC) at three altitudinal range i.e. lower (1000-1300 m), middle (1300-1500 m) and upper (1500-1800 m). Tree density, tree diameter, tree height, growing stock volume density (GSVD) and tree basal area decreased with increase in altitude. Similarly, above ground biomass density (AGBD), below ground biomass density (BGBD), total carbon density (TCD) and equivalent CO_2(eCO_2) in Mg ha^{-1} was recorded maximum at lower altitude i.e. 225.97 ± 14.04, 63.27 ± 3.93, 135.94 ± 8.44 and 498.90 ± 31.00 respectively. Soil bulk density and pH also decreased with increase in attitude. Reverse trend was observed for SOC which was maximum (13.70 ± 0.50 g kg^{-1}) at upper altitude and minimum (9.73 ± 0.64 g kg^{-1}) at lower. *Pinus roxburghii* recorded maximum growth and biomass production at an altitudinal gradient around 1000-1300 m therefore, resulting in maximum CO_2 sequestration in this range.

Keywords: Biomass, Carbon stock, Soil organic carbon, *Pinus roxburghii*, Altitude, Billawar

Global warming is responsible for the climate change, which is a burning issue of today. Despite of all the efforts, there is a continuous rise in global average temperature due to increasing green house gases. Carbon dioxide (CO_2) is the major green house gas contributing to about 76% (EPA 2017) of all other gases such as chlorofluro carbons, ozone, methane, water vapour and nitrous oxide. The concentration of CO_2 in the atmosphere is increasing due to the anthropogenic activities such as deforestation, burning of fossils fuel and change in land use and land cover. Globally during the last decade, the concentration of CO_2 in the atmosphere has increased from 391 to 414.66 ppm (NOAA 2021). Growing global concern over increasing levels of CO_2 in the atmosphere has led to underlining the various mitigation options. Sequestering carbon in trees is one such option. Among all the ecosystems, forests are considered to be the best and most reliable reservoir of carbon due their long term storage in the form of wood (Liu and Nan 2018) making them suitable for combating climate change. Globally, forests cover an area of 4.06 billion ha i.e. 31% of total land area, that contains 557 billion m^3 of growing stock with a total of 662 gigatonnes of carbon stock (FAO 2020). Forest biomass contributes approximately 90% of all the living terrestrial biomass and thus is the largest carbon pool (Khera 2001). However, deforestation due to natural and human activities have certainly reduced their role in mitigating climate change. In the last five years, globally deforestation rate was 10.20 million ha yr^{-1} (GFGR 2021). Estimation of carbon preserved in the forest is significant towards calculating the efficiency of the forests and its positive contribution to global change (Litton et al 2004). It is also useful for achieving the targets of REDD$^+$ (Reducing Emission from Deforestation and Forest Degradation) policy initiated at the Kyto Protocol (Djomo et al 2010). Different forest species are adapted to different climatic conditions, therefore knowledge of a species with respect to its carbon sequestration potential at a particular location is essential (Chauhan et al 2004).

Pinus roxburghii (Chir Pine) is an indigenous tree species of subtropical region of the Himalayan range spreading from Afghanistan, India, Nepal and Bhutan covering an area of about 8.90 lac ha (Jasrotia and Raina 2017). According to Champion and Seth (1968) classification of Indian forests, Chir Pine forests are categorised under Himalayan subtropical pine forest (9/C_1). It is a climax species and almost forms a pure forest at an elevation of 900-1800 m, however, it descends down to an altitude of 500 m and ascends up to 2200 m. Microclimate varies from elevation to elevation and will seriously impact the production of biomass and carbon stock, therefore it is very important to know the altitudinal range in which it sequesters maximum carbon. Biomass and carbon stock in a forest are affected by various locality factors (Climatic, edaphic, topographic and biotic) which are responsible for the growth of vegetation and distribution of species diversity (Bhatt et al 2020). Among these factors, altitude (topographic) is the most important environmental gradient as it decides the temperature system and diversification of forest species (Enright et al 2005) which is responsible for the distribution and storage of carbon. Increase in altitude affects the precipitation and temperature which brings about change in climate along the elevation thus influences the productivity of vegetation and affects the amount of soil organic matter and soil organic carbon (SOC) (Tao et al 2019). Twenty four per cent of the global land area is covered by mountains which is facing rapid climate change from past many years. In the past many studies have been carried out in relation to the species composition and distribution along the altitudinal gradients (Becker et al 2007) but studies related to pattern of biomass and carbon stock distribution along the attitudinal gradients are limited to few researchers like Bhardwaj et al (2021) in Himachal Pradesh, Kumar et al (2013) and Singh et al (2009) in Uttarakhand. Therefore, the present study was carried out in the Billawar forest division of Kathua district of Jammu division, Union territory of Jammu & Kashmir to study the pattern of biomass and carbon stock distribution in *Pinus roxburghii*, as well as SOC along the three altitudinal gradients.

MATERIAL AND METHODS

Study area : The study was carried out in the year 2020-21 at the Billawar forest range of Billawar forest division in Kathua district of Jammu division in the union territory of Jammu & Kashmir, India (Fig. 1) in the *Pinus roxburghii* forest along the three altitudinal gradients i.e. lower (1000-1300 m), middle (1300-1500 m) and upper (1500-1800 m). The area lies within the 32^0 38.68'' N to 32^0 40.09'' N latitude and 75^0 35.17'' E to 75^0 37.70'' E longitude. Billawar forest division is bounded by Bhaderwah and Ramnagar forest division in the north, Kathua forest division in the south, Jammu forest division in the west and towards the east it is separated from Chamba district of Himachal Pradesh by the river Ravi. The climate is subtropical in the lower elevation which gradually changes to temperate on the higher altitudes. The mean annual rainfall is around 1500 mm. (Billawar forest working plan). The famous spot around the sampling plots were Sukrala Mata temple and Machedi Mata temple. The site had almost pure Chir Pine forest but in some patches, species like *Phoenix sylvesteis* was also found. Towards the upper limit of Chir Pine was associated with temperate tree species such as *Quercus leucotrichophora*, *Quercus semicarpifolia*, *Rhododendron arboretum*, *Lyonia ovilifolia*, and *Pyrus pashia*.

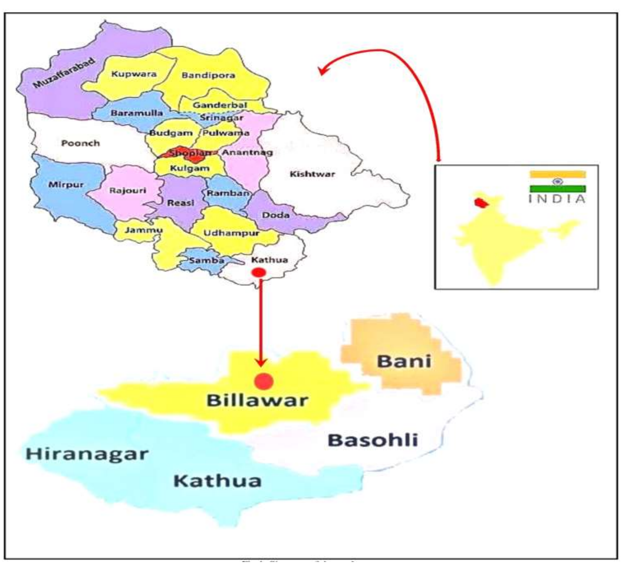

Fig. 1. Study area

Sampling and data collection: Random sampling method was used for collecting the data, sampling plots were selected after going through topographical maps. The data were collected along an altitudinal gradient from 1000 m to 1800 m and was divided into three categories namely lower (1000-1300 m), middle (1300-1500 m) and upper (1500-1800 m). Five quadrates of size 20 x 20 m^2 were laid out in each category. All the trees within the quadrate were painted with yellow paint at breast height (1.37 m) and diameter at breast height (dbh) was recorded with help of tree calliper. The tree height was measured with help of Nikon Forestry Pro Laser Rangefinder 8381. The growing stock volume density (GSVD) (m^3 ha^{-1}) was determined with the help of species specific regression equation ($\sqrt{V}=0.05131+3.98598D-1.0245\sqrt{D}$) (D: dbh) developed by FSI (1981) for *Pinus roxburghii* of western Himalayas. The above ground biomass density (AGBD) was estimated by multiplying GSVD with the wood density of *Pinus roxburghii* which was taken as 0.46 g cm^{-3} (Uniyal et al 2002), this was further multiplied with suitable biomass expansion factor of 1.3 (Brown 1997) to calculate AGBD for tree components such as stem, twigs, branches and leaves. The below ground biomass density (BGBD) was determined by multiplying the factor 0.28 to the AGBD (Mokany et al 2006). Total biomass density (TBD) was obtained by adding AGBD and BGBD. For calculating above ground carbon density (AGCD) and below ground carbon density (BGCD), factor 0.47 (IPCC 2006) was multiplied to AGBD and BGBD respectively. Likewise, total carbon density (TCD) was estimated by summing AGCD and BGCD. Carbon dioxide equivalent (eCO_2) was calculated by multiplying TCD to factor 3.67 (ratio of CO_2 to C) (Siraj 2019).

Composite soil samples were collected from each quadrate at a soil depth of 0-30 cm in a randomized pattern. The soil samples were collected in poly bags and were shade dried, sieved with 2 mm sieve and stored in zip lock poly bags for further analysis at the laboratories of the Division of Soil

Science & Agricultural Chemistry, SKUAST-Jammu. The bulk density was determined with the help of core tube method (Johnson 1962), the soil samples for bulk density were oven dried at 105°C till all the moisture was removed. The weight of oven dried sample was dived by its initial volume to obtain the bulk density on dry weight basis. Soil pH was determined in 1:2.5 soil: water suspension with the help of glass rod pH meter (Jackson 1973). Soil organic carbon (SOC) was estimated with the wet digestion method as suggested by Walkley and Black (1934).

RESULTS AND DISCUSSION

Tree growth parameters: Mean tree density of *Pinus roxburghii* was maximum (433 trees ha^{-1}) in lower altitude, whereas, lowest (269 trees ha^{-1}) in the upper altitude (Table 1). Mean tree diameter was maximum (35.10 cm) at middle altitude and minimum (31.84 cm) at upper altitude. Similarly, mean tree height was maximum (18.25 m) in the lower altitude and minimum (15.83) at upper altitude. There was a decrease in GSVD with increase in altitude, highest (377.87 m^3 ha^{-1}) reported from lower altitude and lowest (217.29 m^3 ha^{-1}) from upper altitude. The maximum and minimum tree basal area was 37.67 and 22.60 from the lower and from upper altitude. In the current study, tree growth parameters such as tree density, diameter, height, GSVD and basal area decreased with increase in altitude. This variation in growth parameters could be due to various site factors, lower altitudes have better moisture condition and higher temperature whereas, higher altitude suffer from nutrient leaching and moisture deficiency (Singh et al 2016). Chir Pine is a subtropical tree growing in warmer locations and its growth is affected by temperature which decreases with increase in altitude. Such decrease in growth parameters of *Pinus roxburghii* has been reported by earlier researchers (Bhardwaj et al 2021, Kumar et al 2013 and Singh et al 2009). The higher mean tree density, mean diameter and mean tree height at lower altitude are similar to the results reported by Banday et al (2017). However, at lower altitude higher tree density, lesser diameter and lesser tree height was reported by Kumar et al (2013) and Singh et al (2009) from Garhwal Himalayas. Similarly, less tree density, more tree diameter and more tree height from lower altitude was reported by Kumar et al (2021). Theses variation at similar altitude in growth parameters from place to place may be due to the difference in the ages of trees and due to various biotic and abiotic factors, aspect, soil characteristics etc.

Biomass and carbon stock: AGBD decreased with increasing altitude, maximum (225.97 Mg ha^{-1}) was at lower altitude whereas, minimum (129.94) at upper (Table 2). BGBD also followed the same trend as AGBD. TBD decreased with increasing altitude, maximum (289.24 Mg ha^{-1}) was from lower altitude whereas, minimum (166.32 Mg ha^{-1}) from upper. AGCD, BGCD and TCD also decrease with increasing elevation. The highest from the lower altitude (106.20 , 29.74 and 135.94 Mg ha^{-1}) while, lowest from the upper altitude (61.07, 17.10 and 78.17 ± 13.32 Mg ha^{-1}). eCO_2 was also maximum (498.99 Mg ha^{-1}) in lower altitude and minimum (286.89 Mg ha^{-1}) in the upper altitude. In the present study, biomass and carbon content per unit volume in different parts of tree (*Pinus roxburghii*) i.e. AGBD, BGBD,

Table 1. Growth parameters of *Pinus roxburghii* at different altitudinal gradient in Jammu, J&K, India

Altitude gradient (m)	Tree density (Trees ha^{-1})	Mean tree diameter (cm)	Mean tree height (cm)	GSVD (m^3 ha^{-1})	Mean tree basal area (m^2 ha^{-1})
Lower, 1000-1300 m	433 ± 30.05	32.68 ± 0.93	18.25 ± 0.19	377.87 ± 23.47	37.67 ± 1.79
Middle, 1300-1500 m	350 ± 62.91	35.10 ± 4.48	17.96 ± 1.71	302.86 ± 29.47	31.68 ± 4.53
Upper, 1500-1800 m	269 ± 52.42	31.84 ± 3.76	15.83 ± 0.70	217.29 ± 37.03	22.60 ± 3.34
Mean	351 ± 47.51	33.21 ± 0.98	17.35 ± 0.76	299.34 ± 46.39	30.43 ± 4.20
($p \leq 0.05$)	0.140	0.902	0.224	0.027	0.043

±: Standard error and GSVD: Growing stock volume density

Table 2. Biomass and carbon stock of*Pinus roxburghii* along thealtitudinal gradient (Mg ha^{-1})*in Jammu, J&K, India

Altitude gradient (m)	AGBD	BGBD	TBD	AGCD	BGCD	TCD	eCO_2
Lower, 1000-1300 m	225.97± 14.04	63.27± 3.93	289.24± 17.97	106.20± 6.60	29.74± 1.85	135.94± 8.44	498.90± 31.00
Middle,1300-1500 m	181.11± 17.62	50.71± 4.93	231.82± 22.55	85.12± 8.28	23.83± 2.32	108.96± 10.60	399.87± 38.91
Upper,1500-1800 m	129.94± 22.15	36.38± 6.20	166.32± 28.35	61.07± 10.40	17.10± 2.91	78.17±13.32	286.89± 48.90
Mean	179.01± 27.74	50.12± 7.76	229.13± 35.50	84.13± 13.03	23.56± 3.65	107.69± 16.69	395.22± 61.25
($p \leq 0.05$)	0.027	0.027	0.027	0.027	0.027	0.027	0.027

*Mega gram per hector, Mean ± Standard error, AGBD: Above ground biomass density, BGBD: below ground biomass density, TBD: total biomass density, AGCD: above ground carbon density, BGCD: below ground carbon density TCD: total carbon density and eCO_2: equivalent CO_2

Table 3. Soil pH, bulk density and soil organic carbon (SOC) in the *Pinus roxburghii* forest along the altitudinal gradient in Jammu, J&K, India

Altitude gradient (m)	Soil pH	Bulk density (g cm^{-3})	SOC (g kg^{-1})
Lower, 1000-1300 m	5.21 ± 0.09	1.29 ± 0.14	9.73 ± 0.64
Middle, 1300-1500 m	4.95 ± 0.10	1.23 ± 0.18	11.57 ±0.67
Upper, 1500-1800 m	4.87 ± 0.35	1.10 ± 0.15	13.70 ± 0.50
Mean	5.01± 0.10	1.21 ± 0.06	11.67 ± 1.15
($p \leq 0.05$)	0.650	0.667	0.005

Mean ± Standard error

TBD, AGCD, BGCD, TCD and eCO_2 decreased with increase in altitude. Similar trend of decrease in tree biomass and carbon stock along the altitudinal gradients have been reported by many researchers (Bhardwaj et al 2021, Kumar et al 2013, Singh et al 2009, Leuschner et al 2007 and Kitayama et al 2002).Various factors could be responsible for this decline in biomass accumulation with increase in altitude such as decline in optimum temperature, nutrient deficiency due leaching and higher runoff in upper altitude etc. The higher biomass and carbon stock in *Pinus roxburghii* forest from the lower altitude is similar to the findings of Banday et al (2017) from Himachal Pradesh. Low tree biomass and carbon stock in Chir Pine from upper altitude (>1600 m) have also been observed by earlier researchers (Pant and Tiwari 2020, Singh 2019, Kaur and Kaur 2016, Lal and Lodhiyal 2016, Kumar et al 2013, Pant and Tiwari 2013. Sharma et al 2010). Kaushal and Baishya (2021) have reported higher biomass from upper altitude. These variations in biomass and carbon stock of *Pinus roxburghii* at similar altitudes from different parts of the Himalayas may be due to the difference in the age of forest and due to the site quality factors.

Soil organic carbon (SOC): Soil pH decreased with an increase in altitude, maximum pH (5.21) was at the lower altitude and minimum pH (4.87) at upper (Table 3). Soil bulk density also followed the similar trend, it decreased with increasing altitude, maximum soil bulk density (1.29 g cm^{-3}) was at lower altitude, whereas, minimum soil bulk density (1.10 g cm^{-3}) was at upper altitude. Reverse trend was observed for SOC which increased with an increase in altitude, maximum (13.70 g kg^{-1}) at the upper altitude and minimum (9.73 g kg^{-1}) at the lower. In the present study, soil pH and bulk density were negatively related with the increasing elevation while SOC was positively related. Soil pH and bulk density are negatively correlated to SOC hence, maximum SOC led to minimum soil pH and bulk density in the upper altitude (Zhou et al 2020). Increase in SOC with increase in altitude may be due the slower decomposition of organic matter in the higher elevation and also due to the gradual change in vegetation composition. The increase in SOC in the *Pinus roxburghii* forest with increasing altitude are similar to the findings of Joshi et al (2021), Shapkota and Kafle (2021), Thakur et al (2020), and Kumar et al (2013_b), However, few researchers have also reported decrease in SOC with an increase in altitude (Bhardwaj et al 2021, Kumar et al 2013 and Sheikh et al 2010). The trend in variation of SOC from place to place may be due the variation in diversity of vegetation at different regions. Other factors such climatic conditions; soil texture, aspect and slope may also affect the SOC at a particular site.

CONCLUSIONS

The variations in tree growth parameters, biomass and carbon stock and soil organic carbon along the three altitudinal gradients are clearly marked in the present study. *Pinus roxburghii* which has a vast altitudinal and geographical stretch was found to accumulate maximum biomass and carbon stock in the altitudinal range around 1000-1300 m. Therefore, we can conclude that *Pinus roxburghii* sequesters maximum CO_2 in this altitudinal range in the Billawar forest of Jammu. Anthropogenic activities both directly and indirectly affect the regeneration and potential of forest in sequestering the CO_2, which can be controlled by proper supervision and management of the forest area.

REFERENCES

Banday M, Bhardwaj DR and Pala NA 2017. Variation of stem density and vegetation carbon pool in subtropical forests of North-western Himalaya. *Journal of Sustainable Forestry* 1-14, DOI:10.1080/10549811.2017.1416641.

Becker A, Korner C, Brun JJ, Guisan A and Tappeiner U 2007. Ecological and land use studies along elevational gradients. *Mountain Research Development* **27**: 58-65.

Bhardwaj DR, Tahiry H, Sharma P, Pala N, Kumar D, Kumar A and Bharti 2021. Influence of aspect and elevational gradient on vegetation pattern, tree characteristics and ecosystem carbon density in Northwestern Himalayas. *Land* **10**(1109): 1-18.

Bhat JA, Kumar M, Negi A, Todaria N, Malik ZA, Pala NA, Kumar A and Shukla G 2020. Species diversity of woody vegetation along altitudinal gradient of the Western Himalayas. *Global Ecology and Conservation* **24**: 1-17.

Brown S 1997. *Estimating Biomass and Biomass Changes of Tropical Forests: A Primer*. Volume 137 of FAO Forestry Paper, FAO, Rome, p 55.

Champion HG and Seth SK 1968. *A Revised Survey of Forest Types in India*. Government of India Publication, New Delhi.

Chauhan PS, Manhas RK, Bhandari D and Negi JDS 2004. Carbon stock assessment in old growth *Pinus roxburghii* Sarg. Plantation of Forest Research Institute, New Forest, Dehradun, India. *Indian Journal of Forestry* **27**(1): 45-49.

Djomo AN, Ibrahima A, Saborowski J and Gravenhorst G 2010. Allometric equations for biomass estimation in cameroon and pan moist tropical equation including biomass data from Africa. *Forest Ecology Management* **260**: 1873-1885.

Enright N, Miller B and Akhter R 2005. Desert vegetation and vegetation-environment relationships in Kirthar National Park, Sindh, Pakistan. *Journal of Arid Environment* **61**: 397-418.

EPA 2017. *Inventory of U.S. Greenhouse Gas Emission and Sinks.* Https://www. epa.gov/gh gemissions/inventory-us-greenhouse-gas-emmision-andsinks. Accessed on 19 January , 2022.

FAO 2020. *Global Forest Resources Assessment 2022*. Https://www.fao.org/3/CA8753 EN/CA8753EN.pdf. Accessed on 20 January, 2022.

FSI (Forest Survey of India) 1981. *Volume Equations Used for Different Tree Species in Each Physiographic* Zone. Http://fsi.nic.in/carbon_stock/annexureI.pdf. Accessed on 12 April, 2022.

GFGR 2021. The *Global Forest Goals Report 2021*. Https://www.un.org/esa/fore sts/wp-content/uploadeds/2021/04 /global-forest-goals-report-2021.pdf. Accessed on 20 January , 2022

IPCC 2006. *Guidelines for National Greenhouse Gas Inventories*; Volume 4: Agriculture, Forestry and Other Land Use.

Jackson ML 1973. *Soil chemical analysis: Advanced*, Madison, Wisconsin, USA.

Jasrotia RS and Raina AK 2017. Temporal variation in tree biomass and carbon stocks of *Pinus roxburghii* Sargent forests of Rajouri Forest Division in Jammu & Kashmir State. *Environment Conservation Journal* **18**(3): 123-133.

Johnson AI 1962. Methods of Measuring Soil Moisture in the Field. *Geological survey water-supply paper 1619-U*, PP.15-156. United State Government Printing Office, Washington.

Joshi VC, Bisht D, Sundriyal RC, Chandra N and Arya D 2021. Physico-chemical properties of soil in relation to species composition and diversity of subtropical and temperate forest stands in the Western Himalaya. *Asian Journal of Plant and Soil Sciences* **6**(2): 37-45.

Kaur R and Kaur S 2016. Growth, biomass, carbon sequestration and soil nutrient dynamics under pine forest in North-West Himalayas. *International Journal of Advanced Research* **4**(6): 738-746.

Kaushal S and Baishya R 2021. Stand structure and species diversity regulate biomass carbon stock under major Central Himalayan Forest Types of India. *Ecological Processes* **10**(1): 1-18.

Khera N, Kumar A, Ram J and Tewari A 2001. Plant biodiversity assessment in relation to disturbances in Mid Elevational Forest of Central Himalaya. India. *Tropical Ecology* **42**(1): 83-95.

Kitayama K and Aiba SI 2002. Ecosystem structure and productivity of tropical rain forests along altitudinal gradients with contrasting soil phosphorus pools on Mount Kinabalu. *Borneo Journal of Ecology* **90**: 37–51.

Kumar M, Kumar A, Kumar R, Konsam B, Nazir AP and Bhat JA 2021. Carbon stock potential in *Pinus roxburghii* forests of Indian Himalayan regions. *Environment, Development and Sustainability*, DOI:10.1007/s10668-020-01178-y.

Kumar M, Singh H, Bhat JA and Rajwar GS 2013b. Altitudinal variation in species composition and soil properties of Banj Oak and Chir Pine Dominated Forests. *Journal of Forest Science* **29**(1): 29-37.

Kumar S, Kumar M and Sheikh MA 2013. Carbon stock variation of *Pinus roxburghii* Sarg. forest along altitudes of Garhwal Himalaya, India. *Russian Journal of Ecology* **44**(2): 131-136.

Lal B and Lodhiyal LS 2015. Vegetation structure, biomass and carbon content in *Pinus roxburghii* Sarg. dominant forests of Kumaun Himalaya. *International Journal of Science & Technology* **10**: 117-124.

Leuschner C, Moser G, Bertsch C, Röderstein M and Hertel D 2007. Large altitudinal increase in tree root/shoot ratio in tropical mountain forests of Ecuador. *Basic and Applied Ecology* **8**: 219-230.

Litton CM, Rayan MG and Knight D 2004. Effects of tree density and stand age on carbon allocation patterns in Postfire Lodgepole Pine. *Forest Ecology Application* **14**: 460-475.

Liu N and Nan H 2018. Carbon stocks of three secondary coniferous forests along an altitudinal gradient on Loess Plateau in Inland China. *PLoS ONE* **13**(5): e0196927, DOI:10.1374/journal. pone.019627.

Mokany K, Raison JR and Prokushkin AS 2006. Critical analysis of root: Shoot ratios in terrestrial biomasses. *Global Change Biology* **12**: 84-96.

NOAA 2021. Global Monitoring Laboratory. https://www.esrl.noaa. gov. Accessed on 19 Jan uary, 2022.

Pant H and Tewari A 2013. Carbon sequestration potential of chir pine (*Pinus roxburghii.* Sarg) forest on two contrasting aspects in Kumaun Central Himalaya between 1650 and 1860 m Elevation. *Applied Ecology and Environmental Sciences* **1**(6): 110-112.

Pant H Tewari A 2020. Green sequestration potential of chir pine forests located in Kumaun Himalaya. *Forest Products Journal* **70**(1): 64-71.

Shapkota J and Kafle G 2021. Variation in soil organic carbon under different forest types in Shivapuri Nagarjun National Park, Nepal. *Scientifica* 1382687: 1-9, DOI:10.115 5/2021/1382687.

Sharma CM, Baduni NP, Gairola S, Ghildiyal SK and Suyal S 2010. Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. *Forest Ecology and Management* **260**: 2170-2179.

Sheikh MA and Kumar M 2010. Carbon sequestration potential of trees on two aspects in subtropical forest. *International Journal of Conservation Science* **1**(3): 143-148.

Singh H, Kumar M and Sheikh MA 2009. Distribution pattern of oak and pine along altitudinal gradients in Garhwal Himalaya. *Nature and Science* **7**(11): 81-85.

Singh P 2019. *Climate change response on tree phenology of major tree species in the central Himalaya*. Ph.D. Dissertation, Kumoun University, Nainital, Uttarakhand, India.

Singh S, Malik ZA and Sharma CM 2016. Tree species richness, diversity, and regeneration status in different oak (Quercus Spp.) dominated forests of Garhwal Himalaya, India. *Journal of Asia Pacific Biodiversity* **9**: 293-300.

Siraj M 2019. Forest Carbon stocks in woody plant of Chilmo-Gaji Forest, Ethopia; Implication of Managing forests for climate mitigation. *South African Journal of Botany* **127**: 213-219.

Tao J, Dong J, Zhang Y, Yu X, Zhang G, Cong N and Zhang X 2019. Elevation-dependent effects of growing season length on carbon sequestration in Xizang plateau grassland. *Ecological Indicators* **1**(110): 1-9.

Thakur V, Singh M and Bhardwaj SK 2020. Soil organic carbon stock under different forests in mid-hills of Himachal Pradesh. *Journal of Natural Resource Conservation and Management* **1**(2): 131-136.

Uniyal DP, Verma SK, Sharma SK and Sharma VK 2002. Provenance variation in the specific gravity of wood of Chir Pine (*Pinus roxburghii* Sarg.). *Indian Forester* **128**(12): 1376-1378.

Walkley A and Black IA 1934. An examination of degtijareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

Zhou W, Han G, Liu M, Zeng J, Liang B, Liu J and QUR 2020. Determining the distribution and interaction of soil organic carbon, nitrogen, pH and texture in soil profiles: A case study in lancangjiang River Basin, Soutrhwest China. *Forests* **11**(532): 1-13.

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Efficacy of Biodegradable Containers in Nursery Raised with Teak Seedlings

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Abstract: An investigation was carried out at College of Forestry, Kerala Agricultural University, Thrissur, India in 2020 to determine efficacy of six types of biodegradable containers such as nonwoven cloth bag, coco pot, mud pot, bamboo splits, cashew nut shell liquid treated cardboard and coir root trainer. Each container had equivalent capacity of 12cm x 15cm filled with soil mixture of soil: coir pith: vermicompost @ 2:1:1 by volume in which 15 days old uniform sized teak seedlings were grown for 5 months. Excepting 1st month in all other months, seedling quality index varied significantly among the containers (0.46 to 1.03) at 5-month age. Nonwoven bag was most efficient producing superior quality seedling followed by bamboo splits, coco pot, cashew nut shell liquid treated cardboard, coir root trainer and mud pot. The economics of raising teak seedling of 5-month old in six biodegradable containers differed significantly and was compared with conventional polythene bag. The benefit: cost ratio varied remarkably among different containers ranging from 0.30 to 2.60.The value was highest in case of seedlings raised in polythene bag (non-biodegradable) followed by bamboo splits, nonwoven bag, cashew nut shell liquid treated cardboard, coir root trainer, coco pot and mud pot.

Keywords: Biodegradable, Container, Nursery, Seedling, Teak

The plastic based materials are widely used in the nursery production sector both in forestry and agriculture primarily as seedling containers. The conservative estimates suggest that roughly 0.35 million tonnes of plastic is used in agricultural sector annually in India (Patel and Tandel 2017). In the last six decades, the massive production of plastics has led to an enormous amount of waste worldwide (Tomadoni et al 2020). Over 320 million tons of polymers were produced across the globe in 2015, but unfortunately, less than 10% of the manufactured plastics are actually recycled, and a huge amount is gathering in landfills or thrown away into the environment as litter (NatGeo 2019). Approximately, 500 million plant containers and seed trays are produced every year worldwide. The vast majority are either disposed in landfill or burnt in an uncontrolled manner. A large quantity of fossil fuel is used to manufacture plastic pots, which takes around 500 years to decompose (Tomadoni et al 2020). The excessive use of non-biodegradable plastic has started impacting the environment in serious proportions. Biodegradable containers or biopots are a sustainable alternative to petroleum-based pots that could easily adjust to agriculture and forestry reducing the enormous amount of plastic waste, and providing outstanding marketing opportunities. The main disadvantages include: biodegradable containers are fragile and require careful handling during transportation of seedlings. They also lack a solid wall which prevent in training the roots to the lower part of the container. Being bio-materials, chances of the container being infested with algae and fungi are more which may affect the growth of seedlings and overall hygiene. Yet another factor of concern is the high cost of biodegradable containers. However, consumer demand for environmentally conscious products and practices is on the rise and consumers are willing to pay more for eco-friendly products, such as plants grown in biodegradable containers (Behe et al 2013). In the present study, the efficacy of some locally available biodegradable containers has been studied in a forest nursery raising teak seedlings.

MATERIAL AND METHODS

The investigation was carried out at College of Forestry, Kerala Agricultural University, Thrissur, Kerala, India in 2020. The experimental site is located at 10^{0}32' N latitude and 76^{0}26'E longitude with an altitude of 40 m above mean sea level which comes under the humid tropical zone. The area receives an annual rainfall ranging from 2650 to 3200mm with almost bulk share of the rain during June-August. The mean maximum temperature during the study period was 36^{0}C (March) and mean minimum temperature 23^{0}C (January). Six types of biodegradable containers were taken for the trial: nonwoven cloth bag, coco pot, mud pot, bamboo splits, cashew nut shell liquid treated cardboard and coir root traineer. The experiment was done in complete randomized design with 4 replications. Each treatment included 30 plants per replication. The data were compared under DMRT. For this, 15-days old uniform sized teak seedlings were transplanted in different containers in March 2020. Each container had equivalent capacity of 12cm x 15cm filled with soil mixture of soil: coir pith: vermicompost @ 2:1:1 by volume. The efficacy of different containers was studied in terms of growth and quality of seedlings monthly for 5 months and economics of raising seedlings in them. The quality of planting stock was determined in terms of Quality Index (QI) (Dickson et al 1960).

$$QI = \frac{\text{Total dry matter (g)}}{\dfrac{\text{Shoot height (cm)}}{\text{Collar diameter (mm)}} + \dfrac{\text{Shoot dry matter (g)}}{\text{Root dry matter (g)}}}$$

RESULTS AND DISCUSSION

Height of seedlings: Different containers imparted significant effect on height growth of seedlings (Table 1). At the age of 5-month, varied from 17.4 to 31.5 cm. The seedlings in nonwoven bag registered significantly higher height over others followed by bamboo split (29.5 cm). Mud pot witnessed significantly lower height. Seedling height in containers is often strongly influenced by the container type especially the shape and cubic contents (Aghai and Davis 2014, Tian et al 2017). Such factors again influence the root development especially root elongation and spread. Ideally tree seedling containers with reasonably larger size (height) and moderate diameter are preferred which ensure deep root production and training of roots by the side walls. Nonwoven bags are similar to polythene bags in terms of durability and physical sturdiness to hold soil. The possible reason is that the nonwoven container is permeable and allows water and soluble nutrients to move laterally, which could affect the water and nutrient availability for each seedling and thus impact the seedling growth (Tian et al 2017). The container walls are strong enough to train the roots to the deeper soil. Bamboo splits also had high durability and better length to diameter ratio which permit the faster growth of the root system. This could be reason for the better height growth of teak seedlings in these two types of containers. Furthermore, better soil aeration, ability to hold water and minerals may also have contributed to the better height growth. Interestingly height growth of teak seedlings in the mud pot was the lowest despite its physical soundness. Probably, the short stature and broad base of the mud pots may have adversely affected the root and shoot growth.

Collar diameter of seedlings: Various containers significantly influenced the collar diameter of teak seedlings in every month (Table 2). At 5-month age it ranged from 5.2 to

Table 1. Height of teak seedlings in different biodegradable containers

Type of containers	Seedling height of teak seedling (cm)				
	1-month old	2-month old	3-month old	4-month old	5-month old
Nonwoven bag	3.7^{a}	10.2^{a}	17.6^{a}	24.9^{a}	31.5^{a}
Coco pot	3.5^{a}	8.3^{c}	13.6^{bc}	20.1^{c}	24.9^{c}
Mud pot	3.2^{a}	5.8^{e}	9.0^{e}	14.1^{f}	17.4^{f}
Bamboo split	3.6^{a}	9.2^{b}	15.2^{ab}	21.5^{b}	29.5^{b}
CNSL treated cardboard pot	3.5^{a}	7.8^{c}	12.2^{cd}	18.4^{d}	22.1^{d}
Coir root trainer	3.4^{a}	6.9^{d}	10.6^{de}	16.5^{e}	20.0^{e}
CV	14.6	7.3	14.2	7.7	13.8

Values with at least one common letter are not significantly different

Table 2. Collar diameter of teak seedlings in different biodegradable containers

Type of containers	Collar diameter of teak seedlings (mm)				
	1-month old	2-month old	3-month old	4-month old	5-month old
Nonwoven bag	1.8^{a}	3.0^{a}	6.2^{a}	8.4^{a}	10.6^{a}
Coco pot	1.7^{ab}	2.4^{bc}	4.5^{bc}	6.2^{c}	7.9^{c}
Mud pot	1.2^{c}	1.7^{e}	2.8^{d}	3.8^{e}	5.2^{e}
Bamboo split	1.8^{a}	2.7^{ab}	5.2^{b}	7.6^{b}	9.7^{b}
CSNL treated cardboard pot	1.5^{abc}	2.2^{cd}	4.1^{c}	5.6^{cd}	7.3^{cd}
Coir root trainer	1.4^{bc}	1.8^{de}	3.2^{d}	5.2^{d}	6.8^{d}
CV	12.5	11.6	11.3	8.2	7.6

Values with at least one common letter are not significantly different

10.6 mm. Nonwoven bag recorded highest value while mud pot the lowest diameter. Optimal collar diameter is inevitable for healthy growth of the plants which should be proportional to the height growth (Mohapatra et al 2008, Nayak et al 2017). A larger collar diameter also indicates a larger root system and a larger stem volume (Haase 2008). The poor collar diameter and faster height growth often lead to weaker seedlings which may eventually topple with increase in biomass. The better radial growth of teak seedlings in the non-woven bag followed by bamboo splits suggest their ability to maintain better soil biophysical conditions especially for optimal root growth in addition to their enhanced physical suitability and durability. Most of the remaining container types exhibited varying levels of degradation due to infestation by fungi and termites. This might has further influenced the general health of the seedlings.

Shoot dry weight of seedlings: The biodegradable containers resulted significant variation in shoot dry weight in each month of evaluation (Table 3). At the age of 5-month, varied from 1.95 to 4.00 g per seedling. In consistent with the general trends observed so far, the non-woven bag and bamboo splits grown seedlings had higher shoot weight while the mud potted seedlings had the lowest value. Shoot weight often reflects the total aboveground biomass allocation potential by plants with progressive time. The rate of shoot weight accumulation may vary with advancement in time for variable container types consequent to the changes in biophysical conditions. The variation in shoot dry weight under different container types may be attributed to difference in shoot growth in terms of height, diameter, number of leaves and leaf area.

Root dry weight of seedlings: At 5-month age, ranged from 0.78 to 1.63 g and nonwoven bag recorded maximum which was at par with bamboo split pot (1.49 g) (Table 4). Mud pot demonstrated the minimum root growth. The seedlings with larger root dry weight tend to grow more and survive better than those with smaller root mass. The higher root biomass associated with seedlings grown in non-woven bag and bamboo splits suggest physical suitability of the container material to facilitate root growth. The variations in root biomass with container types have also been reported before (de Oliveira and Milioranza 2015). The faster root production is often a continuation of the better aboveground biomass accumulation. However, the size, shape and wall flexibility of the containers may limit the root growth considerably despite the better soil properties and moisture regimes.

Table 3. Shoot dry weight of teak seedlings in different biodegradable containers

Type of containers	Shoot dry weight of teak seedlings (g)				
	1-month old	2-month old	3-month old	4-month old	5-month old
Nonwoven bag	0.20	1.26^{a}	2.34^{a}	3.25^{a}	4.00^{a}
Coco pot	0.18	0.84^{c}	1.70^{c}	2.25^{c}	3.15^{b}
Mud pot	0.13	0.46^{d}	0.90^{e}	1.4^{d}	1.95^{c}
Bamboo split	0.19	0.99^{b}	2.00^{b}	2.75^{b}	3.65^{a}
CNSL treated cardboard pot	0.16	0.72^{c}	1.40^{d}	2.15^{c}	2.85^{b}
Coir root trainer	0.15	0.55^{d}	1.10^{e}	1.65^{d}	2.35^{c}
CV	11.20	10.70	9.99	10.45	8.10

Values with at least one common letter are not significantly different

Table 4. Root dry weight of teak seedlings in different biodegradable containers

Type of containers	Root dry weight of teak seedlings (g)				
	1-month old	2-month old	3-month old	4-month old	5-month old
Nonwoven bag	0.14^{a}	0.52^{a}	1.00^{a}	1.30^{a}	1.63^{a}
Coco pot	0.11^{bc}	0.35^{bc}	0.72^{bc}	1.00^{b}	1.25^{b}
Mud pot	0.09^{c}	0.18^{e}	0.34^{d}	0.54^{c}	0.78^{d}
Bamboo split	0.12^{ab}	0.41^{b}	0.89^{ab}	1.17^{a}	1.49^{a}
CNSL treated cardboard pot	0.11^{bc}	0.29^{cd}	0.61^{c}	0.87^{b}	1.09^{bc}
Coir root trainer	0.10^{bc}	0.24^{de}	0.46^{c}	0.68^{c}	0.95^{cd}
CV	11.10	7.90	6.20	10.82	12.77

Values with at least one common letter are not significantly different

Total dry weight of seedlings: The total dry weight of teak seedlings varied from 2.73g (mud pot) to 5.63g (nonwoven bag) at 5-month age and (Table 5). The highest total biomass production in the nonwoven bagged seedlings is on account of the cumulative higher shoot and root biomass production. Similarly mud pot positioned last because of its minimum shoot and root weight. The variation of dry weight under different container types has also been reported by various authors (Koeser et al 2013, Castronuovo et al 2015, de Oliveira and Milioranza 2015).

Quality index of seedlings: The six different biodegradable containers resulted seedlings of different qualities. Except in 1st month, in all other months seedling quality index varied significantly among the containers (Table 6). The quality index differed from 0.46 to 1.03 at 5-month age. Nonwoven bag was most efficient producing superior quality seedling followed by bamboo splits. Mud pot witnessed to be the least efficient among the containers tested. The order of performance with regard to seedling quality was: nonwoven bag> bamboo splits> coco pot> cashew nut shell liquid

Table 5. Total dry weight of teak seedlings in different biodegradable containers

Type of containers	Total dry weight of teak seedlings (g)				
	1-month old	2-month old	3-month old	4-month old	5-month old
Nonwoven bag	0.34^{a}	1.78^{a}	3.34^{a}	4.55^{a}	5.63^{a}
Coco pot	0.29^{abc}	1.19^{bc}	2.42^{c}	3.25^{c}	4.40^{c}
Mud pot	0.22^{d}	0.64^{d}	1.24^{e}	1.94^{e}	2.73^{f}
Bamboo split	0.31^{ab}	1.40^{b}	2.89^{b}	3.92^{b}	5.14^{b}
CNSL treated cardboard pot	0.27^{bcd}	1.01^{c}	2.01^{d}	3.02^{c}	3.94^{d}
Coir root trainer	0.25^{cd}	0.79^{d}	1.56^{e}	2.33^{d}	3.30^{e}
CV	8.70	10.45	5.29	6.10	6.97

Values with at least one common letter are not significantly different

Table 6. Quality Index of teak seedlings in different biodegradable containers

Type of containers	Quality Index of teak seedlings				
	1-month old	2-month old	3-month old	4-month old	5-month old
Nonwoven bag	0.10^{a}	0.30^{a}	0.64^{a}	0.83^{a}	1.03^{a}
Coco pot	0.08^{a}	0.20^{bc}	0.45^{b}	0.59^{c}	0.77^{c}
Mud pot	0.05^{a}	0.10^{e}	0.22^{d}	0.30^{f}	0.46^{f}
Bamboo split pot	0.09^{a}	0.24^{b}	0.56^{a}	0.75^{b}	0.93^{b}
CNSL treated cardboard	0.07^{a}	0.16^{cd}	0.38^{bc}	0.52^{d}	0.69^{d}
Coir root trainer	0.06^{a}	0.13^{de}	0.29^{cd}	0.41^{e}	0.60^{e}
CV	15.39	13.80	14.90	6.25	4.30

Values with at least one common letter are not significantly different

Table 7. Economics of raising teak seedlings (5-month-old) in different bio degradable containers

Name of container	Cost of one container (Rs)	Cost of soil mixture for one teak seedling (Rs)	Cost of labour and other inputs for one teak seedling (Rs)	Survival percentage of seedlings in 5 months (Rs)	Total cost of raising one 5-month-old teak seedling (Rs)	Sale price of one 5-month-old teak seedling(Rs)	Benefit: cost ratio
Nonwoven bag	4.0	1.5	5.0	94	11.10	20.00	1.80
Coco pot	55.0	1.5	5.0	98	62.70	20.00	0.31
Mud pot	40.0	1.5	5.0	68	68.40	20.00	0.30
Bamboo split pot	7.0	1.5	5.0	100	13.50	27.00	2.00
CNSL treated cardboard	8.0	1.5	5.0	88	16.50	20.00	1.21
Coir root trainer	20.0	1.5	5.0	90	29.44	20.00	0.70
Polythenebag (check)	0.50	1.5	5.0	90	7.70	20.00	2.60

treated cardboard> coir root trainer> mud pot. Seedling quality is often considered as the net effect of growth potential and the effective allocation of biomass to the aboveground and belowground. The containers with higher seedling quality index indicate their better efficiency to support higher shoot growth, root growth as well as higher shoot biomass and root biomass.

Economics of raising seedlings: The economics of raising teak seedling of 5-month-old in six biodegradable containers differed significantly (Table 7). The benefit: cost ratio of raising 5-month age teak seedling varied among different containers and ranged from 0.30 to 2.60. The highest of 2.60 was in polythene bag (non-biodegradable) followed by degradable containers such as bamboo split pot, nonwoven bag, treated card board, coir root trainer, coco pot and mud pot. This was primarily due to the variation in the cost of containers and survival percentage of seedlings in different containers.

CONCLUSION

The efficacy of different biodegradable containers was different with regard to raising quality seedlings in nursery. Their performance varied remarkably with respect to height, diameter, shoot dry weight, root dry weight, total dry weight and seedling quality. Nonwoven bag was best closely followed by bamboo split pot among the biodegradable containers tested. Polythene bag seedlings were cheaper having higher benefit: cost ratio than biodegradable containers. Further research is necessary to find out cheaper biodegradable containers having stability during nursery period.

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REFERENCES

Aghai M, Pinto JR and Davis AS 2014. Container volume and growing density influence western larch (*Larix occidentalis* Nutt.) seedling development during nursery culture and establishment. *New Forests* **45**(2): 199-213.

Behe B K, Campbell B L, Hall C R, Khachatryan H, Dennis J H and Yue C 2013. Consumer preferences for local and sustainable plant production characteristics. *Horticultural Science* **48**: 200-208.

Castronuovo D, Picuno P, Manera C, Scopa A, Sofo A and Candido V 2015. Biodegradable pots for Poinsettia cultivation: Agronomic and technical traits. *Scientia Horticulturae* **197**: 150-156.

de Oliveira CLG and Miglioranza A 2015. Quality levels of organic coffee seedlings in black and white nonwoven fabric (NWF) containers of various sizes. *African Journal of Agricultural Research* **10**(9): 886-894.

Dickson A, Leaf AL and Hosner JF 1960. Quality appraisal of White spruce and White pine seedling stocks in nurseries. *Forestry Chronicle* **36**: 10-13.

Haase DL 2008. Understanding forest seedling quality: Measurements and interpretation. *Tree Planters' Notes* **52**(2): 24-30.

Koeser AK, Kling G, Miller C and Warnock D 2013a. Compatibility of bio containers in commercial greenhouse crop production. *Hort Technology* **23**: 149-156.

Mohapatra SR, Bhol N and Nayak RK 2018. Influence of Potting Mixture on Growth and Quality of Sandalwood (*Santalum album L.*) Seedlings. *Indian Forester* **144**(11): 1049-1053.

NatGeo 2019. *Planet or plastic? A whopping 91% of plastics is not recycled*. https://news.nationalgeographic.com.

Nayak H, Sinha A, Bhol N and Kumar J 2017. Variation in productivity and progeny quality of some teak clones. *Progressive Research* **12**: 2160-2164.

Patel AH and Tandel YN 2017. Use of plastics in horticulture production. *Indian Farmer* **4** (Special Issue III): 108-112.

Tian N, Fang S, Yang W, Shang X and Fu X 2017. Influence of container type and growth medium on seedling growth and root morphology of *Cyclocarya paliurus* during nursery culture. *Forests* **8**(10): 387.

Tomadoni B, Merino D, Casalongué C and Alvarez V 2020. Biodegradable materials for planting pots. advanced applications of bio-degradable green composites. *Materials Research Foundations* **68:** 85-103.

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Effect of Canopy Management Practices on Growth Characteristics of *Melia composita*

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***Abstract*:** Due to increase in population, the demand for tree products is increasing rapidly in India, necessitating imports of timber, paper, pulp, and wood products from other countries. Growing trees outside the forests is an option in the form of agroforestry. *Melia composita* is an upcoming agroforestry tree for agroforestry plantations in India. A study was conducted to underline the effect of early debranching and pollarding (canopy management) on growth characteristics of *Melia composita*. Tree height was maximum in unpollarded treatments compared to pollarded treatments. There was no significant effect of canopy management practices (pollarding) on dbh during both the years. Crown spread and number of branches per tree also varied significantly with management practices (treatments). Maximum aboveground biomass was recorded in unpollarded treatments. Light transmission ratio of *Melia composita* was significantly affected by different treatments. The effect of different treatments on the leaf area of *Melia composita* was statistically non-significant. The findings indicate that debranched trees showed a minor decline in few of the growth characteristics both in pollarded and unpollarded treatments. However, this reduction is temporary or permanent, needs to be explored further.

Keywords: *Melia composita*, Debranching, Pollarding, Canopy management

Due to increase in population, the demand for tree products is increasing rapidly in India. Over 40% of India's forest and tree cover are degraded as a result of anthropogenic activities (ISFR 2021). Until a ban on green felling was implemented, the demand for timber was partially met by the forests. Focus thereafter shifted towards on and off farm planted trees for catering the needs of modern forest-based industries. Even then, the forest based industries have been hindered by a lack of long-term sustained wood supply, necessitating imports of timber, paper, pulp, and wood products from other countries. In order to produce more wood, integration of trees on farms in the form of agroforestry was initiated. Now, in agroforestry and other afforestation programmes, planting of fast-growing, short-rotation tree species is preferred. One such promising agroforestry species is *Melia composita*. The tree is found in India, Africa, China, Malaya and Australia. In India *Melia composita* occurs in tropical moist deciduous forests of Sikkim Himalayas, North Bengal and Upper Assam, the Khasi hills of Orissa, Deccan and the Western Ghats, at altitudes of 1,500-1800 meters. It grows up to 20-25 meters tall, with a cylindrical bole up to 9 meters long and 1.5 meters wide (Saravanan et al 2013). It has a high calorific value of 5043-5176 calories (Tripathi and Poonia 2015). The wood is moderately hard and is used to make packing cases, ceiling boards, building materials, agricultural equipment, pencils, match boxes, splints, musical instruments, and tea boxes (Swaminathan et al 2012). *Melia composita* has pulp recovery higher than that of Eucalyptus and superior bleachability, indicating its feasibility as an alternate pulpwood species (Chaturvedi et al 2017). It has become a preferred tree for forestry plantations in the states of Punjab, Haryana, and Uttar Pradesh due to its rapid growth and diverse uses (Chavan 2022). In order to make full use of the species in agroforestry, it is important to understand the tree growth characteristics as well as its ability to withstand management practices. There have been scanty studies on effect of canopy management practices like pruning, lopping and pollarding on growth and development of *Melia composita* under sub-tropical climates of north India. Study was therefore conducted to underline the effect of early debranching and pollarding on growth characteristics of *Melia composita*.

MATERIAL AND METHODS

The research was conducted at the Experimental Farm, Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, located at 320-40′ N latitude and 740-58′ E longitude at 332 metres above mean sea level. The study site is a subtropical region with maximum temperature up to 45 °C during summer and minimum falls to 1°C during winter. The average annual temperature in Jammu is 21.3 ºC and average annual rainfall ranges from 1000 - 1250 mm, 75-80 % of which is received during July to September.Status of soil was ascertained by collecting a composite soil sample from the experimental field at the beginning of the experiment in order to analyse the soil properties. The texture of the soil was sandy loam with organiccarbon (4.11 %), available nitrogen (243.25 kg/ha), available phosphorus (17.02 kg/ha) and available potassium (134.85 kg/ha), respectively. In July, 2015 planting of *Melia composita* was done in 2 blocks at a spacing 6m × 4m in a randomized block design). After six months of planting, no tree management practice was carried out in the first block (T_1) whereas, in the second block, debranching was done by removing all the branches except top 4 in all the saplings (T_2) which shall be referred to as initial debranching throughout the text. After two years in December 2017, marked trees were pollarded by cutting off the main stem at 3.50 m height in both the blocks. Treatment T_3 refers to the pollarded trees in the first block (T_1) whereas, treatment T_4refers to the pollarded trees (T_2) in the second block. The data was collected on various growth parameters like tree height, diameter at breast height (dbh), crown spread, number of branches per tree and crown spread. Above-ground biomass of tree was estimated using a non-destructive method by multiplying volume and wood specific gravity (Shah et al 2014). Light transmission ratio (LTR) was recorded with a digital illuminance metre (Model: TES-1332A). The measurements were taken to determine the amount of light blocked by the *Melia composita*canopy. The content of leaf chlorophyll was determined using a SPAD-502 plus chlorophyll metre and expressed as the average chlorophyll content of leaves in percent (Ling et al 2011).The entire data generated from the present investigations were analysed statistically using the technique of analysis of variance for Randomized Block Design (RBD) design using the technique of analysis of variance (ANOVA) at 0.05 level of significance.

RESULTS AND DISCUSSION

Tree height was maximum (8.08 m) in T_1 in 2018, which was statistically at par with T_2 (7.98 m) but significantly different from T_3 and T_4, respectively (Table 1). In the year 2019, the tree height in T_1 was maximum (11.80 m), which was statistically superior to rest of the treatments. Tree height in treatments T_1 and T_2 was higher in compared to T_3 and T_4 because pollarding T_3 and T_4 at 1.37 m restricted their height. Tree height was more in the trees that were not subjected to debranching (T_1 and T_3) as compared to debranched treatments (T_2 and T_4). It may be due to the fact that initial debranching might have slowed down the growth in the early stage which the trees were unable to make up. Similar results have been reported by Lydie et al (2018). Crown spread showed significant difference in response to different treatments. It was maximum (6.21 m) in T_1, which was

Table 1. Effect of canopy management on growth characteristics of *Melia composita*

Treatments	2018								2019							
	Tree height (m)	Diameter at breast height (cm)	Crown spread (m)	Number of branches tree^{-1}	Above ground biomass (kg tree^{-1})	Leaf rea (cm^2)	LTR (%)	Leaf chlorop hyll (%)	Tree height (m)	Diameter at breast height (cm)	Crown spread (m)	Number of branches tree^{-1}	Above ground biomass (kg tree^{-1})	Leaf rea (cm^2)	LTR (%)	Leaf chloroph yll (%)
T_1	8.08	21.58	6.21	33.40	96.04	6.34	29.37	60.80	11.80	22.76	7.12	36.20	111.64	6.56	26.82	63.98
T_2	7.98	19.46	4.60	19.76	94.72	6.50	42.95	57.94	9.94	20.64	5.55	27.44	110.34	6.78	40.19	62.91
T_3	4.20	19.11	0.87	4.60	32.77	6.34	61.70	56.71	5.24	20.40	2.91	25.40	36.43	6.54	76.73	64.73
T_4	3.36	18.68	0.68	4.48	32.68	7.04	64.07	55.10	4.28	20.36	2.46	24.60	35.33	7.38	55.36	63.64
CD (p=0.05)	0.74	N.S	0.34	13.98	4.47	NS	2.99	NS	0.51	N.S	0.44	5.49	6.18	NS	2.76	NS

T_1(no treatment), T_2(initial debranching), T_3(pollarded T_1), T_4(pollarded T_2)

statistically higher than that of T_2, T_3 and T_4 in 2018. The crown spread in T_3 and T_4 was statistically at par. A similar trend was observed in 2019 where, the maximum crown spread was recorded in T_1 which was statistically higher than remaining treatments and was also statistically at par in T_3 and T_4. Crown spread was higher in T_1 and T_2 because these trees were not subjected to pollarding and had undisturbed crown compared to pollarded trees in T_3 and T_4. The number of branches per tree also varied significantly with management practices (treatments) both in 2018 and 2019, respectively. Maximum number of branches (33.40) were observed in T_1 which was statistically at par with T_2 but significantly superior than T_3 and T_4. A similar trend was observed in 2019. The effect of different treatments on the leaf area of *Melia composita* was statistically non-significant. Diameter at breast height was not affected neither by initial debranching nor by pollarding during both the years. In 2018, maximum aboveground biomass was in T_1(96.04 kg) which was statistically at par with treatment T_2. In treatment T_3, aboveground biomass was statistically at par with treatment T_4. During 2019 maximum above ground biomass was recorded in treatment T_1, which was statistically at par with T_2. In T_3 above ground biomass was statistically at par with T_4. Higher above ground biomass was recorded in T_1 and T_2 compared to T_3 and T_4 because, a large portion of tree trunk was removed in treatments T_3 and T_4 due to pollarding. However, the values for aboveground biomass were at par in $T_3$and T_4 during both the years implies that initial debranching did not affect the aboveground biomass. Light transmission ratio in *Melia composita* was significantly affected by different treatments during both the years. Light transmission ratio was maximum for treatment T_4, followed by T_3 and $T_2$and minimum in T_1. In 2019, the light transmission ratio was maximum (76.73 %) for T_3which was followed by T_4. Light transmission ratio in treatment T_2 was statistically at par with T_1. Increased light transmission ratio was observed in pollarded treatments (T_3 and T_4) which may be due to difference in the canopy thickness and crown spread that might have resulted in increased penetration of light through the canopy in the pollarded treatments. Similar results were reported by Sehgal (2011) and McIvor et al (2010). In 2018, maximum chlorophyll content was in T_1 followed by T_2 and T_3, and the minimum chlorophyll content was inT_4. However, during 2019, no particular trend was observed.

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CONCLUSION

The debranched trees showed a minor decline in few of the growth characteristics. However, this reduction is temporary or permanent, needs to be explored further. However, pollarding in *Melia composita* (T_1 and T_2) did affect the number of branches, crown spread and above ground biomass. The effect of various treatments on physiological parameters like chlorophyll content and leaf area were non-significant.

REFERENCES

Chaturvedi OP, Handa AK, Uthappa AR, Sridhar KB, Kumar N, Chavan SB and Rizvi J 2017. *Promising Agroforestry Tree Species in India*. Central Agroforestry Research Institute, Jhansi, South Asia Regional Programme of the World Agroforestry Research Centre, New Delhi, India, pp. 141-148.

Chavan SB, Uthappa AR, Sridhar KB and Vijaysinha Kakade. 2022. Scientific techniques for Melia dubia-based agroforestry systems: An emerging indigenous tree species for wood-based industries in India. Current Science **122**(12): 1451-1454.

Forest Survey of India. 2021. *Indian State of Forest Report 2021*. Published by Forest Survey of India (Ministry of EnvironmentForest and Climate Change) Dehradun, India. www. https://fsi.nic.in/forest-report-2021-details

Ling Q, Huang W and Jarvis P 2011. Use of a SPAD-502 meter to measure leaf chlorophyll concentration in Arabidopsis thaliana. *Photosynthesis Research* **107**: 209-214.

Lydie Dufour, Marie Gosme, Jimmy Le Bec and Christian Dupraz. 2018. Impact of pollarding on growth and development of adult agroforestry walnut trees. 4. European Agroforestry Conference. EURAF 2018, Jun 2018, Nijmejen, Netherlands. 567 p.

McIvor IR, Hedderley D and Mason K 2020. Effect of pollarding for fodder on fine root dynamics of soil conservation willow trees in New Zealand. *Advances in Environmental Studies* **4**(1): 252-260.

Sandeep Sehgal 2011. Growth and productivity of Ocimum basilicum under *Leucaena leucocephala* hedgerows in Western Himalayan mid hills. *Range Management and Agroforestry* 32(2): 83-86.

Saravanan V, Parthiban KT, Kumar P and Marimuthu P 2013. Wood characterization studies on Melia dubia cav. for pulp and paper industry at different age gradation. *Research Journal of Recent Sciences* **2**: 183-188.

Shah S, Sharma DP, Tripathi P and Pala NA. 2014. Carbon partitioning in subtropical Pinus roxiburghii forest, Solan India. *Journal of Tropical Forest Science* **26**(3): 355-361.

Swaminathan C, Vijendra Rao R and Shashikala S 2012. Preliminary evaluation of variations in anatomical properties of *Melia dubia* Cav. *Wood International Research Journal of Biological Sciences* **1**(4): 1-6.

Tripathi S and Poonia PK 2015. Treatability of *Melia* composita using vaccum pressure impregnation. Maderas. *Ciencia Y Tecnologia Agropecuaria* **17**(2): 373-384.

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Response of Economic Tree Species to Extremely Severe Cyclonic Storm- Fani in Selected Coastal Districts of Odisha

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Abstract: The Extremely Severe Cyclonic Storm "Fani' made landfall on 3rd May 2019 near Puri on Odisha coast with maximum sustained surface wind speed of 170-180 kmph gusting to 250 kmph and then passed over Puri, Khurda, Cuttack, Jagatsinghpur, Kendrapara, Jajpur, Bhadrak, Balasore and Mayurbhanj districts of Odisha. Immediately after cyclone, an extensive survey was made in four seriously affected districts such as Puri, Khordha, Cuttack and Jagatsinghpur and 25 economic tree species commonly found in such areas were evaluated to find out their response to cyclone. *Borassus flabellifer* (Palmyra palm) responded strongly exhibiting significantly lower damage followed by *Phoenix sylvestris, Cocos nucifera, Areca catechu,* etc.*Moringa oleifera* (Drumstick) faced significantly higher damage followed by *Acacia mangium, Leucaena leucocephala, Eucalyptus tereticornis,* etc. The overall per cent of plants (tree, sapling, pole & seedling) uprooted, trunk snapped, branch broken, bent and leaf stripped/ dried were 6.57, 3.88, 13.51, 3.41 and 31.56, respectively and their corresponding scores of damage were 6.57, 3.10, 8.11, 1.36 and 6.31, respectively. Damage was significantly higher in tree stage followed by pole, sapling and seedling stage. The total score of damage was 53.01, 33.61, 12.67 and 2.54 in tree, pole, sapling and seedling stage, respectively.

Keywords: Tree, Pole, Sapling, Seedling, Fani, Cyclone, Storm

In the process of global warming and climate change in recent years, the frequency and intensity of tropical cyclones are increasing in some areas. The East Coast of India is one of the six most cyclone-prone areas in the world. Although the North Indian Ocean (the Bay of Bengal and Arabian Sea) generates only about 7% of the World's cyclones (5 to 6 TCs per year) their impact is comparatively high and devastating, especially when they strike the coasts bordering the North Bay of Bengal. In the last century, the Indian subcontinent has experienced 1019 cyclonic disturbances, of which 890 were along the eastern coast and 129 were along the western coast and 260 cyclonic disturbances had their landfall along the Odisha coast. The revisit or recurrence time of a severe storm to the Odisha coast is around four years; for West Bengal coast it is 5 years. As far as cyclones are concerned, the revisit time for the Odisha coast is nearly 2 years which is much shorter than that of the other states indicating that Odisha is the most frequently cyclone affected coastal state in the country (Govt. of Odisha 2019).Cyclones are common features in the coastal areas of Odisha as its location comes within the latitudinal range of cyclones (Mishra, 1999). The Extremely Severe Cyclonic Storm "Fani' made landfall at about 8.30 AM on 3rd May 2019 near Puri (Fig. 1). The maximum sustained surface wind speed of 170-180 kmph gusting to 250 kmph was observed during landfall. After the landfall, the cyclone with nearly same intensity continued for next 06 hours. It passed over Puri, Khordha, Cuttack, Jagatsinghpur, Kendrapara, Jajpur, Bhadrak, Balasore and Mayurbhanj districts of Odisha. Then, it emerged into Gangetic West Bengal as a Severe Cyclonic Storm with wind speed of 90-100 kmph gusting to 115 kmph by early morning of 4th May. The track of Fani is shown in Figure 2-3.

Fani was the strongest cyclone to have passed Odisha since the super cyclone in1999. It is also the first time since 1976 that a cyclone of such intensity blew through India. Under the influence of the cyclone, very heavy rainfall occurred in many parts of the state on 3rd and 4th May, 2019. Nine districts have recorded average rainfall of more than100 mm. The Khordha district recorded highest 187.8 mm rainfall followed by Cuttack-171.1 mm, Jajpur- 143.9 mm and Nayagarh- 141.7 mm. Five more districts have received average rainfall between 50 mm and 100 mm. The objective of the present study was to find out resistant economic tree species for the cyclone affected areas in Odisha like states.

MATERIAL AND METHODS

An investigation was carried out to assess the response of 25 economic tree species to Extremely Severe Cyclonic Storm- *Fani* that occurred on 3rd May 2019 in coast of Odisha (India) with maximum sustained surface wind speed of 170-180 kmph gusting to 250 kmph. The study was carried out in four most affected districts of Odisha state (India) such as

Puri, Khordha, Cuttack and Jagatsinghpur district (Fig. 3). These districts cover about 11,983 km^2 geographical area. These are most populated districts of the state having population 77,11,844 (2011 census) and include the four most important cities of the state such as Bhubaneswar (capital city of Odisha), Puri (most important tourist destination of the state), Cuttack (oldest city of the state) and Paradeep (Port city of Odisha). These are coastal districts are located within 100 km aerial distance from coast of Bay of Bengal. The study area experiences tropical hot and humid climate with annual rainfall about 1500mm.

An extensive inventory was made in these four districts and data was collected within 20 days of cyclone. The important 25 economic tree species which are commonly found in tropics were included in the investigation. Each species was assessed in its 4 stages of growth such as tree, pole, sapling and seedling stage. The mean of total score of damage was compared both stagewise and species wise with split plot design considering 4 stages of growth as main plot units, 25 tree species as sub-plot units and four districts as 4 replications. Since the comparison for species needs more precision, they have been in sub plots, whereas, stages of growth which needs comparatively lesser precision are placed in main plots. For each species 100 plants were selected from each district, hence a total of 10,000 plants were studied. Dead, severely diseased and plants with hollow or decayed trunk were not considered. The species studied are given in Table 1. R software has been used for data analysis.

The observations were recorded on parameters related to extent of damage such as percentage of trees uprooted, trunk snapped, branch broken, trees bent, leaf stripped/dried and rating of species damage (Bhol and Sinha 2006). The percentage of uprooted trees was determined by counting the number of trees in a sampling unit which had been totally uprooted with respect to total number of trees in the sampling unit. The trunk snapped was estimated in case of trees which had lost total crown due to breakage of main bole and expressed in per cent. The branch broken trees was determined by counting the trees in which breakage of branches were roughly more than 50 % of the total branches in eye estimation and expressed in per cent. For calculating the per cent of plants bent, the plants which bent more than 15^0 with respect to vertical axis were considered. The per cent of leaf stripped/dried plants were estimated by taking into consideration the plants in which more than 50% of total leaves approximately in eye estimation were stripped off/ dried. The stages of plant growth such as tree, pole, sapling and seedling stage were determined as per the definition of Khanna (1991).

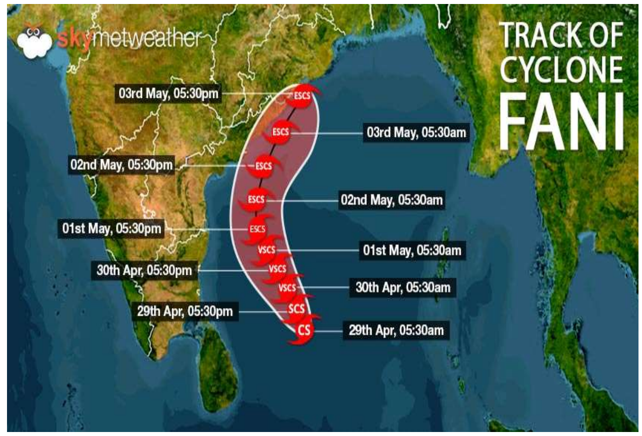

Fig. 1. Extremely severe cyclonic storm - Fani hitting Odisha coast on 3rd May 2019

Fig. 2. Track of Fani on India map

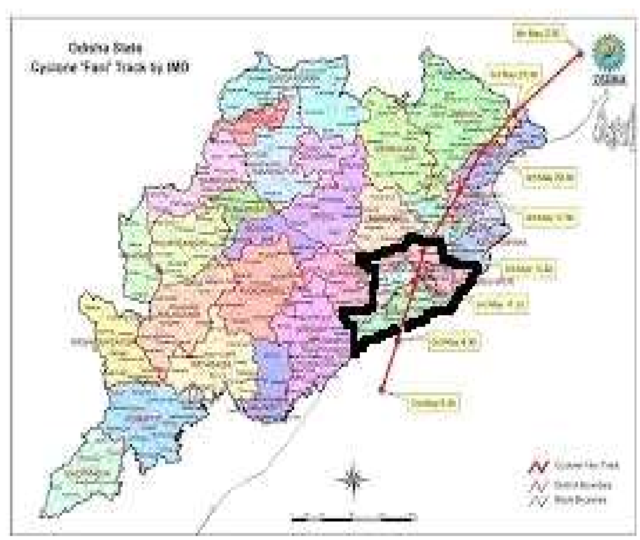

Fig. 3. Track of Fani on affected state Odisha and study area (marked)

Table 1. Damage of tree species by *Fani* and scoring of damage at different stages of plant growth

Growth stage	Per cent of plants damaged					Score of damage (Points)				
	Uprooted	Crown snapped	Branch broken	Plants bent	Leaf stripped/ dried	Uprooted (@ 100 points/ plant)	Crown snapped (@ 80 points/ plant)	Branch broken (@ 60 points/ plant)	Plants bent (@ 40 points/ plant)	Leaf stripped/ dried (@ 20 points/ plant)
1. *Acacia auriculiformis*										
Tree	28	4	30	12	26	28	3.2	18	4.8	5.2
Pole	8	0	26	10	56	8	0	15.6	4	11.2
Sapling	0	0	0	5	54	0	0	0	2	10.8
Seedling	0	0	0	0	6	0	0	0	0	1.2
2. *Acacia mangium*										
Tree	54	2	22	14	8	54	1.6	13.2	5.6	1.6
Pole	36	0	15	11	38	36	0	9	4.4	7.6
Sapling	0	0	0	12	62	0	0	0	4.8	12.4
Seedling	0	0	0	0	12	0	0	0	0	2.4
3. *Aegle marmelos*										
Tree	7	2	24	3	53	7	1.6	14.4	1.2	10.6
Pole	0	0	11	0	64	0	0	6.6	0	12.8
Sapling	0	0	0	0	36	0	0	0	0	7.2
Seedling	0	0	0	0	14	0	0	0	0	2.8
4. *Anacardium occidentale*										
Tree	33	0	48	0	19	33	0	28.8	0	3.8
Pole	12	0	28	20	40	12	0	16.8	8	8
Sapling	0	0	20	0	66	0	0	12	0	13.2
Seedling	0	0	0	0	16	0	0	0	0	3.2
5.*Anogeissus acuminata*										
Tree	12	0	58	6	24	12	0	34.8	2.4	4.8
Pole	0	0	48	0	52	0	0	28.8	0	10.4
Sapling	0	0	20	0	54	0	0	12	0	10.8
Seedling	0	0	0	0	12	0	0	0	0	2.4
6.*Anthocephaluscadamba*										
Tree	36	22	40	2	0	36	17.6	24	0.8	0
Pole	20	12	34	5	29	20	9.6	20.4	2	5.8
Sapling	0	0	0	0	36	0	0	0	0	7.2
Seedling	0	0	0	0	18	0	0	0	0	3.6
7. *Areca catechu*										
Tree	10	4	0	9	62	10	3.2	0	3.6	12.4
Pole	0	0	0	0	27	0	0	0	0	5.4
Sapling	0	0	0	0	0	0	0	0	0	0
Seedling	0	0	0	0	0	0	0	0	0	0
8. *Artocarpus heterophyllus*										
Tree	12	0	32	3	52	12	0	19.2	1.2	10.4
Pole	0	0	22	1	58	0	0	13.2	0.4	11.6
Sapling	0	0	0	0	39	0	0	0	0	7.8
Seedling	0	0	0	0	16	0	0	0	0	3.2

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Growth stage	Per cent of plants damaged					Score of damage (Points)				
	Uprooted	Crown snapped	Branch broken	Plants bent	Leaf stripped/ dried	Uprooted (@ 100 points/ plant)	Crown snapped (@ 80 points/ plant)	Branch broken (@ 60 points/ plant)	Plants bent (@ 40 points/ plant)	Leaf stripped/ dried (@ 20 points/ plant)
9.*Azadirachta indica*										
Tree	3	0	12	9	66	3	0	7.2	3.6	13.2
Pole	0	0	4	1	53	0	0	2.4	0.4	10.6
Sapling	0	0	1	0	44	0	0	0.6	0	8.8
Seedling	0	0	0	0	12	0	0	0	0	2.4
10. *Borassus flabellifer*										
Tree	6	2	0	7	39	6	1.6	0	2.8	7.8
Pole	0	0	0	0	12	0	0	0	0	2.4
Sapling	0	0	0	0	0	0	0	0	0	0
Seedling	0	0	0	0	0	0	0	0	0	0
11.*Calophylluminophyllum*										
Tree	4	0	72	1	21	4	0	43.2	0.4	4.2
Pole	0	0	24	0	66	0	0	14.4	0	13.2
Sapling	0	0	10	0	32	0	0	6	0	6.4
Seedling	0	0	0	0	8	0	0	0	0	1.6
12. *Casuarina equisetifolia*										
Tree	26	38	18	8	10	26	30.4	10.8	3.2	2
Pole	18	24	12	6	38	18	19.2	7.2	2.4	7.6
Sapling	0	0	0	2	46	0	0	0	0.8	9.2
Seedling	0	0	0	0	18	0	0	0	0	3.6
13.*Cocos nucifera*										
Tree	9	3	0	10	58	9	2.4	0	4	11.6
Pole	0	0	0	0	24	0	0	0	0	4.8
Sapling	0	0	0	0	0	0	0	0	0	0
Seedling	0	0	0	0	0	0	0	0	0	0
14. *Eucalyptus tereticornis*										
Tree	35	26	24	12	3	35	20.8	14.4	4.8	0.6
Pole	22	11	28	10	29	22	8.8	16.8	4	5.8
Sapling	0	0	0	6	58	0	0	0	2.4	11.6
Seedling	0	0	0	0	14	0	0	0	0	2.8
15. *Leucaena leucocephala*										
Tree	35	28	24	10	3	35	22.4	14.4	4	0.6
Pole	22	11	28	9	30	22	8.8	16.8	3.6	6
Sapling	0	0	0	7	61	0	0	0	2.8	12.2
Seedling	0	0	0	0	15	0	0	0	0	3
16. *Mangifera indica*										
Tree	16	5	48	5	26	16	4	28.8	2	5.2
Pole	0	0	38	3	59	0	0	22.8	1.2	11.8
Sapling	0	0	22	0	78	0	0	13.2	0	15.6
Seedling	0	0	0	0	14	0	0	0	0	2.8

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Growth stage	Per cent of plants damaged					Score of damage (Points)				
	Uprooted	Crown snapped	Branch broken	Plants bent	Leaf stripped/ dried	Uprooted (@ 100 points/ plant)	Crown snapped (@ 80 points/ plant)	Branch broken (@ 60 points/ plant)	Plants bent (@ 40 points/ plant)	Leaf stripped/ dried (@ 20 points/ plant)
17. *Moringa oleifera*										
Tree	12	82	6	0	0	12	65.6	3.6	0	0
Pole	0	54	46	0	0	0	43.2	27.6	0	0
Sapling	0	0	22	16	62	0	0	13.2	6.4	12.4
Seedling	0	0	0	0	54	0	0	0	0	10.8
18. *Phoenix sylvestris*										
Tree	7	3	0	8	45	7	2.4	0	3.2	9
Pole	0	0	0	0	16	0	0	0	0	3.2
Sapling	0	0	0	0	0	0	0	0	0	0
Seedling	0	0	0	0	0	0	0	0	0	0
19. *Pongamia pinnata*										
Tree	3	0	14	9	60	3	0	8.4	3.6	12
Pole	0	0	6	1	53	0	0	3.6	0.4	10.6
Sapling	0	0	1	0	45	0	0	0.6	0	9
Seedling	0	0	0	0	12	0	0	0	0	2.4
20. *Psidium guajava*										
Tree	32	0	16	22	30	32	0	9.6	8.8	6
Pole	0	0	12	0	88	0	0	7.2	0	17.6
Sapling	0	0	8	0	66	0	0	4.8	0	13.2
Seedling	0	0	0	0	12	0	0	0	0	2.4
21. *Samanea saman*										
Tree	32	4	52	11	1	32	3.2	31.2	4.4	0.2
Pole	12	0	48	8	32	12	0	28.8	3.2	6.4
Sapling	0	0	0	2	52	0	0	0	0.8	10.4
Seedling	0	0	0	0	14	0	0	0	0	2.8
22. *Syzygium cumini*										
Tree	13	0	62	8	17	13	0	37.2	3.2	3.4
Pole	0	0	49	0	51	0	0	29.4	0	10.2
Sapling	0	0	26	0	59	0	0	15.6	0	11.8
Seedling	0	0	0	0	14	0	0	0	0	2.8
23. *Tamarindus indica*										
Tree	17	0	12	6	51	17	0	7.2	2.4	10.2
Pole	0	0	6	3	42	0	0	3.6	1.2	8.4
Sapling	0	0	0	0	18	0	0	0	0	3.6
Seedling	0	0	0	0	8	0	0	0	0	1.6
24. *Tectona grandis*										
Tree	31	35	22	8	4	31	28	13.2	3.2	0.8
Pole	19	12	24	7	38	19	9.6	14.4	2.8	7.6
Sapling	0	0	0	5	56	0	0	0	2	11.2
Seedling	0	0	0	0	20	0	0	0	0	4
25.*Terminalia arjuna*										
Tree	15	4	44	8	30	15	3.2	26.4	3.2	6
Pole	0	0	24	0	76	0	0	14.4	0	15.2
Sapling	0	0	8	0	36	0	0	4.8	0	7.2
Seedling	0	0	0	0	8	0	0	0	0	1.6
Average	6.57	3.88	13.51	3.41	31.56	6.57	3.10	8.11	1.36	6.31

Rating of species damage: To compare the damage of different species quantitatively, different parameters of damage were given different scores. The trees uprooted, trunk snapped, branch broken, bent and leaf stripped/dried were scored as 100, 80, 60, 40, 20 points, respectively and rating was calculated by the formula: per cent damage x respective score (Bhol and Sinha 2006).

Ranking of resistant species: The ranking of tree species resistant to cyclone was done in the reverse order of damage score i.e. the species scoring lowest damage was considered as most resistant.

RESULTS AND DISCUSSION

There was a significant difference in response of trees to the Extremely Severe Cyclonic Storm '*Fani*' with regard to damage. There was variation in the extent of damage among different species studied as well as the damage in different stages of growth in the same species (Table 1). Among the 25 species studied at different stages of growth, the average per cent of plants uprooted, trunk snapped, branch broken, bent and leaf stripped/ dried were 6.57, 3.88, 13.51, 3.41 and 31.56, respectively. The average respective score of damage of these parameters were 6.57, 3.10, 8.11, 1.36 and 6.41. *Borassus flabellifer* (Palmyra palm) resisted most exhibiting least damage with a damage score of 18.2 in tree stage and 2.4 in pole stage only with average score of 5.15 (Table 2). *Moringa oleifera* (Drumstick) recorded the highest score of damage (81.2, 70.8, 32.0 and 10.8 in tree, pole, sapling & seedling stage, respectively) with average score of 48.72.The total score of damage was highest in tree stage

Table 2. Total score of damage of different economic tree species by *Fani* at different stages of plant growth

Tree species	Common name	Total score of damage (points) at different stages of growth				
		Tree	Pole	Sapling	Seedling	Mean
1. *Acacia auriculiformis*	Australian wattle	59.20	38.80	12.80	1.20	28.00
2. *Acacia mangium*	Mangium	76.00	57.00	17.20	2.40	38.15
3. *Aegle marmelos*	Bael	34.80	19.40	7.20	2.80	16.05
4. *Anacardium occidentale*	Cashewnut	65.60	44.80	25.20	3.20	34.70
5.*Anogeissus acuminata*	Button tree	54.00	39.20	22.80	2.40	29.60
6.*Anthocephaluscadamba*	Kadam	78.40	57.80	7.20	3.60	36.75
7. *Areca catechu*	Areca nut	29.20	5.40	0.00	0.00	8.65
8. *Artocarpus heterophyllus*	Jack tree	42.80	25.20	7.80	3.20	19.75
9.*Azadirachta indica*	Neem	27.00	13.40	9.40	2.40	13.05
10. *Borassus flabellifer*	Palmyra palm	18.20	2.40	0.00	0.00	5.15
11.*Calophylluminophyllum*	Alexandrian laurel	51.80	27.60	12.40	1.60	23.35
12. *Casuarina equisetifolia*	Casuarina	72.40	54.40	10.00	3.60	35.10
13.*Cocos nucifera*	Coconut	27.00	4.80	0.00	0.00	7.95
14. *Eucalyptus tereticornis*	Blue gum	75.60	57.40	14.00	2.80	37.45
15. *Leucaena leucocephala*	Subabul	76.40	57.20	15.00	3.00	37.90
16. *Mangifera indica*	Mango	56.00	35.80	28.80	2.80	30.85
17. *Moringa oleifera*	Drumstick	81.30	70.80	32.00	10.80	48.72
18. *Phoenix sylvestris*	Sugar palm	21.60	3.20	0.00	0.00	6.20
19. *Pongamia pinnata*	Pongam tree	27.00	14.60	9.60	2.40	13.40
20. *Psidium guajava*	Guava	56.40	24.80	18.00	2.40	25.40
21. *Samanea saman*	Rain tree	71.00	50.40	11.20	2.80	33.85
22. *Syzygium cumini*	Jamun	56.80	39.60	27.40	2.80	31.65
23. *Tamarindus indica*	Tamarind	36.80	13.20	3.60	1.60	13.80
24. *Tectona grandis*	Teak	76.20	53.40	13.20	4.00	36.70
25.*Terminalia arjuna*	Arjun	53.80	29.60	12.00	1.60	24.25
Mean		53.01	33.61	12.67	2.54	25.46

$CD_{(0.05)}$ for species = 0.69
$CD_{(0.05)}$ for stages of growth = 1.24
$CD_{(0.05)}$ for species x stages of growth= 1.39

(53.01) followed by pole stage, sapling stage and seedling stage. The mean total score of damage was 25.46. This means the cyclone *Fani* completely damaged 25.46% of these 25 economic tree species in the study area.

The higher aged plants suffered more than the lower aged plants (Table 3). Trees were more damaged (19.5 %, 10.6% , 27.2% , 7.6% & 28.3% uprooted, crown snapped, branch broken, bent & leaf stripped/dried, respectively) followed by pole and saplings. Seedlings did not face such damage. The corresponding score of damage followed the similar trend (Table 4). The ranking of trees with respect to their resistance to cyclone *Fani* was in the following order: *Borassus flabellifer* ranked top followed by *Phoenix sylvestris, Cocos nucifera, Areca catechu, Azadirachta indica, Pongamia pinnata, Tamarindus indica, Aegle marmelos, Artocarpus heterophyllus, Calophyllum inophyllum, Terminalia arjuna, Psidium guajava, Acacia auriculiformis, Anogeissus acuminate, Tectona grandis, Mangifera indica, Syzygium cumini, Samanea saman, Anacardium occidentale, Casuarina equisetifolia, Anthocephalus cadamba, Eucalyptus tereticornis, Leucaena leucocephala, Acacia mangium* and *Moringa oleifera* (Table 5).

The response of palms was remarkably better to *Fani*, although there was difference in ability among them to resist cyclonic wind. The small crown, clear bole, fibrous stem, massive adventitious root system, etc might help them against strong wing to resist. Further, the species like *Borassus flabellifer* and *Phoenix sylvestris* grow wildly having better anchorage of roots in the site. Duryea and Kampf (2017a) observed broad-leaved and other conifer trees (such as pines) and found palms to be more resistant to winds. Palms grow differently than other trees because they have one terminal bud. If that bud is not damaged, palms may lose all their fronds (leaves) and still survive. Palms in the coastal plain and tropical and subtropical regions are often more resistant to winds. However, individual palm species do vary in their responses to wind.

The high wood density, better geometry of branching passing wind, strong root system, small to moderate height, ability to lose leaves, etc help to resist wind (Bhol and Sinha, 2006; Skatter and Kucera, 2000; Duryea and Kampf, 2017a; Kushla, 2017). In Super Cyclone 1999 in the present area, species like *Azadirachta indica, Pongamia pinnata* and *Emblica officinalis* were also found resistant (Bhol and Sinha, 2006). The vulnerability of some species to cyclonic wind may be primarily because of their fast growth rate and brittleness of stem and branches. Some species have shallow root system and compact crown. Most of these damaged species had also witnessed poor resistance to Super Cyclone 1999 in such area (Bhol and Sinha, 2006). Similar findings have been reported by Calvert (2011), SCPL (2012), Sundarapandian et al (2014), Duryea and Kampf (2017b).

CONCLUSION

The response of palms such as *Borassus flabellifer, Phoenix sylvestris, Cocos nucifera* and *Areca catechu* was significantly higher over other tree species to resist Extremely Severe Cyclonic Storm- *Fani* followed by *Azadirachta indica, Pongamia pinnata* and *Tamarindus*

Table 3. Overall per cent of plants damaged at different stages by *Fani*

Stage of plant	% of plants damaged irrespective of species				
	Uprooted	Trunk snapped	Branch broken	Plants bent	Leaf stripped/ dried
Tree	19.5	10.6	27.2	7.6	28.3
Pole	6.8	5.0	21.3	3.8	42.8
Sapling	0.0	0.0	5.5	2.2	42.4
Seedling	0.0	0.0	0.0	0.0	12.7

Table 4. Overall score of damage at different stages of plant by *Fani*

Stage of plant	Score of damage irrespective of species (points)					
	Uprooted (@ 100 points/ plant)	Crown snapped (@ 80 points/ plant)	Branch broken (@ 60 points/ plant)	Plants bent (@ 40 points/ plant)	Leaf stripped/ dried (@ 20 points/ plant)	Total score of damage in a stage (points)
Tree	19.5	8.4	16.3	3.1	5.7	53.0
Pole	6.8	4.0	12.8	1.5	8.6	33.6
Sapling	0.0	0.0	3.3	0.9	8.5	12.7
Seedling	0.0	0.0	0.0	0.0	2.5	2.5

Table 5. Ranking of economic tree species resisting to extremely severe cyclonic storm-*Fani*

Tree species	Common name	Family	Mean score of damage of all 4 stages of growth (out of 100)	Rank of economic tree species resistant to *Fani*
Borassus flabellifer	Palmyra palm	Arecaceae	5.15[u]	1
Phoenix sylvestris	Sugar palm	Arecaceae	6.20[t]	2
Cocos nucifera	Coconut	Arecaceae	7.95[s]	3
Areca catechu	Areca nut	Arecaceae	8.65[r]	4
Azadirachta indica	Neem	Meliaceae	13.05[q]	5
Pongamia pinnata	Pongam tree	Fabaceae	13.40[pq]	6
Tamarindus indica	Tamarind	Caesalpiniaceae	13.80[p]	7
Aegle marmelos	Bael	Rutaceae	16.05[o]	8
Artocarpus heterophyllus	Jack tree	Moraceae	19.75[n]	9
Calophylluminophyllum	Alexandrian laurel	Clusiaceae	23.35[m]	10
Terminalia arjuna	Arjun	Combretaceae	24.25[l]	11
Psidium guajava	Guava	Myrtaceae	25.40[k]	12
Acacia auriculiformis	Australian wattle	Mimosaceae	28.00[j]	13
Anogeissus acuminata	Button tree	Combretaceae	29.60[i]	14
Mangifera indica	Mango	Anacardiaceae	30.85[h]	15
Syzygium cumini	Jamun	Myrtaceae	31.65[g]	16
Samanea saman	Rain tree	Mimosaceae	33.85[f]	17
Anacardium occidentale	Cashew	Anacardiaceae	34.70[e]	18
Casuarina equisetifolia	Casuarina	Casuarinaceae	35.10[e]	19
Tectona grandis	Teak	Lamiaceae	36.70[d]	20
Anthocephaluscadamba	Kadam	Rubiaceae	36.75[d]	21
Eucalyptus tereticornis	Blue gum	Myrtaceae	37.45[c]	22
Leucaena leucocephala	Subabul	Mimosaceae	37.90[bc]	23
Acacia mangium	Mangium	Mimosaceae	38.15[b]	24
Moringa oleifera	Drumstick	Moringaceae	48.70[a]	25
CD (p=0.05) for species			0.69	

Values with at least one common letter are not significantly different

indica. On the other hand the most susceptible economic species was *Moringa oleifera* followed by *Acacia mangium, Leucaena leucocephala, Eucalyptus tereticornis, Anthocephalus cadamba* and *Tectona grandis which* should not be grown in commercial scale in such areas. Further, the plants in tree stage were significantly affected by cyclone followed by poles and saplings. Seedlings were found not affected by cyclone.

REFERENCES

Bhol N and Sinha SK 2006. Effect of super cyclone on different tree species in and around Bhubaneswar. *Indian Journal of Forestry* **29**(1): 25-30.

Calvert G 2011. *An assessment of tree susceptibility and resistance to cyclones: A study based on Severe Tropical Cyclone Yas*i, Australia 138p.

Duryea ML and Kampf E 2017a. *Wind and Trees: Lessons Learned from Hurricanes. FOR118, UF/IFAS* Extension, School of Forest Resources and Conservation, University of Florida. USA.

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Duryea ML and Kampf E 2017b. *Selecting Tropical and Subtropical Tree Species for Wind Resistance. FOR 120, UF/IFAS* Extension, School of Forest Resources and Conservation, University of Florida. USA.

Govt of Odisha 2019. Memorandum -Extremely Super Cyclonic Storm 'Fani' 3rd May 2019. 87p.

Khanna LS 1991. *Principles and Practices of Silviculture*. 473 pp.

Kushla JD 2017. Storm-Resistant Trees for Mississippi Landscapes.3111 (POD-08-17). North Mississippi Research and Extension Center, Mississippi State University.USA.

Mishra S 1999. Hatigumpha inspiration has Earliest Cyclone Report. *The Asian Age*.

SCPL 2012. *The Best Practice Guide to Timber Plantations in Cyclonic- Prone Areas of Queensland: A review of the science and knowledge.* Select Carbon Pty Ltd, Australia. 34p.

Skatter S and Kucera B 2000. Tree breakage from torsional wind loading due to crown asymmetry. *Forest Ecology and Management* **135**(1-3): 97-103.

Sundarapandian SM, Mageswaran K, Gandhi DS and Dar JA 2014. Impact of Thane Cyclone on tree damage in Pondicherry University Campus, Puducherry, India. *Current World Environment* **9**(2): 287-300.

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GGE Biplot and Genotype x Environment Interaction Analysis in Eggplant (*Solanum melongena* L.) under Subtropical Conditions of Jammu

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Abstract: Additive Main Effects and Multiplicative Interaction (AMMI) and GGE biplot analysis are widely used now a days to delineate stable genotypes under different environments, across different seasons, locations or years. The present study was undertaken to decipher nature and magnitude of Genotype x Environment Interaction (GEI) among 25 eggplant genotypes across six different environments. The individual experiment was conducted in randomized complete block design with three replications and uniform, healthy seedlings were planted on ridges maintaining inter and intra row spacing of 90 x 60 cm, respectively. Results revealed the presence of Genotype x Environment interaction (GEI) and the first two principal components accounted for 84.99 per cent variation viz., 55.31 and 29.68 per cent respectively for yield per plant thereby, indicating that genotypes may be selected for adaptation with respect to specific environments. With respect to ranking of environments, the discriminating ability of V_3 and V_6 was closest to the ideal environment. The stability mean of genotypes revealed that G_1 (Rajni), G_9 (Shamli) and G_{23} (PPC) were the best performing genotypes whereas, Nisha Improved was found to be most unstable genotype. 'Which-won-where' analysis depicted three mega environments (ME) among the test locations with ME1 represented by four locations V_1 (Autumn-winter, 2013), V_2 (Spring-summer, 2014), V_4 (Autumn-winter, 2014) and $\mathbf{V_7}$ with G_1 (Rajni) as winning genotype and second ME (ME2) consisting of V_3 (Rainy, 2014) and V_6 (Rainy 2015) with G_{15} (Arka Nidhi) and G_{16} (Arka Neelkanth) as winning genotypes. Third ME (ME3) was represented by V_5 (Spring-summer, 2015) with G_8 (Nisha Improved) as winning genotype.

Keywords: AMMI, Eggplant, GEI, GGE Biplot

Eggplant (*Solanum melongena* L.), is a popular and principal vegetable crop widely grown in tropics and subtropical parts of India. India is the second largest producer of brinjal in the world next to China and produces 13154 '000 MT from an area of 758 '000 ha (Anonymous 2021 a). In Union Territory of J&K, brinjal is grown over an area of 1.67' 000 ha, with total production of 34.40'000MT (Anonymous 2021b). There are numbers of commercially grown varieties and hybrids available in the market, released by both public and private sector. However, a genotype possessing considerably high yield potential coupled with stable performance in different environments has great value for its adaptation on large scale and in plant breeding programme (Bora et al 2011). There is an utmost need for development of high yielding stable varieties and hybrids for specific environments. Stability in productivity, therefore, is a major and important consideration to identify brinjal genotypes capable of performing well across the environments and seasons. Most of the economic characters in brinjal are quantitative in nature and thus, susceptible to environmental fluctuations. Various statistical models like principle component analysis (pca) and linear regression have been suggested over time to understand the complex GEI. Genotype (G) main effect plus GE interaction (GGE) biplot is a biplot) based on environment-centered data, which removes the environment main effect and integrates the genotypic main effect with the GE interaction effect of a GE dataset (Yan et al 2000). It is a robust method to visualize and interpret multi environment data graphically as well. The GGE biplot analysis combines the additive effect of genotype with the multiplicative effect of the GEI, building the biplot graphics from the main components (MC), in order that the first component represents the proportion of products obtained from the genotype traits, and the second component shows the ratio of the production that occurs due to the GEI (Yan and Holland 2010). AMMI model is also considered better at explaining the effects of G×E interactions as compared to other models of stability analysis, thereby defining clarification of multi-environmental data set. The precision in this model is achieved by separation of structural variation from uproar and it has been widely used in the evaluation of the stability of yield-related traits (Bhartiya et al 2017). Earlier work show the efficiency and superiority of the GGE biplot analysis and AMMI model for the recommendation of genotypes (Hongyu et al 2015, Koundinya et al 2019 , Pardeshi et al 2021). Therefore, the present investigation was undertaken to have an insight into the nature and magnitude of GEI among 25 brinjal genotypes across six environments using GGE biplot analysis as well as identification of mega environments within the test locations.

MATERIAL AND METHODS

Agro-climatically, the Jammu location represents Zone V of Jammu and Kashmir and is characterized by subtropical climate. The place experiences hot dry summer, hot and humid rainy season and cold winter months, the maximum temperature goes up to 45° C during summer (May to June) and minimum temperature falls to 1° C during winters. The mean annual rainfall is about 1000-1200 mm. The experimental material comprised of 25 brinjal genotypes including 10 F_1 hybrids namely, Rajni,PPL-74, Navkiran Improved, Sandhya, MH-80, Chhaya, PBH-3, Nisha Improved, Shamli, and Abhishek, and fifteen open pollinated varieties i.e. Punjab Sadabahar, Arka Shirish, Arka Kusumkar, Arka Keshav, Arka Nidhi, Arka Neelkanth, Pusa Shyamala, Pusa Kranti, Pusa Ankur, Pusa Uttam, PPL, PPR, PPC, BR-14 and Puneri Kateri collected from different parts of the country (Table 1) were tested under six environments comprised of three seasons of sowing spreading across two years during 2013-2014 and 2014-2015 (V_1- Autumn-winter, 2013; V_2- Spring-summer, 2014; V_3 -Rainy, 2014; V_4- Autumn-winter, 2014; V_5- Spring-summer, 2015 and V_6- Rainy, 2015). The individual experiment was conducted in randomized block design with three replications. The uniform, healthy seedlings were planted on ridges maintaining inter and intra row spacing of 90 x 60 cm, respectively. All standard crop management practices were followed to raise a healthy crop. The total weight of fruits from each plot was obtained from each picking and pooled. The fruit yield per plant (kg) and fruit yield per hectare (q) was calculated on the basis of total plot yield. The data so generated was analyzed using R studio software. GEI was analyzed by the use of biplot graph in which the yield means are plotted against the scores of first principal component of interaction (IPCA1) (Yan et al 2000). Similarly, data was analyzed for discrimitiveness *vs* representativeness ranking of environments and ranking of genotypes relative to ideal environment and ranking of environment based on ideal genotype was also performed. Mega-environments and winning genotypes in given set of environments was identified by using option 'which-won-where'.

RESULTS AND DISCUSSION

The presence of GEI was clearly demonstrated by AMMI model and the interaction was partitioned among the first two interaction principal component axis (IPCA), as 55.31% and 29.68% respectively, and the cumulative variance was 84.99 % for fruit yield per plant (kg) (Table 2) while, for fruit yield per hectare (q) the first two interaction principal component axis (IPCA) were portioned as 53.60 % and 30.77% respectively

Table 1. List of eggplant genotypes included in the experiment

Genotypes	Fruit shape	Source
F_1 Genotypes		
Rajni	Round	Nunhems Seeds
PPL-74	Long	Century Seeds
Navkiran Improved	Round	Sungrow Seeds
Sandhya	Round	Nunhems Seeds
MH-80	Round	Mahycco Seeds
Chhaya	Long	Nunhems Seeds
PBH-3	Oblong	PAU, Ludhiana
Nisha Improved	Oblong	Century Seeds
Shamli	Long	Seminis Seeds
Abhishek	Round	Nunhems Seeds
Open pollinated genotypes		
Punjab Sadabahar	Long	PAU, Ludhiana
Arka Shirish	Long	IIHR, Banglore
Arka Kusumkar	Oblong	IIHR, Banglore
Arka Keshav	Long	IIHR, Banglore
Arka Nidhi	Long	IIHR, Banglore
Arka Neelkanth	Long	IIHR, Banglore
Pusa Shyamla	Oblong	IARI, New Delhi
Pusa Kranti	Oblong	IARI, New Delhi
Pusa Ankur	Round	IARI, New Delhi
Pusa Uttam	Round	IARI, New Delhi
PPL	Long	IARI, New Delhi
PPR	Round	IARI, New Delhi
PPC	Oblong	IARI, New Delhi
BR-14	Round	IIVR, Varanasi
Puneri kateri	Oblong	Safal Seeds Co., Jalna

Table 2. Additive main effects and multiplicative interaction (AMMI) analysis of variance for fruit yield per plant (kg) of brinjal genotypes across six environments

Source of variation	df	MS	Variation explained (%)
Environment	5	3782516.17***	
Genotype	24	151513.24	
G x E Interaction	120	283346.17	84.99
IPCA 1	28	671628.39	55.31
IPCA 2	26	388165.79	29.68
Error	66	77327.81	

and the cumulative variance was 84.37% (Table 3) thereby, demonstrating that genotypes may be selected for adaptation to specific environments. These results are in harmony with the findings of Koundinya et al (2019) and Pardeshi et al (2021) on G x E interactions effects in eggplant and vegetable soyabean, respectively. There were significant differences among environments for both the traits viz., fruit yield per plant (kg) and fruit yield per hectare (q) which indicated that the environments under study were different from each other (Table 2, 3). The model was additive and the results of AMMI analysis were represented in the form of graphs called biplots (Gauch and Zobel 1996). Further Gauch (1988) recommended that the most accurate model for AMMI can be predicted by using first two principal component analysis. Admassu et al (2008), in accordance with Zobel et al (1988), proposed that two interaction principal component axes for the AMMI model were sufficient for a predictive model. Thus, the interaction of 25 eggplant genotypes with six environments was predicted by the first two components of genotypes and environments (Akhtar et al 2019). Stable genotypes were identified by graphical representation (GGE biplot) which uses genotype and G x E components and identifies G x E interaction pattern of multi-environment data and clearly shows which variety performs best in which environment (Heldari et al 2016). According to Khan et al (2021), Biplots are frequently used to graphically depict the interactions between genotypes (G), environments (E), and GEIs, as well as to reveal interaction patterns and indicate the genotypes that are comparatively stable across environments.

Identification of stable genotypes with highest mean performance: The complex GEI was divided into many principle components (PCs) in GGE biplot, and the data are graphically displayed against PCs as presented in Figure 1. GGE biplots used PC1 (45.84%) and PC2 (19.02%) to capture 64.86% of the variation. The projection of a genotype's absolute length is used to assess the stability of

Table 3. Additive main effects and multiplicative interaction (AMMI) analysis of variance for fruit yield per hectare (q) of brinjal genotypes across six environments

Source of variation	df	MS	Variation explained (%)
Environment	5	36359.07***	
Genotype	24	1196.20	
G x E interaction	120	2481.90	84.37
IPCA 1	28	5700.77	53.60
IPCA 2	26	3524.93	30.77
Error	66	705.43	

*** indicate significance at $p<0.0001$

the genotype. The GGE biplot abridgment mean performance and stability of different genotypes has been depicted. Thus, G_1, G_9 and G_{23} were the best performing genotypes followed by G_{16}, G_{24} and G_{15}. G_8 was observed as most unstable genotype and considered as good performer only in specific environment. The genotype, G_1 was closest to the "ideal genotype" followed by G_9, G_{23}, G_{16} and G_{24} which is denoted by small circle at the centre of concentric rings (Fig. 2). The genotypes best suited to a particular environment within a multi-environment are chosen by plant breeders using data from yield performance tests based on mean and stability, whereas genotypes close to the ideal genotype are also more promising or appropriate. Khan et al (2021) observed similar findings in 30 Bambara groundnut across 4 environments as evidence of our result.

Environment evaluation: Angles between environment vectors in biplots indicate their relationship as the cosine of the vector angles is indicative of their correlation. Acute angle between two environment vectors indicates positive correlation while an obtuse angle indicates negative correlation and right angle suggests no relation. Environments show complex relationship among themselves. The 'ideal environment' is denoted by a small circle at the centre of the concentric rings. Maximum discriminating ability and representativeness with highest vector length indicates an "ideal environment". V_1 with V_2, V_4 with V_7 and V_3 with V_6 having acute angles (Fig. 3 and 4) were positively correlated with ideal environment. Environments generating similar information may be removed from multi-location testing as they will provide similar results. This will help in optimum allocation of limited resources during multi-location trials. Obtuse angled vectors show negative correlation with ideal environment for instance V_5 with V_6. Discrimination ability of the environments was measured by the length of the environment vectors and the testing environment could be ranked from top to bottom as $V_6>V_3>V_4>V_7>V_2>V_1>V_5$. V_3 and V_6 was considered to be close to an "ideal environment".

"Which-won-where" and mega environment identification: "Which-won-where' 'analysis involving GEI, mega-environment differentiation, specific adaptation of genotypes etc. are graphically addressed (Fig. 6). Genotypes located on the vertices of the polygon performed either the best or the poorest in one or more environments (Yan and Kang, 2003). In the current study 'Which-won-where" biplots gave rise to a hexagon with six genotypes, G_8, G_{25}, G_{12}, G_{14}, G_{15} and G_{16} at vertices. The equality lines divided the biplot into six sectors effectively. Six testing environments were spread within the biplot, three in one and remaining three in other sector. Testing environment could be partitioned into mega-environment (ME). Three out of six sectors had no single environment and hence it did not reflect any separate ME and could be merged into nearest MEs. First ME (ME1) was represented by V_1, V_2, V_4 and V_7 with G_1 as winning genotype and second ME (ME2) was composed of V_3 and V_6 with G_{15} and G_{16} as another winning genotype.

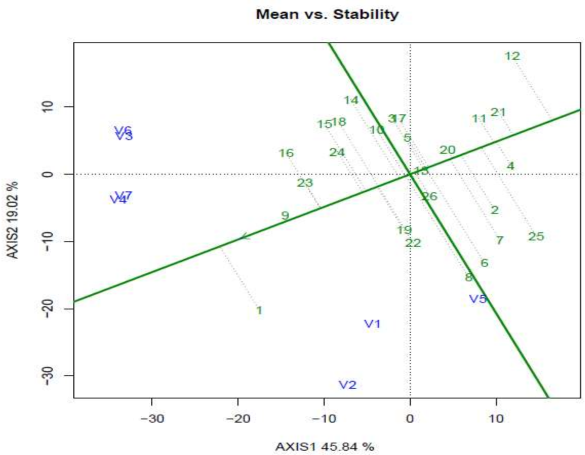

Fig. 1. GGE Biplot of combined analysis for yield: Mean vs. Stability of genotypes

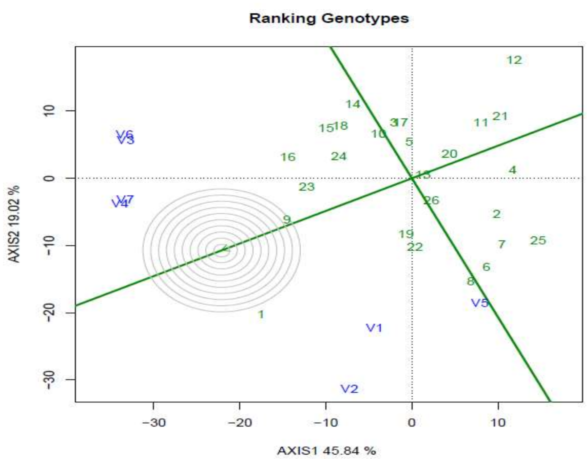

Fig. 2. Ranking of genotypes

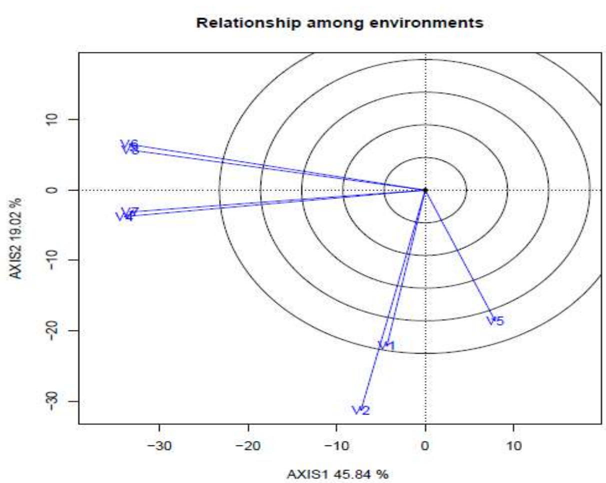

Fig. 3. GGE Biplot combined analysis: Relationship among environments

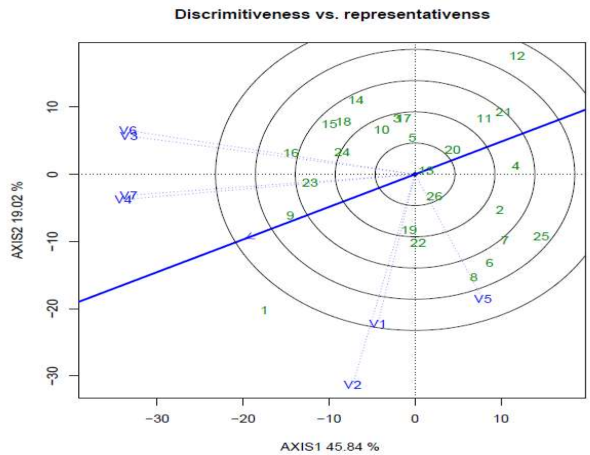

Fig. 4. Ranking of environments based on discriminating ability and representativeness

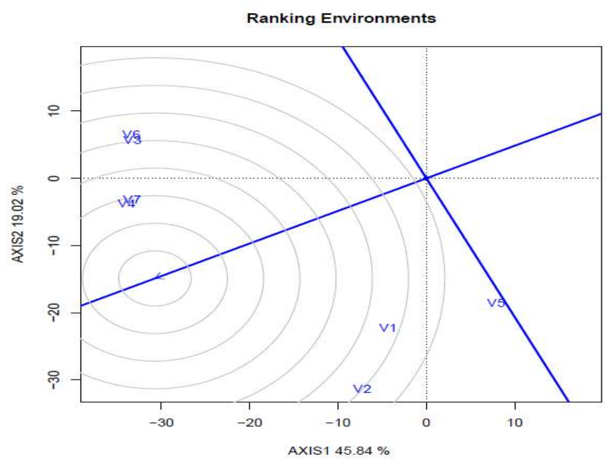

Fig. 5. Ranking of environment

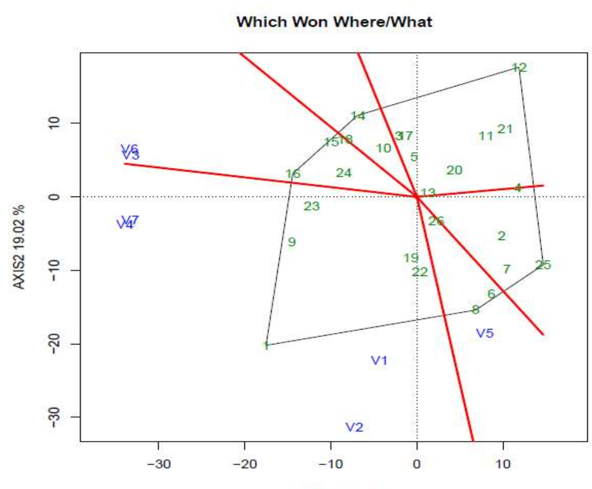

Fig. 6. GGE Biplot combined analysis: 'Which-won-where'

Third ME (ME3) was represented by V_5 with G_8 as winning genotype. Thus, this study established the effectiveness of GGE biplot analysis in identifying stable and superior genotypes. Similar findings and interpretation have been made by Hashim et al (2021) in rice and Bana et al (2022) in eggplant.

CONCLUSION

Present investigation deciphered the influence of G x E interaction on yield of eggplant while, discriminating ability of rainy season was found to be closest to the ideal environment as per the ranking. Rajni, Shamli and PPC were identified as stable genotypes whereas, Nisha Improved was found to be the most unstable genotype. 'Which-won-where' analysis depicted three mega environments viz., ME1 represented by four locations, V_1 (Autumn-winter, 2013), V_2 (Spring-summer 2014), V_4 (Autumn-winter 2014) and V_7 with G_1 (Rajni) as winning genotype and second ME (ME2) consisting of V_3 (Rainy 2014) and V_6 (Rainy 2015) with G_{15} (Arka Nidhi) and G_{16} (Arka Neelkanth) as winning genotypes. Third ME (ME3) was represented by V_5 (Spring-summer 2015) with G_8 (Nisha Improved) as winning genotype.

REFERENCES

Admassu S, Nigussie M and Zelleke H 2008. Genotype x environment interaction and stability analysis for grain yield (*Zea mays* L.) in Ethiopia. *Asian Journal of Plant Sciences* **7**: 163-169.

Anonymous 2021a. Area and Production of Horticulture Crops, 2020-2021 Second Advance Estimates. Horticulture Statistics Division, DAC & FW.

Anonymous 2021b. *Annual report of area and production of vegetables 2020-2021*. Agricoop database, India https://agricoop.nic.in/en/statistics/horticulture-crops

Akhtar S, Kumari AR, Solankey SS and Baranwal DK 2019. Phenotypic stability in brinjal genotypes. *Journal of Crop and Weed* **15**(3): 79-86.

Bana RS, Jat GS, Grover M, Bamboriya SD, Singh D, Bansal R, Choudhary AK, Kumar V, Laing AM, Godara S, Bana RC, Kumar H, Kuri BR, Yadav A and Singh T 2022. Foliar nutrient supplementation with micronutrient-embedded fertilizer increases biofortification, soil biological activity and productivity of eggplant. *Scientific Reports* **12**: 5146.

Received 22 August, 2022; Accepted 15 September, 2022

Bhartiya A, Aditya JP, Kumari V, Kishore N, Purwar JP and Agrawal A 2017. GGE biplot & ammi analysis of yield stability in multi-environment trial of soybean [*Glycine max* (L.) merrill] genotypes under rainfed condition of north western himalayan hills. *Journal of animal & plant sciences* **27**(1): 227-238.

Bora L, Singh Y and Bhushan KB 2011. Stability for fruit yield and yield contributing traits in brinjal (*Solanum melongena* L.). *Vegetable Science* **38**(2): 194-196.

Gauch HG 1988. Model selection and validation for yield trials with interaction. *Biometrics* **44**: 705-715.

Gauch HG and Zobel RW 1996. *AMMI analysis of yield trials. In: Genotype-by-Environment Interaction,* Kang MS and HG Gauch (Eds.). Boca Raton CRE CRC, New York, USA, 85-122.

Hashim N, Rafii M Y, Oladosu Y, Ismail M R, Ramli A, Arolu F and Chukwu S 2021. Integrating multivariate and univariate statistical models to investigate genotype-environment interaction of advanced fragrant rice genotypes under rainfed condition. *Sustainability* **13**(8): 4555.

Heldari S, Azizinezhad R and Haghparast R 2016. Yield stability analysis in advanced durum wheat genotypes by using AMMI and GGE biplot models under diverse environment. *Indian Journal of Genetics and Plant Breeding* **76** (3): 274-283.

Hongyu K, Silva FL, Oliveira ACS, Sarti DA, Araújo LB and Dias CTS 2015. Comparação entre os modelos ammi egge biplot para os dados de ensaios multi-ambientais. *Revista Brasileira de Biometria* **33**(2): 139-155.

Khan MMH, Rafii MY, Ramlee SI, Jusoh M and Mamun MA 2021.AMMI and GGE biplot analysis for yield performance and stability assessment of selected Bambara groundnut (*Vigna subterranea* L. Verdc.) genotypes under the multi-environmental trials (METs). *Scientific Reports* **11**: 22791.

Koundinyaa AVV, Pandita MK, Ramesh D and Mishra P 2019. Phenotypic stability of eggplant for yield and quality through AMMI, GGE and cluster analyses. *Scientia Horticulturae* **247**: 216-223.

Pardeshi PP, Sakhare SB, Jadhav PV, Zhunjare RU, Varghese P, Sonkamble PA, Rathod DR, Katkar RN and Nandanwar RS 2021.Analysis of genotype x environment interactions for yield and quality traits in vegetable soybean (*Glycine max* (L.) Merill). *The Pharma Innovation Journal* **10**(8): 1503-1513.

Yan W and Holland JB 2010. A heritability-adjusted GGE biplot for test environment evaluation. *Euphytica* **171**(3): 355-369.

Yan W, Hunt LA, Sheng Q and Szlavnics Z 2000. Cultivar evaluation and mega environment investigation based on the GGE biplot. *Crop Science* **40**(3): 597-605.

Yan W and Kang MS 2003. *GGE biplot analysis: A graphical tool for breeders, geneticists and agronomists*, CRC Press, Boca Raton, FL.

Zobel RW, Wright M J and Gauch HG 1988. Statistical analysis of a yield trial. *Agronomy Journal* **80**: 388-393.

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Graphical Analysis (Vr-Wr) for Fruit Yield and Its Component Traits in Eggplant

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Abstract: The objectives of this study were to determine the gene action in all the way for fourteen fruit yield and biochemical traits in eggplant that can be used in targeted breeding program. The experiment was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, (SKUAST-J), Jammu, India. A total 29 progenies including the seven parental lines, 21 hybrid F_1's generated through 7 × 7 half diallel mating design, and one standard check were arranged in a randomized complete block design. The results demonstrated that existence of both additive and non-additive genetic variation for the inheritance of most of the studied traits. The Vr-Wr graphical analysis exhibited that higher proportion of dominance alleles for days to 50% flowering, days to first picking, fruit girth, fruit weight, branches per plant, plant height, fruit yield per plant, ascorbic acid content and total phenol content. The higher proportion of recessive alleles recorded for number of fruits per cluster, fruit length, number of fruits per plant and crop duration.

Keywords: *Solanum melongena* L., Half diallel, Genetic analysis

Eggplant is a versatile vegetable crop and has been widely cultivated in India as well as in the world (Rani et al 2018). Aside from being observed as an important vegetable crop, it is exploited for medicinal purposes owing to its high antioxidant properties *viz*., anthocyanins, phenolic compounds and alkaloids that have beneficial effects on human health (Mistry et al 2016, Dranca and Oroian 2017). It is an economic crop that provides a great income source for small-scale farmers globally (Datta et al 2021). Most of the inter-varietal F_1 hybrids of eggplant exhibited considerable vigor in economic traits; mainly fruit yield (Kaushik et al 2018). The parental selection to get high yielding hybrid F_1's is most important footstep in any crop breeding program (Boyaci et al 2020). Genetic analysis furnishes a direction for the appraisal of relative breeding potential of the genitors or identifies best combiners (Akpan et al 2016). Diallel analysis assists in understanding the genetic control of trait, which escort crop breeder to forward and select segregating generations. The nature of gene action involved in the inheritance of different traits is most important to decide the breeding strategy for improvement of the crop (Meena et al 2020). It could be estimated by graphical approach (Vr-Wr graph). The graphical statistic offers an estimate of the associate number of dominance to recessive genes existing in the common arrays of the parents, with the Vr and Wr statistics, calculated from diallel tables, graphs can be drawn and the geometric representation of these statistics could be interpreted. The position of the regression line in the graph indicates the degree of dominance and assembles parabola limits in the graph. The elucidations of graphical analysis results are simple and genuine if the principal assumptions of the diallel analysis are fulfilled (Hussain et al 2018, Patel and Kathiria 2018). Thus, the current research was conducted with the objective to assess the gene action in all the ways for various horticultural traits to provide appropriate information that could be utilize in the eggplant breeding programs aimed at improving fruit yield and its components.

MATERIAL AND METHODS

Seven genetically diverse parental lines of eggplant *viz*., Pusa Purple Cluster (PPC), IC 261797, IC 261767, IC 354611, IC 203585, IC 104101 and IC 310886 (received from National Bureau of Plant Genetic Resources, New Delhi, India) were included in the research. Twenty F_1 hybrids were generated through 7 × 7 half diallel mating design (excluding reciprocals) at Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, (SKUAST-J), Jammu, India. The resultant 21 F_1 hybrids along with their parents and one standard check (Pusa Hybrid-5) were arranged in randomized complete block design with three replications. The seedlings were transplanted on ridges, and the row × the plant spacing was maintained at 75 cm × 60 cm. Standard cultural practices, such as fertilization, irrigation, weeding, diseases and insect-pests control were performed whenever required (Anonymous 2016). Fourteen fruit yield and biochemical traits were studied by recording observations on five plants from each replication. The traits included plant height (cm), number of primary branches per plant, days to 50% flowering, days to first picking, number of fruits per cluster, fruit length (cm), fruit girth (cm), number of fruits per plant, average fruit weight (g), crop duration (days from transplanting to final harvesting of fruits), fruit yield per plant (g), total fruit yield (q/ ha), ascorbic acid content (mg/ 100 g) and total phenols content (mg/ 100 g). The graphical analysis was done according to Hayman (1954). The data collected were analyzed by using computer software Windostat (Indostat services Ltd. Hyderabad, India).

RESULTS AND DISCUSSION

The estimates of component of analysis indicated significant additive (D) and non-additive (H_1 and H_2) effects were observed for days to 50% flowering, days to first picking, number of fruits per cluster, fruit length, fruit girth, plant height. Non-additive (H_1 and H_2) effects were higher in magnitude than additive (D) effects. The graphical analysis (Vr-Wr) of research data recorded in order to get knowledge on allelic constitution of parents utilized in diallel cross. In the current study, the regression coefficient (b) was non-significant for all the traits depicting presence of non-allelic interactions, and the results of studied traits presented as Vr-Wr graphs (Figs. 1-8). The t^2 values were not significant for any of the characters hence the basic assumptions of diallel analysis are fulfilled and were further analyzed. Hayman's approach known as graphic analysis based on variance-covariance matrics (Vr-Wr) was used for testing the validity of assumptions of diallel analysis. Graphical analysis depicted partial dominance for all the traits except for days to first picking and average fruit weight for which no dominance was recorded. The graphical analysis revealed partial dominance as the regression line intersected the Wr-axis above the point of origin. Scattering of array points along the regression line indicated wide genetic diversity among parents for the studied traits. The graphical analysis revealed no dominance for days to first picking and average fruit weight as the regression line did not intersect the Wr-axis. The relative position of the parental points along the regression line indicated the distribution of dominant and recessive genes in the parents. The location of array points nearer to the point of origin and far away from the point of origin suggested higher proportion of dominant and recessive genes in the parents, respectively. The line of regression intercepted Wr axis passed below the origin indicating the presence of over-dominance in the control of expression of the respective trait. For days to 50% flowering, parent IC 261767 had excess of dominant genes and IC 203585 had excess of recessive alleles, while all other parents had more or less equal proportion of dominant and recessive genes. Parent IC 261797 having mostly recessive genes for days to first picking as it was lying far from the point of origin. The rest of the parents possessed almost equal proportions of dominant and recessive genes. For number of fruits per cluster, the parent IC 261767 exhibited maximum frequency of dominant genes being nearest to the origin point. However, IC 354611 had the greater number of recessive genes, being farthest from the origin; and remaining parents had mostly equal proportion of dominant and recessive genes. Distribution of parental arrays near to the regression line exhibited that parent IC 104101 had more number of dominant genes for fruit length while rest all the parents were having recessive genes as they are lying away from the point of origin. For Fruit girth, parent IC 261767 had higher number of dominant genes. While all other parents had maximum frequency of recessive genes except for PPC which was having more or less equal proportion of dominant and recessive genes. The parent IC 203585 and PPC had high number of dominant genes and remaining all the parents were having recessive genes, as they were lying for away from point of origin for average fruit weight. In case of number of fruits per plant, all the parents had balanced proportion of dominant and recessive genes, as they were lying for away from the point of origin. For primary branches per plant, parent IC 261797, IC 354611, PPC and IC 104101 had more number of dominant genes, as they were lying close to the point of origin. Rests of the parents were having maximum number of recessive genes.

Parents Pusa Purple Cluster, IC 354611, IC 104101 and IC 261767 had excess of dominant genes for plant height, whereas, rest of the parents had greater number of recessive genes. The distribution of parental arrays along the regression line suggested that IC 310886 and IC 104101 had the maximum number of dominant genes, and the parent IC 261767 and IC 203585 had the maximum number of recessive genes for crop duration. The rest of parents had more or less equal proportion of dominant and recessive genes. For fruit yield per plant, the parent IC 104101 had maximum number of dominant genes as it was found near the point of origin. Rests of the parents carried the maximum number of recessive alleles being farthest from the origin. The parents IC 310886 and IC 203585 had more recessive genes for ascorbic acid content as they were lying far from the point of origin and remaining parents were having more or less equal proportion of dominant and recessive genes. For total phenol content (mg/100g), the parents IC 261767, IC 354611 and IC 310886 possessed more number of dominant genes,

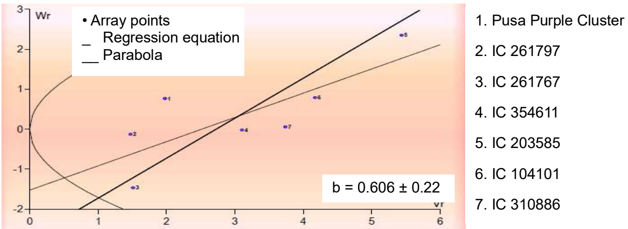

Fig. 1. Vr-Wr graph for days to 50% flowering

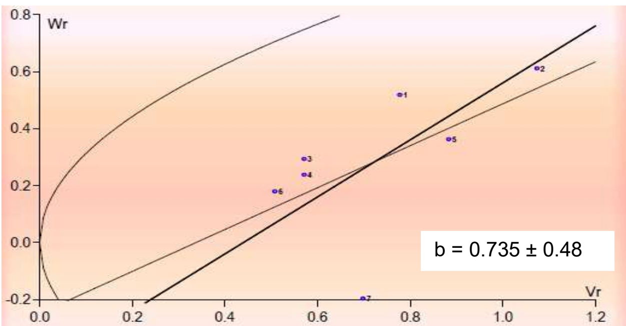

Fig. 2. Vr-Wr graph for days to first picking

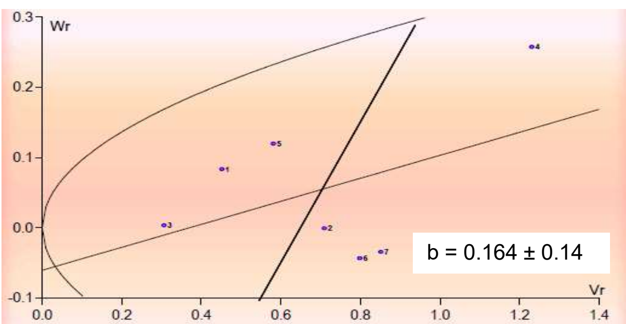

Fig. 3. Vr-Wr graph for number of fruits per cluster

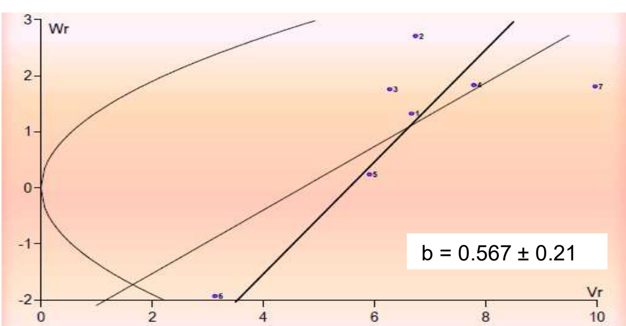

Fig. 4. Vr-Wr graph for fruit length (cm)

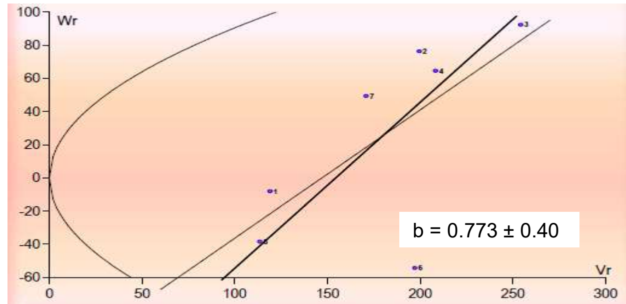

Fig. 5. Vr-Wr graph for average fruit weight (g)

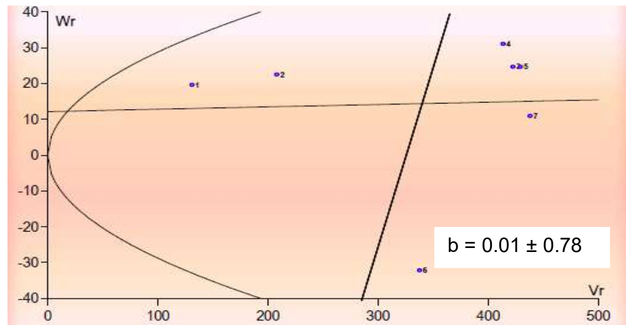

Fig. 6. Vr-Wr graph for number of fruits per plant

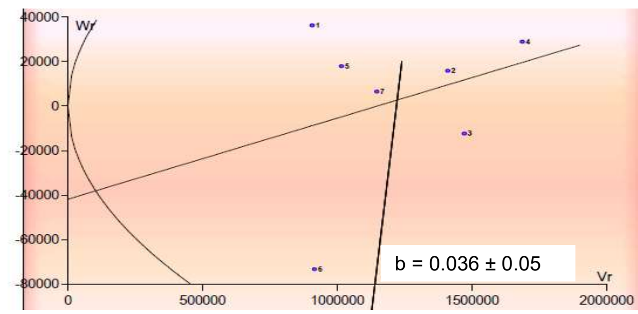

Fig. 7. Vr-Wr graph for fruit yield per plant (g)

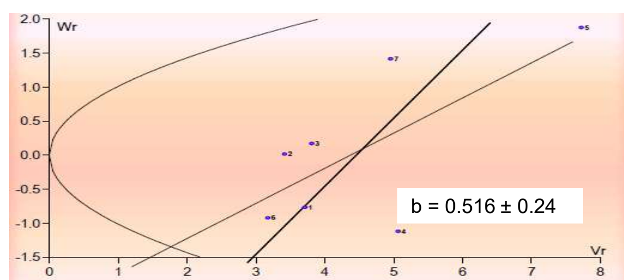

Fig. 8. Vr-Wr graph for ascorbic acid content (mg/100g)

and maximum number of recessive genes was shown by IC 104101. The parents namely Pusa Purple Cluster, IC 261797, IC 203585 and IC 310886 which had a balanced proportion of dominant and recessive genes. Most of the findings results have also been corroborated with observation of Biswajit et al (2004), Quamruzzaman et al (2006), Samlindsujin et al (2020) for various traits in eggplant.

CONCLUSIONS

In the current study, the estimates of component of analysis indicated significant additive and non-additive effects were observed for days to 50% flowering, days to first picking, number of fruits per cluster, fruit length, fruit girth, plant height. The regression coefficient (b) was non-significant for all the traits depicting presence of non-allelic interactions. Graphical analysis depicted partial dominance for all the traits except for days to first picking and average fruit weight for which no dominance was recorded. The parents possessed higher proportion of dominant genes than recessive ones for all the traits except for number of fruits per cluster, fruit length, number of fruits per plant and crop duration.

REFERENCES

Akpan N, Ogbonna P, Onyia V, Okechukwu E, Atugwu A and Dominic I 2016. Studies on the variability and combining ability for improved growth and yield of local eggplant genotypes (*Solanum melongena* L.). *Notulae Scientia Biologicae* **8**(2): 226-231.

Anonymous 2016. Brinjal/Eggplant (*Solanum melongena*), pp 14-17. In: *Package of Practices for Vegetable Crops*. Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, (SKUAST-J), Jammu.

Biswajit P, Singh YV and Ram H 2004. Comparison of graphical and numerical approach for determination of gene action in round fruited brinjal (*Solanum melongena* L.). *Vegetable Science* **31**: 30-35.

Boyaci HF, Prohens J, Unlu A, Gumrukcu E, Oten M and Plazas M 2020. Association of heterotic groups with morphological relationships and general combining ability in eggplant. *Agriculture* **10**(6): 203.

Datta DR, Rafii MY, Misran A, Jusoh M, Yusuff O, Haque MA and Jatto MI 2021. Half diallel analysis for biochemical and morphological traits in cultivated eggplants (*Solanum melongena* L.). *Agronomy* **11**(9): 1769.

Dranca F and Oroian M 2017. Total monomeric anthocyanin, total phenolic content and antioxidant activity of extracts from eggplant (*Solanum melongena* L.) peel using ultrasonic treatments. *Journal of Food Process Engineering* **40**(1): e12312.

Hayman BI 1954. The theory and analysis of diallel cross. *Genetics* **39**: 789-809.

Hussain K, Khan SH, Afroza B, Zehra SB, Dar ZA, Mushtaq F, Mufti S and Nazir G 2018. Graphical analysis for yield and yield attributing traits in brinjal (*Solanum melongena* L.). *Journal of Pharmacognosy and Phytochemistry* **7**(1): 367-370.

Kaushik P, Plazas M, Prohens J, Vilanova S and Gramazio P 2018. Diallel genetic analysis for multiple traits in eggplant and assessment of genetic distances for predicting hybrids performance. *PLoS ONE* **13**(6): e0199943.

Meena OP, Dhaliwal MS, Jindal SK and Rani M 2020. Cytoplasmic male sterile lines with desirable combining ability enhance the concentration of biochemical attributes and total yield in *Capsicum annuum* under temperature stress conditions. *Industrial Crops and Products* **145**: 112107.

Mistry C, Kathiria KB, Sabolu S and Kumar S 2016. Heritability and gene effects for yield related quantitative traits in eggplant. *Annals of Agricultural Science* **61**(2): 237-246.

Patel AL and Kathiria KB 2018. Graphical analysis for fruit yield and its component traits in chilli (*Capsicum annuum* L.). *Electronic Journal of Plant Breeding* **9**(3): 926-932.

Quamruzzaman AKM, Nazim Uddin M, Mashiur Rahman M, Salam MA and Jamil MK 2006. Genetic architecture of yield in eggplant (*Solanum melongena*). *Pakistan Journal of Scientific and Industrial Research* **49**(2): 134-139.

Rani M, Kumar S and Kumar M 2018. Estimation of heterosis for yield and its contributing traits in brinjal. *Journal of Environmental Biology* **39**(5): 710-718.

Samlindsujin G, Karuppaiah P, Anbuselvam Y, Muraleedharan A, Elakkuvan S and Hephzibah Jeevi SS 2020. Graphical analysis for fruit yield and its component traits in brinjal (*Solanum melongena* L.). *Plant Archives* **20**(2): 8030-8034.

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Constraints Faced by Farmers in Commercial Cultivation of Vegetables in Samba district, Jammu and Kashmir, India

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Abstract: Vegetable farmers of district Samba are facing various constraints in vegetable production and therefore present study was conducted in three vegetable growing villages covering marginal, small, and big farmers (20 from each category totaling 60 in number). A pre tested interview schedule was prepared to collect the data and appropriate statistical procedure was employed to analyze the data for different constraints like social, organizational, technology transfer and economic. The mean score for all these constraints were higher among marginal farmers as compared to small and big farmers for vegetable production in Samba district. The study has confirmed that lack of proper follow up service, lack of location specific recommendations, lack of community awareness and lack of effective supervision are also contributing to low production. Thus there is a need to organize training programmes, proper demonstration of improved technologies, and introduction of post-harvest technologies to encourage the farmers for vegetable production so that the farmers become more economically independent. Based on these training needs, farmers, public and private organizations may organize various training cum awareness programmes.

Keywords: Vegetable production, Social, Economic, Organizational constraints, Technology transfer

Vegetables are important constituents of agriculture for attaining food and nutritional security has ability to generate on-farm and off-farm employment. An increase in availability, affordability and consumption of nutrient dense vegetables is one of the ways to prevent malnutrition. India is bestowed with huge diversity of vegetables and is the largest contributors (59.20%) of the total horticultural produce in the country in 2017-18 (Kumar et al 2017). India, with its wide variability of climate and soil, has good potential for growing a wide range of vegetable crops. Since the mid eighties, Government identified horticultural crops as a means of diversification for making agriculture more profitable through efficient land use, optimum utilization of natural resources and creating skilled employment for rural masses, especially women folk with the past efforts rewarding. Area under vegetable cultivation is continuously increasing, mainly due to higher productivity, shorter maturity cycle, high value and greater income leading to improved livelihoods. Production of vegetables is touching new records every year, making it the most favoured agricultural commodity by the farmers. Production during 2017-18 was recorded 184 million tons from 10.3 million hectares, whereas it was less than 20 million tons during independence. This manifold increase needs to be sustained to meet the demand of 1.5 billion people by 2030 (Horticultural Glance, 2018 and https://apeda.gov.in/apedawebsite/six_head_product/FFV.htm). Even though the productivity level of our crops have increased still it will not be sufficient to feed the increasing population. By adopting improved techniques and high yielding varieties, production and productivity can be increased (Sahu et al 2009). In vegetable cultivation, a number of technologies have been developed, but farmers do not show keen interest in adopting this technology. So, to enhance the production and adoption of new farming technology it is imperative to know, why farmers are reluctant in adaptation of this technology. So, to know that what are the constraints faced by farmers in adoption of Modern practice of vegetable cultivation. This study was undertaken at district Samba. Samba has a longitude of 75.1108^{0}E and latitude of 32.553^{0}N and is situated on range of Shivalik hills alongside the bank of river. About two third of the area of Samba is Kandi & rainfed. The area on southern side downside the national highway is irrigated through Ravi Tawi irrigation canal network.

MATERIAL AND METHODS

The study was under taken in three vegetable growing villages of Rajpura, Ghagwal and Nud Blocks of district during the year 2020-21. The block and villages were selected purposively where random sampling technique was followed to select the respondent. It was decided to draw samples from all categories of farmer's i.e., small (<0.5 ha), marginal (0.5-0.9 ha) and large (>0.9 ha) farmers. The criteria of selection were based on the consideration that farmers were growing vegetables constantly and sell them to earn income. The farmers growing vegetables for commercial purpose were selected. A random technique was followed to select 20 vegetable growers from each village. Thus, a total of 60 vegetable growers were finally selected. For analysis of data responses were secured on 3-points scales fitting to the statements as very much (3) much (2) not so much (1). The results were calculated as mean score for each of the constraint (Sharma et al 2010).

$$\text{Mean Score (MS)} = \frac{\text{No. of VM} \times 3) + (\text{No. of M} \times 2) + (\text{No. of NM} \times 1)}{\text{Total No. of VM + M + NM}}$$

The climate of the district being sub-tropical zone is hot and dry in summer and cold in winter and provides enough scope to grow a variety of vegetables in different parts of the district. Being in the foot hills of the mountains nights are bit cooler than that of neighbouring areas of Punjab the scope of vegetable export has also increased. The temperature ranges between 6 degree Celsius and 47 degree Celsius. The average annual rainfall of district Samba is 1100-1250 mm. A number of vegetable crops like knol-khol, peas, beans, tomato, brinjal, chilli, cauliflower, cabbage, onion, okra etc. are grown in the district. The farmers of the area are facing lot of constraints like, social, organizational, economic, technology transfer in cultivation of vegetables. Keeping this in view, the study was made related to constraints associated with vegetable cultivation and to overcome these constraints.

RESULTS AND DISCUSSION

The constraints in vegetable production are many, diversified and differs from individual to individual depending upon their social status, family, requirement, family obligation, cultural background and economic position. For analysis of data the constraints were classified into four groups' namely social, organizational, technology transfer and economic.

Social constraints: The lack of awareness (2.30) followed by Groupism in village, low adoption by neighbours, traditional norms and adverse socio-political system in the villages are the most important constraints which do not permit farmers to accept and adopt new technology in vegetable farming (Table 1). Mostly these constraints are being faced by marginal farmers of the area as compared to small and big farmers except co-ordination among farmers (2.50) which have observed more in the small farmers of the area. Similar findings were reported by Samantaray et al (2009).

Organizational Constraints: Focusing attention towards vegetable farming six important organizational constraints were observed (Table 2). Lack of effective supervision (2.48), irregular visit of extension workers (2.23), lack of timely technical advice (2.16), poor co-ordination among grass root level workers (2.16) was recorded in the marginal farmers while non-availability of production inputs timely (2.0) and low credibility of extension worker (2.06) were identified in both marginal and small farmers as the constraints in vegetable farming system. However, most of them are related to government actions that need to be stream lined to make vegetable farming profitable. These findings have been supported by Samantaray et al (2009) who have observed similar types of constraints being faced by the farmers of Orissa.

Constraints in technology transfer*:* The absence of proper post-harvest technology (2.36), followed by inadequate training programmes, lack of approach to demonstration, non-communication of location specific recommendations, inadequate follow up services for vegetable are the major constraints being faced by the marginal farmers as compared to small and big farmers of the area (Table 3). The other constraints were of low level like non-exposure to mass media lack of land consolidation etc. However, most of them are related to Government actions that need to be stream lined to make vegetable farming profitable. These findings were supported by Meena (2003) and Rai et al (2010).

Economic constraints: The eight economic constraints were identified which seemed to be barrier in increasing

Table 1. Social constraints in vegetable production

Social constraints	Farmers			Mean score		
	Marginal	Small	Large	Marginal	Small	Large
Lack of community awareness	30	18	12	2.30	2.00	1.90
Traditional norms of farmers	35	20	5	2.50	1.75	1.50
Adverse socio-political interference	28	24	8	2.33	1.93	1.73
Low-adoption of by neighbours	32	20	8	2.40	1.80	1.80
Lack of co-ordination of farmers	26	22	12	1.34	1.93	1.83
Groupism	29	20	11	2.30	1.85	1.85

production and productivity of vegetables. Poor marketing facility (2.33) is the most important constraint followed by poor economic status of the farmers (2.26), low risk bearing capacity (2.26), poor transport facility (2.20), absence of storage facility (2.12) and high cost of production (2.12) are being faced by the marginal farmers. The subsequent factors were non-availability of agriculture loan and complicated procedures to avail loan mentioned by the sample under study. Corroborative results have been given by Sharma et al (2008) and Samantaray et al (2009).

The constraints like lack of post harvest technologies, absence of storage facilities, inadequate training programme and inadequate demonstration of new technology are faced by the growers. The study has confirmed that lack of proper follow up service, lack of location specific recommendations, lack of community awareness and lack of effective supervision are also contributing to low production. Thus there is a need to organize training programmes, proper demonstration of improved technologies, and introduction of post harvest technologies to encourage the farmers for vegetable production so that the farmers become more economically independent. Moreover, it will improve nutritional status of the family. Based on these training needs, farmers, public and private organizations may organize various training cum awareness programmes.

Table 2. Organizational constraints in vegetable production

Organizational constraints	Farmers			Mean score		
	Marginal	Small	Large	Marginal	Small	Large
Poor co-ordination and co-operation among extension worker	22	26	12	2.16	2.06	1.76
Low credibility of extension worker	20	24	16	2.06	2.06	1.86
Lack of timely advice and guidance by extension personnel	24	22	14	2.16	1.96	1.86
Timely non availability of inputs for production	20	20	20	2.0	2.0	2.0
Irregular visit of extension worker	26	22	12	2.23	1.93	1.83
Lack of effective supervision	28	23	9	2.48	1.91	1.76

Table 3. Constraints in transfer of technology to farmers

Technology transfer	Farmers			Mean score		
	Marginal	Small	Large	Marginal	Small	Large
Inadequate training of farmers	24	26	12	2.26	2.10	1.83
Inadequate demonstration of new technology	21	24	15	2.10	2.05	1.85
Inadequate follow-up services	23	23	14	2.15	2.00	1.85
Lack of location specific recommendation	24	22	14	2.16	1.96	1.86
Lack of technical know-how	28	22	10	2.30	1.90	1.80
Lack of soil testing facilities	19	22	19	2.0	2.0	1.95
Inadequate availability of mass media sources of information	21	20	19	2.03	1.98	1.98
Lack of land consolidation	18	22	20	1.96	2.06	1.96
Lack of post-harvest technology	28	26	6	2.36	1.96	1.66

Table 4. Economic constraints in increasing production

Economic constraints	Farmers			Mean score		
	Marginal	Small	Large	Marginal	Small	Large
High cost of technology	22	23	15	2.12	2.02	1.86
Poor economic condition of farmers	28	26	6	2.26	1.96	1.66
Non-availability of Argil. Credit	20	20	19	1.98	1.96	1.95
Complicated procedure to avail loans	20	20	19	1.98	1.96	1.95
Low risk bearing capacity	28	26	6	2.26	1.96	1.66
Poor transportation	24	24	12	2.20	2.00	1.80
Poor marketing facility	27	26	7	2.33	1.98	1.68
Absence of storage facility	22	23	15	2.12	2.02	1.86

REFERENCES

Horticultural Statistic at Glance 2018. Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India

Kumar R, Bhatia AK and Singh D 2017. Present status of vegetable production and their impact in human nutrition. *International Journal of Agriculture Sciences* **9**(55): 4945-4949.

Meena KC 2003. Constraints faced by the farmers in adoption of improved cultivation of cabbage in Udaipur district of Rajasthan. *Indian Research Journal of Extension Education* **3**(2): 69-71.

Rai DP and Singh Bhupendra 2010. Extents of knowledge and constraints in cotton production technology in Madhya Pradesh. *Indian Research Journal of Extension Education* **10**(2): 78-80.

Sahu RP, Sachan VK, Singh Raman Jeet and Singh Khilendra 2009. Knowledge gap of farm women in vegetable cultivation. *Journal of Communication Studies* **27**(2): 83-87.

Samantaray SK, Prusty S and Raj RK 2009. Constraints in vegetable production experiences of tribal vegetable growers. *Indian Research Journal of Extension Education* **9**(3): 32-34.

Sharma Arun Kumar, D Uma Maheshwer Rao and Lakhan Singh. 2008. Achievement motivation in vegetable growers. *Indian Research Journal of Extension Education* **8**(1): 79-82.

Sharma Neerja, Arora RK and Sanjay Kher 2010. KVK trainings for the farmers in hilly areas of Poonch district a need of hour. *Journal of Hill Agriculture* **1**(2): 140-145.

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Standardization of Micropropagation Protocol in Garden Pea (*Pisum sativum* L.)

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Abstract: Garden Pea, being aleguminous vegetable crop is not very responsive to growth and regeneration under *in vitro* culture. Therefore, a reliable tissue culture protocol has always been difficult to establish in garden pea (*Vicia faba* L.) due to its recalcitrant nature. In the present investigation a rapid, reproducible and efficient tissue culture protocol was developed for garden pea. The variety used was P-89, a high yielding and widely cultivated garden pea variety developed by PAU, Ludhiana, Two explants i.e. seed and embryo were used for establishing aseptic cultures.The results obtained during different *in vitro* experiments revealed pre-treatment of seeds with Bavistin (0.2%) + Streptomycin (0.02%) for 10 minutes followed by 70% ethanol dip and 2% sodium hypochlorite treatment for 3 minutes resulted in highest survival for both the explants viz., embryo and seed(68.24 and 50.64%, respectively). Among all the regeneration medium, R_{16} - MS+2.00 mg/l BAP and 1.00 mg/l Kinetin was superior in terms of early shoot initiation and highest morphogenetic response in embryo (15.00 days and 73.33%) as well as seed (17.23 days and 53.76%). Embryo explant was more superior as compared to seed explant for culture establishment. In relation to multiple shoot formation, M_4 -MS + 2.00mg/l BAP + 1.00 mg/l TDZ produced the earliest and considerably superior response (19.00 days, 5.50 shoots/explant and.56 cm shoot length, respectively). For rooting, R_3 i.e. MS+ 1.00 mg/l IBA was found to be the optimum concentration forming maximum number of roots (3.67) and root length (4.24cm). The *in vitro* raised seedlings were hardened in plastic cups containing sterilized potting mixture comprised of FYM, sand and vermicompost in 1:1:1 ratio under partially controlled conditions in green house for 3 weeks before field transfer.

Keywords: Feasibility, Garden Pea, *In vitro,* Sterilization, Tissue culture

Garden pea (*Pisum sativum* L.), a member of the Fabaceae family, is a widely cultivated cool-season vegetable crop in temperate and sub-tropical climates around the world. In the recent years, consumers and researchers have paid much attention to the nutritional and physiological benefits of peas and their by-products that are enhanced with biomolecules. It is preferable to develop pea cultivars with increased abiotic stress tolerance and pest and disease resistance. The Fabaceae species in general are difficult to regenerate *in vitro* due to recalcitrant nature, high genotypic specificity and are not amendable to *in vitro* propagation (Pratap et al 2018). The development of transgenic plants for many legumes is severely hampered by this recalcitrance towards in vitro regeneration since molecular genetics advances, such as gene over-expression, gene suppression, promoter analysis and T-DNA tagging, require effective transformation systems. Efficient tissue culture is an essential step in validating and using the data produced by these potent molecular tools. The pre-requisite for both genetic transformation and other tissue-culture derived techniques is the implementation of robust protocols for regeneration to generate genetic diversity such as somaclonal variation, *in vitro* mutagenesis, doubled haploids culture and wide hybridization (Dita et al2006). Very few or lesser attempts have been made to develop a reliable *in vitro* protocol in pea. The presence of totipotent tissues that react well to *in vitro* methods is a requirement for the success of tissue culture-based approaches in crop plants (Pratap et al 2010). Due to their juvenile nature, embryo culture is a convenient beginning for the establishment of shoot cultures and a critical milestone for mass micropropagation of plants from a small number of original seeds for many recalcitrant species (Khalafalla et al 2011). Establishment of aseptic cultures from field grown explants (seed, embryo, nodal cutting, leaf etc.) is first basic step for carrying out any further *in vitro* studies in the laboratory. Thus, the development of a specific sterilization procedure for field grown explants is a crucial step before identifying the growth stage for the collection of plant materials and perfecting the medium composition for multiplication of plants. Therefore, an attempt was made to develop a reliable and efficient protocol for obtaining rapid shoot multiplication using seed and embryo explants of Garden pea var. P-89 under *in vitro* conditions.

MATERIAL AND METHODS

Genotype and explants used: Two explants viz., seed and embryo were used for standardization of micropropagation protocol in garden pea variety 'P-89'. The experiments were conducted in the Plant Tissue Culture Laboratory of the Division of Vegetable Science and Floriculture, SKUAST-Jammu during the year 2020-21.

Sterilization of explants: To standardize an effective sterilization technique for establishment of contamination free cultures in laboratory, the seeds were washed with water and few drops of Tween-20 for 15-20 minutes in order to clear the debris. The explants were surface sterilized with Bavistin (0.2%) + Streptomycin (0.02%) for 10 minutes followed by 70% ethanol dip and treatment with 2% NaOCl for varying time duration (1, 2 &3 minutes). Thereafter, explants were rinsed in distilled water for 4-5 minutes rapidly.

Different media used: Different concentration and combinations of growth regulators (auxins and cytokinin) have been used to optimize the media concentration for obtaining morphogenetic responses at various stages i.e. shoot initiation, shoot multiplication and elongation and finally rooting to obtain *in vitro* raised pea plantlets. The observations on different parameters were recorded after four weeks of culture.

Hardening: The *in vitro* raised seedlings were hardened in plastic cups containing sterilized potting mixture comprised of FYM, sand and vermicompost in 1:1:1 ratio underpartially controlled conditions in green house for 3 weeks before field transfer.

Culture conditions: All the cultures were incubated at 25°C with a 16 and 8-h light and dark photoperiod using cool white fluorescent tubes and an irradiance of 40 μmol m^{-2} s^{-1}.The photoperiod of incubation room was controlled using an electronic timer.

Statistical analysis: On the basis of observations averaged from 10 flasks/ test tubes per treatment replicated thrice, data was recorded from the *in vitro* experiments laid in Completely Randomized Design. Multiple comparison among the different treatments was undertaken following Tukey test using R studio software (R Core Team 2021).

RESULTS AND DISCUSSION

The results obtained from the various experiments conducted in Plant Tissue Culture laboratory to access the feasibility of *in vitro* seed / embryo culture for development of micropropagation protocol have been described in detail under the following sub-headings:

Refinement of sterilization procedure to enhance culture establishment: The fundamental step for conducting *in vitro* laboratory research is the establishment of aseptic cultures from field grown explants (seed, embryo, nodal cutting, leaf). It was essential to standardise the surface sterilization procedure before initiating tissue culture of *Pisum sativum*utilizing seeds and embryos as explants in order to establish aseptic cultures. It has been demonstrated that pre-treating explants with fungicides and bactericides before using surface sterilant significantly reduces contamination levels (Panathula et al 2014). Ethanol (70%) and sodium hypochlorite (2%) were employed in combination as two surface sterilant for varying periods of time (1, 2 and 3 minutes). The different sterilizing treatments affect the percentage of seeds and embryo explants that survive (Table 1). The treatment combination with the highest survival rate for both explants, the embryo (68.24%) and seed (50.64%), consisted of pre-treatment with Bavistin (0.2%) and Streptomycin (0.02%) for 10 minutes, followed by an ethanol dip (70%) and sodium hypochlorite (2%) treatment for 3 minutes. The results further revealed that when exposed to any change in time period, explants' survivability significantly decreased. The treatment combination comprising of 5 minutes pre-treatment with Bavistin (0.2%) and streptomycin (0.02%) followed by 70% ethanol dip and sodium hypochlorite (2%) treatment for 1 minute recorded minimum survival percentage in both the explants viz., embryo (5.01%) and seed (3.28%). The findings are in accordance with the research of Firoz et al (2016) and Zinabu et al (2018) on the sterilization of cucumber seeds and inset explants, respectively.

Effect of different explants and MS media concentrations on shoot initiation: For shoot induction using embryo and seed as explants, 18 different MS medium concentrations fortified with various dosages of BAP alone (0.50, 1.00, 1.50, 2.00, 3.00, and 4.00 mg/l) and in conjunction with Kinetin (0.50 and 1.00 mg/l) were used. The

Table 1. Refinement of sterilization procedure to enhance culture establishment

Time duration		Explant survival (%)	
Pre-treatment with 0.2% Bavistin + 0.02% Streptomycin	70% ethanol dip followed by treatment with 2 % NaOCl	Embryo	Seed
5	1 minute	5.01^{h}	3.28^{h}
	2 minutes	10.00^{g}	6.05^{g}
	3 minutes	20.76^{e}	14.00^{f}
10	1minute	34.56^{d}	25.75^{d}
	2 minutes	56.69^{b}	41.16^{b}
	3 minutes	68.24^{a}	50.64^{a}
20	1minute	55.70^{b}	25.48^{d}
	2 minutes	47.50^{c}	28.58^{c}
	3 minutes	15.04^{f}	16.04^{e}

Means of all the characters followed by different letters within a column are significantly different accordingly to Tukey's test ($P < 0.05$)

morphogenetic response varied greatly, ranging between 12.67 to 73.33% in case of embryo explants and 8.67 to 53.76% in seeds. Among all the regeneration medium, significantly higher morphogenetic response for both the explants was recorded in R_{16}- MS medium fortified with 2.00 mg/l BAP and 1.00 mg/l Kinetin (73.33, 53.76) followed by two regeneration medium, viz., R_{10} – MS medium fortified with 2.00 mg/l BAP and 0.50 mg/l Kinetin (70.67, 51.00) and R_{11}- MS medium fortified with 3.00 mg/l BAP and 0.50 mg/l Kinetin (64.00,50.33). The lowest morphogenetic response was observed in regeneration medium, R_1, which is MS medium enriched with 0.50 mg/l BAP (12.67 and 8.67, respectively.)As regards to earliness of the response, expressed as days taken to shoot initiation, minimum number of days to shoot initiation (15.00 and 17.23) was recorded in R_{16}-MS medium fortified with 2.00 mg/l BAP and 1.00 mg/l Kinetin which outperformed all other medium. However, maximum days taken to shoot initiation (26.25 and 28.52) was recorded in R_1 - MS basal medium fortified with 0.50 mg/l BAP among all the medium. The overall best and earliest shoot initiation response was obtained in regeneration medium R_{16} i.e., MS medium fortified with 2.00 mg/l BAP + 1.00 mg/l Kinetin in embryo explants (Table 2, Plate1, A and B) and with profuse shoot primordia emergence when seeds were used as explants (Plate 1: C and D).The results revealed that for *in vitro* shoot initiation, embryo explants were superior to seeds, with a higher morphogenetic response and earlier shoot induction. The study corroborate with the findings of Rajput and Singh (2010) that pea embryo explants were superior than other explants.

Effect of various MS media concentrations and combinations on shoot multiplication: Single micro shoots (3-4 cm) were inoculated on MS media fortified with BAP (2.00, 3.00, and 4.00 mg/l) and TDZ (0.50 and 1.00 mg/l) (Table 3). Minimum days to multiple shoot formation (19.00) were in M_4 - MS medium fortified with 2.00 mg/l BAP and 1.00 mg/l TDZ followed by M_1-MS medium fortified with 2.00 mg/l BAP and 0.50 mg/l TDZ (22.17). The maximum number of days to multiple shoot development (28.50) were observed in the multiplication medium, M_6- MS media enriched with 4.00 mg/l BAP and 1.00 mg/l TDZ. However, in multiplication medium, M_6- MS medium enriched with 4.00 mg/l BAP and 1.00 mg/l TDZ, the maximum days to multiple shoot development (28.50) were observed. The maximum number of shoots per explant were in M_4 - MS medium fortified with 2.00 mg/l BAP and 1.00 mg/l TDZ, followed by M_5 - MS medium fortified with 3.00 mg/l BAP and 1.00 mg/l TDZ (4.50), while rest of the medium exhibited an average

Table 2. Effect of different explants and MS media concentrations on shoot initiation

Regeneration medium R*	Concentrations used (mg/l)		Morphogenetic response (%)		Days taken to shoot initiation	
	BAP	Kinetin	Embryo	Seed	Embryo	Seed
R_1	0.50	0.00	12.67^{k}	8.67^{a}	26.25^{j}	28.52^{a}
R_2	1.00	0.00	18.33^{j}	16.67^{b}	25.25^{i}	27.67^{ab}
R_3	1.50	0.00	20.00^{j}	28.33^{bc}	24.00^{h}	26.00^{bc}
R_4	2.00	0.00	38.67^{i}	33.00^{bc}	24.45^{g}	28.00^{ab}
R_5	3.00	0.00	40.33^{hi}	35.67^{cd}	24.65^{fg}	21.00^{efg}
R_6	4.00	0.00	49.67^{g}	30.00^{cd}	23.56^{h}	20.54^{fg}
R_7	0.50	0.50	50.00^{def}	38.33^{cd}	23.66^{ef}	22.54^{ef}
R_8	1.00	0.50	54.00^{ef}	39.67^{cd}	22.00^{e}	20.43^{fg}
R_9	1.50	0.50	56.33^{def}	43.67^{cde}	22.66^{d}	20.00^{g}
R_{10}	2.00	0.50	70.67^{a}	51.00^{i}	17.00^{ab}	22.00^{efg}
R_{11}	3.00	0.50	64.00^{b}	50.33^{hi}	18.00^{b}	22.34^{ef}
R_{12}	4.00	0.50	61.00^{bc}	46.33^{def}	21.67^{cd}	25.00^{cd}
R_{13}	0.50	1.00	52.33^{fg}	39.00^{def}	22.18^{e}	20.21^{fg}
R_{14}	1.00	1.00	57.33^{cde}	44.00^{ef}	21.00^{d}	21.95^{efg}
R_{15}	1.50	1.00	58.67^{cd}	45.33^{fg}	20.00^{d}	23.00^{de}
R_{16}	2.00	1.00	73.33^{a}	53.76^{j}	15.00^{a}	17.23^{h}
R_{17}	3.00	1.00	43.33^{h}	48.67^{gh}	19.00^{bc}	20.45^{fg}
R_{18}	4.00	1.00	17.33^{j}	46.00^{bc}	24.00^{cd}	21.24

Means of all the characters followed by different letters within a column are significantly different accordingly to Tukey's test ($P < 0.05$)

response. However, M_3-MS media fortified with 4.00 mg/l BAP and 0.5 mg/l TDZ showed the minimum number of shoots per explant (3.01). Multiplication medium, M_4- MS medium supplemented with 2.00 mg/lBAP and 1.00 mg/l TDZ recorded the maximum average length of shoot (3.56 cm), followed by M_5- MS medium enriched with 3.00 mg/l BAP and 1.00 mg/lTDZ (2.92 cm) whereas minimum length of shoot (1.96 cm) was recorded in M_3- MS medium fortified with 4.00 mg/l BAP and 0.50 mg/l TDZ. Therefore it was revealed that, among all the multiplication medium, medium M_4 with MS media fortified with 2.00 mg/l BAP and 1.00 mg/l TDZ provided the earliest and greatest outcomes in terms of multiple shoot development (Plate 2). However, at higher BAP concentrations, a noticeable drop in the number of shoots and the average length of shoots was observed. This reduction might be attributed to larger doses of BAP not expressing superiority because of their detrimental effects at higher concentrations (Waseem et al2011). The synergistic effect of BAP and TDZ on the development of multiple shoots has been observed in chrysanthemum by Sushmarani et al (2021).

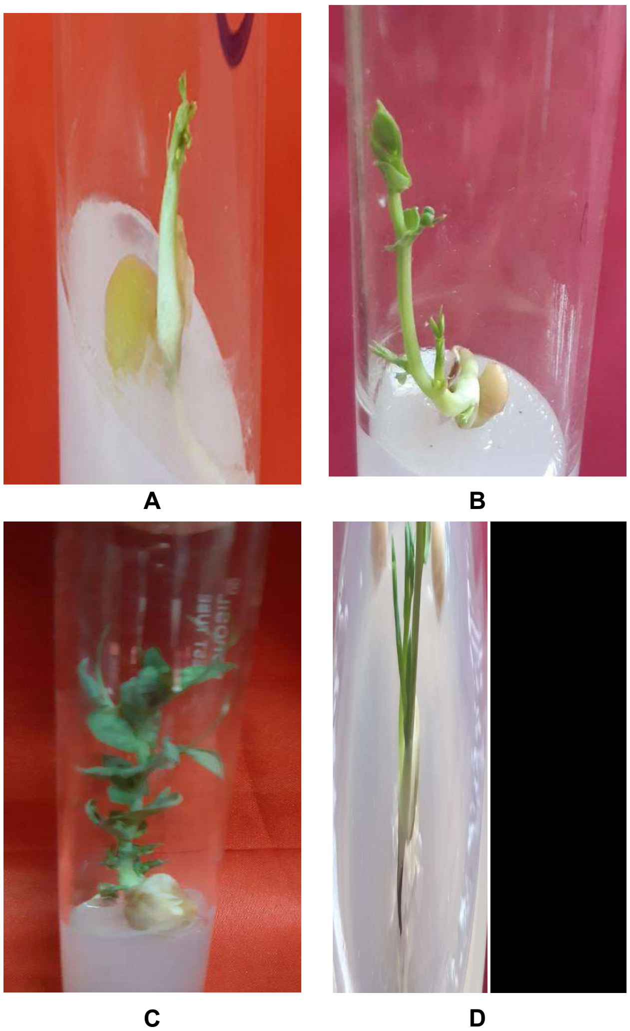

Plate 1. A, B,C and D: Shoot initiation from different explants (embryo & seed) in MS medium fortified with 2.00 mg/l BAP + 1.00 mg/l Kinetin

Effect of different concentrations of IBA on rooting response: Individual shoots were cultured on MS medium enriched with different doses of IBA (0.50, 1.00, 1.50, and 2.00 mg/l) to induce roots in *in vitro* multiplied shoots and the data regarding differential response of various rooting media has been shown in Table 4. The rooting media R_2- MS

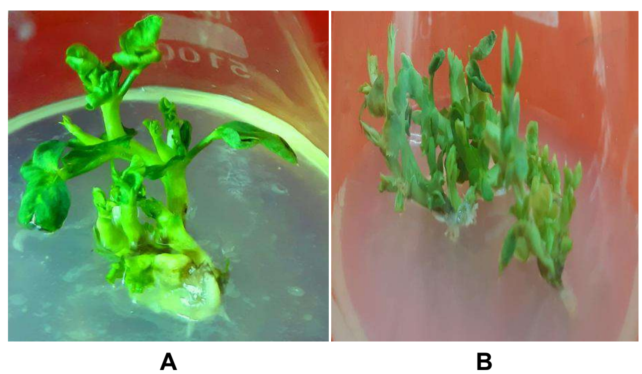

Plate 2. A and B: Multiple shoot formation on MS medium fortified with 2.00 mg/l BAP + 1.00 mg/l TDZ

Table 3. Effect of various MS media concentrations and combinations on shoot multiplication

Multiplication medium M*	Concentrations used (mg/l)		Days taken to formation of multiple shoot	No. of shoots/ explant	Average length of shoot (cm)
	BAP	TDA			
M_1	2.00	0.50	22.17^{d}	4.11^{c}	2.77^{bc}
M_2	3.00	0.50	24.00^{c}	4.00^{c}	2.56^{c}
M_3	4.00	0.50	25.50^{b}	3.01^{e}	1.96^{e}
M_4	2.00	1.00	19.00^{e}	5.50^{a}	3.56^{a}
M_5	3.00	1.00	25.00b^{c}	4.50^{b}	2.92^{b}
M_6	4.00	1.00	28.50^{a}	3.50^{d}	2.22^{d}

Means of all the characters followed by different letters within a column are significantly different accordingly to Tukey's test ($P < 0.05$)

Table 4. Effect of different concentrations of IBA on rooting response

Rooting medium R*	Concentrations used IBA (mg/l)	No. of roots / shoot	Average length of root (cm)
R_0	0.00	1.04^d	2.02^d
R_1	0.50	2.50^b	3.11^b
R_2	1.00	3.67^a	4.24^a
R_3	1.50	1.96^c	2.50^c
R_4	2.00	1.23^d	2.02^d

Means of all the characters followed by different letters within a column are significantly different accordingly to Tukey's test ($P < 0.05$)

A B

Plate 3. A and B: Root development on MS medium + 1.00 mg/l IBA

medium fortified with 1.00 mg/l IBA worked better than any other medium, generating the maximum number of roots/shoots (3.67), and was followed by R_1- MS medium fortified with 0.50 mg/l IBA (2.50) while rest of the rooting medium showed average to below average rooting response, R_0-MS basal medium exhibited poor response and produced only 1.04 roots per shoot. R_2- MS medium enriched with 1.00 mg/l IBA also had the highest root length (4.24 cm), followed by R_1- MS medium fortified with 0.50 mg/l IBA (3.11cm). Thus, it can be inferred that, of all the medium tested, R_2-MS medium enriched with 1.00 mg/l IBA showed the best rooting response (Plate 3). The rooting response decreased with rise in level of IBA concentrations may be due to the fact that roots need lower concentration of auxin for growth, but more auxin slows root growth significantly since it causes the generation of ethylene, which inhibits root growth at this concentration (Taiz and Zeiger, 2002). The results in harmony with those of Khalafalla et al (2010) and Mohapatra et al (2018).

CONCLUSION

A reliable and efficient *in vitro* protocol has been standardized for stages such as shoot bud initiation, multiplication, and rooting by using different hormonal concentrations to obtain micro propagated pea plantlets. It can be concluded that sterilization procedure consisting of pre-treatment of seeds with Bavistin (0.2%) + Streptomycin (0.02%) for 10 minutes followed by 70% ethanol dip and 2% sodium hypochlorite treatment for 3 minutes resulted in highest survival for both the explants viz., embryo and seed. Best shoot initiation response was observed on MS media fortified with 2.00 mg/l BAP and 1.00 mg/l Kinetin in both the explants. Embryo explant was found to be more superior as compared to seed explant for culture establishment. On MS medium fortified with 2.00mg/l BAP and 1.00 mg/l TDZ, minimum days to formation of multiple shoots (19.00), highest no. of shoots/ explant (5.50) and average length of shoot (3.50cm) were reported for shoot multiplication. For rooting, MS medium fortified with 1.00 mg/l IBA was found to be the optimum concentration forming maximum number of roots (3.67) and root length (4.24cm). Finally, it can be stated that the present investigation will be a boon to pea growers in the Jammu region, as it will provide quality planting material which could be further used in the crop improvement programmes and genetic transformation studies.

REFERENCES

Dita MA, RispailN, Prats E, Rubiales D and Singh KB 2006. Biotechnology approaches to overcome biotic and abiotic stress constraints in legumes. *Euphytica* **147**: 1-24.

Firoz Alam M, Ekhlas Uddin M, Ruhul Amin M, Abdur Razzak M, Manik MA and Khatun M 2016. Studies on the effect of various sterilization procedure for *in vitro* seed germination and successful micropropagation of *Cucumis sativus*. *International Journal of Pure and Applied Bioscience* **4** (1): 75-81.

Khalafalla M, Abd Elaleem KG and Modawi RS 2010. Callus formation and organogenesis of potato (*Solanum tuberosum* L.) cultivar Almera. *Journal of Phytology* **2**(5): 40-46.

Khalafalla M, Daffalla HM, Abdellatef E, Elsadig Agabna E and El-shemy HA 2011. Establishment of an *in vitro* micropropagation protocol for *Boscia senegalensis* (Pers.) Lam. ex Poir. *Journal of Zhejiang University-Science B (Biomedicine & Biotechnology)* **12**(4): 303-312.

Mohapatra P, Batra VK, Kajla S and Poonia AK 2018. *In vitro* multiplication and microtuberization of *Solanum tuberosum* L. using different growth regulators. *Vegetos* **31**(2): 114-122.

Pratap A, Prajapati U, Singh CM, Gupta S, Rathore M, Malviya N, Tomar R, Gupta AK, Tripathi S and Singh NP 2018. Potential, constraints and applications of in vitro methods inimproving grain legumes. *Plant Breeding* **137**: 235-249.

Pratap A, Choudhary AK and Kumar J 2010. In vitro techniquestowards genetic enhancement of food legumes: A review. *Journal of Food Legumes* **23**: 169-185.

Panathula CS, Mahadev MDN and Naidu CV 2014. The Stimulatory Effects of the antimicrobial agents Bavistin, Cefotaxime and Kanamycin on *in vitro* plant regeneration of *Centella asiatica* (L.): An important Antijaundice medicinal plant. *American Journal of Plant Sciences* **5**(3): 279-285.

Rajput VD and Singh NP 2010. Studies on *in vitro* regeneration and direct organogenesis in Pea (*Pisum sativum* L.). *Indian Journal of Plant Physiology* **15**(3): 246-249.

R Core Team 2021. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Sushmarani YS, Venkatesha Murthy P and Deeksha Raj N 2021. Influence of BAP with TDZ growth regulators on *in vitro* regeneration in chrysanthemum (*Dendranthema grandiflora* T.) cv. Marigold. *Journal of Pharmacognosy and Phytochemistry* **10**(2): 1171-1176.

Taiz L and Zeiger E 2002. Mineral Nutrition: *Plant Physiology*. 2nd ed. Sinaver Associates Inc. Pub. p. 67-86.

Waseem K, Jilani MS, Jaskani MJ, Khan MS, Kiran M, Khan GU 2011. Significance of different plant growth regulators on the regeneration of chrysanthemum plantlets (*Dendranthema morifolium* L.) through shoot tip culture. *Pakistan Journal of Botany* **43**(4): 1843-1848.

Zinabu D, Gebre E and Daksa J 2018. Explants sterilization protocol for *In-vitro* propagation of elite Enset (*Ensete ventricosum* (Welw.) Chessman) cultivars. *Asian Journal of Plant Science and Research* **8**(4): 1-7.

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Effect of Trash Management of Sugarcane on Soil Organic Carbon Buildup and Sustaining Yields of Successive Ratoon Crop in Khammam District of Telangana

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Abstract: A field study was conducted to assess the impact of sugarcane trash, a crop residue constituting 10-20% of the weight of cane harvested was either burnt, removed, retained and shredding as mulch in two successive ratoon crops in Khammam District of Telangana during 2017-2020. Within two years trash shredding and retaining as mulch increased the soil organic carbon by 0.06% and 0.09%, while trash burning decreased by 0.06% in two successive ratoon crops. Trash shredding recorded the highest values of number of tillers (95.7 and 97.8 thousand per ha), cane height (214.7 and 216.8 cm), no of inter nodes (25.4 and 25.8), the cane girth (3.4 and 3.5 cm), average cane weight (1.53 and 1.55 kg), no of millable canes (78,436 and 79,543 per ha) and cane yield (120.5 and 123.8 t/ha). However, trash retained practice was at par with trash shredding. The lowest number of tillers (87.3 and 83.2 thousand per ha), cane height (207.0 and 201.3 cm), no of inter nodes (23.2 and 22.2), cane girth (2.8 and 2.6 cm), average cane weight (1.46 and 1.44 kg), no of millable canes (75,648 and 72,874 per ha) and cane yield (105.4 t/ha) were recorded with trash burnt practice in second ratoon crop. Trash shredding practice was found as best practice among all the trash management practices in sugarcane crop.

Keywords: Bulk density, Organic carbon, Sugarcane, Trash shredding

In the conventional practice, the sugarcane trash after harvesting is usually burnt in the field which ultimately leads to loss of nutrients, degrades soil fertility and the environment. High C: N ratio, high fibre content and lack of proper composting techniques prolong the decomposition of trash in the field. Besides the loss of organic matter and plant nutrients, burning of crop residues results in increase of atmospheric pollution due to the emission of toxic gases like methane and carbon dioxide. Surface organic mulch such as sugarcane trash is used to conserve soil moisture, moderating soil temperature extremes, checking weed growth and adding organic matter to soils (Malik 2014). Thereby organic mulches create better physical. Chemical and biological environment of soils and in turn, improves crop productivity. Crop residues incorporation in soil is very important source of organic manure. Sugarcane produces nearly 10-12 tones dry leaves (trash) per hectare per year. The trash contains appreciable amount of NPK and other micro and secondary nutrients. In situ trash management can be a good alternative option to mitigate these problems. Similarly, the mechanical handling and incorporation of trash will help to enhance crop yield and improve soil health. The objective of this study was to find out the impact of trash management strategies on the cane yield, organic carbon and bulk density of the soil.

MATERIAL AND METHODS

The adoptive research was conducted at farmer's field during 2017- 2020 with plant crop and two ratoon crops in five locations viz., Rajeswaripuram ($17^{0}.82^{1}$ 16 N $80^{0}.26^{1}$ 22 E), Chennaram ($17^{0}.106^{1}$ 19 N $80^{0}.81^{1}$ 16 E), Kalluru ($17^{0}.102^{1}$ 42 N $80^{0}.854^{1}$ 26 E), Kothuru ($17^{0}.82^{1}$ 23 N $80^{0}.36^{1}$ 48 E) and Pynampalli ($17^{0}.84^{1}$ 32 N $80^{0}.36^{1}$ 57 E) with four treatments replicated five times in a randomized block design. The soil was sandy loam with a pH of 7.38; organic C, 0.54%; available N, 240 kg/ha; P, 48 kg/ha; and K, 300 kg ha^{-1}. The sugarcane crop (Co 86032) was planted under 90 cm spacing on 21 April, 2017 and harvested on 20 February, 2018. Subsequently, two ratoon crops were raised in succession with the above-mentioned trash management practices. Recommended dose of fertilizers, i.e., 280:60:120 kg N: P_2O_5: K_2 O/ha was adopted. Full dose of P was applied in furrows before planting and N and K were applied in two splits in plant crop as well as ratoon crops, and irrigated the main crop through furrow method and flood irrigation to the ratoon crop. During the experimentation, irrigation scheduling was done once in 8, 10, and 15 days at germination (up to 35 DAP), tillering (36-100 DAP), grand growth (101- 270 DAP) and maturity (271 days onward) stages of the cane, respectively. At harvest, number of millable canes (NMC), cane height, cane girth, single cane weight, cane yield was recorded. After harvest of the crops, soil samples were analyzed for organic carbon (Walkley and Black 1934), available N with alkaline $KMnO_4$ method (Subbaiah and Asija 1956), 1 N NH_4OAc-extractable K (Hanway and Heidal 1952) and 0.5 M $NaHCO_3$ (pH 8.5)-extractable P (Olsen et al 1954). Bulk density was measured by a core sampler (Blake and Hartge 1986).

RESULTS AND DISCUSSION

Growth attributes: Growth attributes of sugarcane were significantly influenced by trash management practices. Significantly higher number of tillers (95.7 and 97.8 thousand per ha), cane height (214.7 and 216.8 cm) and inter nodes (25.4 and 25.8) were recorded with trash shredding practice over trash burnt and trash removal followed by trash retained practice in both ratoon crops. It might be improved the soil fertility with obvious increase of organic matter, as well as decrease in pH of the soil through humification with trash shredding practice over all the practices. The results of the present experiment corroborated with the findings Ahmed et al (2014) and Suma et al (2015). The lowest growth attributes were recorded under trash burnt practice over all the treatments. The lowest number of tillers (87.3 and 83.2 thousand per ha) counted at 120 days after planting (DAP) as well as cane height (207.0 and 201.3 cm) and no of inter nodes (23.2 and 22.2) were recorded under trash burnt practice after successive two ratoon crops due to loss of soil fertility by decrease of microfauna activity in the soil with limited moisture conservation, loss of organic carbon by the increase of soil temperature with burnt of trash in the field similar reports were confirmed by Flavio et al (2013) and Henrique et al (2013).

Yield attributes: The yield attributes of sugarcane were significantly influenced by trash management practices. The cane girth (3.4 and 3.5 cm), average cane weight (1.53 and 1.55 kg) and no of millable canes (78,436 and 79,543 thousand per ha) was significantly improved with trash shredding practice over trash burnt and trash removed practices. Improvement in soil fertility due to trash shredding might have been responsible for such an effect and also improve the availability of nutrients from soil to the successive ratoon crops through fast decomposition of trash by shredding into small pieces in the field, as well as Increase in NMC and cane yield in trash shredding plot were attributed to higher soil moisture content and reduction in soil temperature then followed by trash retained practice shown better performance over trash burnt and trash removed practices. Similar trend was observed by Graham et al (2000) and Ridge (2003) and Munoz-Arboleda et al (2011). The lowest yield attributes, average cane girth (2.8 and 2.6 cm), average cane weight (1.46 and 1.44 kg) and no of millable canes (75,648 and 72,874 thousand per ha) were observed with trash burnt due to decreased availability of nutrients by poor organic matter content of the soil as well as less biological activity of microorganisms in soil with burning of trash increased the soil temperature Kumar et al (2015) and Carvalho et al 2017).

Table 1. Effects of different trash management practices on growth attributes after successive harvests of sugarcane in a ratoon system

Treatment	Tillers count (“000/ha)			Cane height (cm)			No. of internodes		
	Plant crop	Ratoon 1	Ratoon 2	Plant crop	Ratoon 1	Ratoon 2	Plant crop	Ratoon 1	Ratoon 2
T_1-Trash burnt	85.4	87.3	83.2	204.6	207.0	201.3	22.5	23.2	22.2
T_2-Trash removed	85.4	88.4	85.5	204.6	208.2	202.5	22.5	23.3	22.5
T_3-Trash retained	85.4	91.4	92.1	204.6	210.5	212.6	22.5	24.3	24.4
T_4-Trash shredding	85.4	95.7	97.8	204.6	214.7	216.8	22.5	25.4	25.8
C.D (p=0.05)	-	4.4	7.4	-	6.6	12.0	-	2.0	3.1

Table 2. Effects of different trash management practices on yield attributes after successive harvests of sugarcane in a ratoon system

Treatment	Cane girth (cm)			Average cane weight (kg)			Number of millable cane (NMC/ha)		
	Plant crop	Ratoon 1	Ratoon 2	Plant crop	Ratoon 1	Ratoon 2	Plant crop	Ratoon 1	Ratoon 2
T_1-Trash burnt	2.9	2.8	2.6	1.45	1.46	1.44	73,675	75,648	72,874
T_2-Trash removed	2.9	2.9	2.7	1.45	1.47	1.45	74,675	75,458	73,921
T_3-Trash retained	2.9	3.0	3.1	1.45	1.48	1.49	74,675	76,412	76,712
T_4-Trash shredding	2.9	3.4	3.5	1.45	1.53	1.55	74,675	78,436	79,543
C.D (p=0.05)	-	0.42	0.6	-	0.06	0.08	-	2938	4812

Table 3. Effects of different trash management practices on cane yield, soil organic carbon content and bulk density after successive harvests of sugarcane in a ratoon system

Treatment	Cane yield t/ha			Organic carbon content (%)			Soil bulk density (g cm-3)		
	Plant crop	Ratoon 1	Ratoon 2	Plant crop	Ratoon 1	Ratoon 2	Plant crop	Ratoon 1	Ratoon 2
T_1-Trash burnt	108.6	110.7	105.4	0.54	0.52	0.48	1.43	1.50	1.55
T_2-Trash removed	108.6	111.4	107.5	0.54	0.56	0.52	1.43	1.47	1.50
T_3-Trash retained	108.6	113.8	114.6	0.54	0.58	0.60	1.43	1.43	1.39
T_4-Trash shredding	108.6	120.5	123.8	0.54	0.60	0.63	1.43	1.40	1.35
C.D (p=0.05)	-	4.2	7.0	-	0.04	0.06	-	0.04	0.06

Yield, soil organic carbon and bulk density: Trash shredding and retaining as mulch each year in the ratoon crop for two years increased the soil organic carbon by 0.06% and 0.09%, while trash burning decreased it by 0.06% (Table 3). Trash shredding and retained conserved soil moisture and regulated soil temperature which might create a congenial, edaphic environment for accelerated activity of soil microorganisms which in turn would have enhanced decomposition of root residues and trash. The trash burning not only destroyed the littered residues in the field but also sterilized the top soil, thus killing the microbes which are responsible for decomposing root residues left under the soil. The bulk density of the soil (1.50 to 1.55 g cm^{-3}) and (1.47 to 1.50 g cm^{-3}) increased, after successive harvests of the crop, in plots with trash burning and removal, but decreased where trash shredded and retained (Table 3). Dahiya et al. (2003) and De Cerqueira et al (2018) also reported a decline in soil organic matter with an increase in soil bulk density. Yadav et al. (2009), Tayade et al (2016) and De Aquinoa et al (2017) observed higher organic carbon and nitrogen contents in the soil after trash incorporation than in the trash burnt soil. Cane yield (120.5 and 123.88 t/ha) of all the ratoon crops significantly increased in plots where trash shredded followed by trash retained as mulch, compared to plots with trash burning and removal it might be conservation of soil moisture and nutrients in the soil by incorporation of sugarcane trash through shredding into small pieces added the organic matter, increased the nutrient status and availability in the soil, similar results were confirmed by Mathew and Varughese (2005) and Muñoz-Arboleda and Quintero-Duran (2011).

CONCLUSION

Trash shredding practice was showed significantly better performance in terms of growth and yield attributes of sugarcane over trash burnt and trash removal practices. The majority of the farmers were realized and obtained significantly higher cane yield (120.5 and 123.8 t/ha) in addition to that added more organic carbon (0.54 to 0.63%) in the soil due to incorporation of trash in the soil with trash shredder in Khammam district, Telangana state of India.

REFERENCES

Ahmed MKP Baiyeri and Echezona BC 2014. Evaluation of organic mulch on the growth and yield of sugarcane in the southern guinea of Nigeria. *The Journal of Animal and Plant Sciences* **24**: 329-335.

Blake GR and Hartge KH 1986. Bulk Density Methods of Soil Analysis, Part 1, *Physical and Mineral Method*. Ed. by A. Klute, 363-382.

Carvalho JLN Nogueirol, RC Menandro, LMS Bordonal, RD Borges CD, Cantarella H and Franco HCJ 2017. Agronomic and environmental implications of sugarcane straw removal: A major review. *Global Change Biology Bioenergy* **9**: 1181-1195.

De Aquinoa, GS Medinaa, CD Da Costaa, D C Shahaba M and Santiago AD 2017. Sugarcane straw management and its impact on production and development of ratoons. *Industrial Crops and Products* **102**: 58-64.

De Cerqueira, DCO Ferreira, VM De Souza, RC Neto, JCD Da Silva VSG and De Almeida FA 2018. Management of soil mulch in weed suppression and sugarcane productivity. *Journal of Agricultural Science* **10**: 125-132.

Dahiya, Malik R, RS and Jhorar BS 2003. Effect of sugarcane trash and enriched sugarcane trash mulches on ratoon cane yield and soil properties. *Journal of the Indian Society of Soil Science* **51**(4): 504-508.

Flavio CD, Morel CP, Rafael M, Marcelo A and Edjair AD 2013. Sugarcane trash management assessed by the interaction of yield with soil properties. *Research Brazilian Crop Journal* **37**: 1709-1719.

Graham MH, Haynes RJ and Meyer JH 2000. Changes in soil fertility induced by trash retention and fertiliser applications on the long-term trash management trial at Mount Edgecombe. P*roceedings of the South African Sugar Technologists Association* **74**: 109-113.

Hanway J and Heidal H 1952. *Soil analysis, as used in lowa State*. College of Soil Testing Laboratory, Iowa. *Agriculture* **57**: 1-31.

Henrique CJ, Maria TB, Joao LN, Paulo SG, Carlos EV, Oscar AC, Andre CV, Oriel TK and Joao RN 2013. Assessment of sugarcane trash for agronomic and energy purposes in Brazil. *Scientia Agricola* **70**: 305-312.

Kumar S, Chand G, Mandal D, Kumar A and Kumar S 2015. Effect of trash mulching on quantitative and qualitative parameters of sugarcane. *Ecology, Environment and Conservation* **21**: 141-143.

Olsen SR, Cole CV, Watanabe FS and Dean LA 1954. *Estimation of available P in soils by extraction with sodium bicarbonate.* Circular of the United States Department of Agriculture 939, US Government Printing Office, Washington D.C.

Subbiah BV and Asija GL 1956. A rapid procedure for determination of available nitrogen in soil. *Current Science* **25**: 256-260.

Malik KA 2014. *Cane and sugar production*. Punjab Agricultural Research Board Technologies for the Prosperity of Agricultural Stakeholder. 375p.

Munoz-Arboleda F and Quintero-Duran R 2011. Trash management after green cane harvesting and its effect on productivity and soil respiration. *International Sugar Journal*. **113**(1355): 804-808

Mathew T and Varughese K 2005. Effect of methods of irrigation and mulching on the quality and productivity of sugarcane. *Sugar Technology* **7**(2): 84-86

Munoz-Arboleda F and Quintero-Duran R 2011. Trash management after green cane harvesting and its effect on productivity and soil respiration. *International Sugar Journal*. **113**(1355): 804-808

Rana NS, Saini SK, Kumar S and Panwar GS 2002. Trash management practices in sugarcane based cropping systems to enhance sugarcane yield and sustain soil productivity. *Indian Journal of Sugarcane Technology* **17**(1/2): 32-34.

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Ridge R 2003. Trends in sugarcane mechanization. *Sugarcane International* (Jan-Feb): 25-28.

Suma R and Savitha CM 2015. Integrated sugarcane trash management: A novel technology for sustaining soil health and sugarcane yield. *Advances in Crop Science and Technology* **3**(1): 160.

Subbiah BV and Asija GL 1956. A rapid procedure for determination of available nitrogen in soil. *Current Science* **25**: 256-260.

Tayade AS, Geetha P, Dhanapal R and Har K 2016. Effect of in situ trash management on sugarcane under wide row planting system. *Journal of Sugarcane Research* **6**(1): 35-41.

Yadav RL, Shukla SK, Suman A and Singh PN 2009. Trichoderma inoculation and trash management effects on soil microbial biomass, soil respiration, nutrient uptake and yield of ratoon sugarcane and subtropical condition. *Biology and Fertility of Soils* **45**: 461-468.

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Effect of Foliar Application of Nano Urea on Productivity and Profitability of Fine Rice under Irrigated Subtropics of Jammu Region

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***Abstract*:** An experiment was conducted to assess the effect of foliar application of nano urea on productivity and profitability of fine rice under irrigated subtropics of Jammu region. The experimental results revealed that 100% recommended NPKZn +2 foliar sprays of nano urea each @ 2ml/liter of water recorded significantly higher effective tillers m^{-2}, number of grains $panicle^{-1}$, 1000-grain weight, grain yield and straw yield and remained statistically at par with treatment 75% recommended N+ recommended PK Zn + 2 foliar sprays of nano urea each @ 2ml/liter of water, 50% recommended N+ recommended PKZn (25:25:15 kg ha^{-1}) + 2 foliar sprays of nano urea each @2ml/liter of water), 50% recommended N+ recommended PKZn (25:25:15 kg ha^{-1}) + foliar sprays of nano urea (@4 ml/liter of water) and 100% recommended NPKZn. However with regard to net returns and B: C ratio, 75% recommended N+ recommended PKZn + 2 Foliar Sprays of nano urea each @ 2ml/liter of water recorded highest net returns and B:C ratio to the tune of ₹ 79305 ha^{-1} and 1.70 respectively which was closely followed by 50% recommended N+ recommended PKZn (25:25:15 kg ha^{-1}) + 2 foliar sprays of nano urea each @ 2ml/liter of water with net returns and B:C ratio to the tune of ₹ 78,724 ha^{-1} and 1.69 respectively.

***Keywords*:** Rice, Foliar application, Nano urea, Grain yield, Straw yield

Rice (*Oryza sativa* L.) is one of the most important cereal crops of India as well as world, grown on wide range of agro-climatic zones. It is a staple food for more than the half of the global population and its demand is expected to increase as population increases (Carriger and Vallee 2007). Globally rice is grown on an area of about 162.06 million hectares with a production of about 700 million tonnes. In India, rice crop is cultivated on an area of about 43.79 million hectares with a production of 116.42 million tonnes (Anonymous 2019a). In Union Territory of Jammu and Kashmir, rice is grown on an area of about 283.4 thousand hectares with a production of 572.5 thousand tonnes and a productivity of 2020 kg ha^{-1}. Out of 283.4 thousand hectares, rice is cultivated over an area of about 116 thousand hectares in Jammu region with production of about 168.5 thousand tonnes (Anonymous 2019b).

Rice plants require a lot of mineral nutrients, especially nitrogen, to grow, develop, and produce grains. Nitrogen is one of the important elements in plant owing to its major part in chlorophyll production, which is essential for the photosynthesis process. Nitrogen is part of different enzymatic proteins that catalyze and regulate plant development processes Sinfield et al (2010). Nano urea is liquid formulations manufactured by Nano Biotechnology Research Center in association with Indian Farmers Fertilizers Cooperative Limited. The 500 ml of nano urea is equivalent to a 45 kg urea fertilizer. It contains nano scale nitrogen particles (55,000 nano particles) with high surface area (10,000 times over 1mm Urea prilled. On foliar application, these small particles are delivered directly to the plant cell, thereby releasing nitrogen inside the cells as per the requirement in a phased manner which ensure low and target efficient release for providing the nutrients to the crop and thus increase nutrient use efficiency. Nano urea when sprayed on crop leaves triggers pathway for uptake and assimilation of nitrogen inside the plants. Thus foliar application of nano urea enhances availability of nitrogen through stomata of leaves via gaseous uptake and may activate many enzymes involved in biochemical pathways for maintenance of biological membranes. Therefore, the present study is being undertaken in view of the importance of rice crop in the region as well as need for eco-friendly foliar Nano-Urea under Jammu conditions as economically viable fertilizer-input options.

MATERIAL AND METHODS

Field experiment was conducted during *Kharif,* 2021 at Research Farm, Sher-e-Kashmir University of Agricultural Sciences Technology of Jammu, Chatha located at latitude of 32°40', longitude of 74°58' and at an altitude of 332 meters above mean sea-level in the Shiwalik foothills of North-Western Himalayas. The soil of the experimental site was sandy clay loam in texture and slightly alkaline in reaction and low in organic carbon and available N; but medium in available P and available K. The DTPA extractable zinc was found below critical level. The experiment was laid out in Randomized block design with three replication and ten treatments (Table 1).

Agronomic practices: Seedlings of *Pusa Basmati*-1121 were transplanted at a spacing of 20 cm x 10 cm during second fortnight of July. The application of fertilizers was done in accordance with the requirement of the treatments as per technical programme of the experiment, besides 17.18 kgha^{-1}sulphur(S) which was applied to the treatmentsT_1, $T_5$and T_9 in addition to have uniformity in the nutrients applied to the crop. The need of application of sulphur was also aroused due to use of single super phosphate to supplement phosphorus in all the other treatments except for treatments T_1, T_5 and T_9 where diammoniumphosphate was used as a source of phosphorus which also supplies nitrogen. Therefore, in order to have uniformity of nutrients in all the treatments gypsum was applied @ 90kgha^{-1} to all the treatments where diammonium phosphate was used as a source of phosphorus. Foliar application of Nano urea was done as per technical programme of the experiment. First foliar spray of Nano urea was done at 30 DAT and second spray of nano urea was done at 75 DAT (one week before flowering) in case of two foliar sprays whereas single foliar spray was applied at 30 DAT only. Weed control was done by applying Butachlor @1.5 kg ha^{-1}, two days after sowing. Intercultural operations and plant protection measures were adopted as per the recommended package of practices, whenever required from sowing up to the crop harvest. The crop was irrigated as and when necessary to maintain the optimum moisture condition of the field.

Grain yield and straw yield: The rice crop harvested from the net plot area of each treatment was sundried, threshed, cleaned and grain yield was recorded at a moisture level of 12 per cent. The straw yield was worked out by subtracting the grain yield from the biological yield. The experimental results were analyzed statistically using SPSS software.

RESULTS AND DISCUSSION

Yield attributes*:* Yield attributing characters of rice were significantly influenced with the foliar application of Nano urea. The significantly higher effective tillers per metre square, number of grains per panicle, 1000-Grain weight (g) were observed with application of 100% recommended N + recommended PKZn +2 fs nano urea each @ 2 ml/litre of water which was at par with 75% recommended N + recommended PKZn +2 FS Nano urea each @ 2 ml/litre of water, 50% recommended N+ recommended PKZn +2FS nanourea each @ 2ml/liter of water, 50% recommended N+recommended PKZn +FS-Foliar spray nanourea @ 4ml/liter of water and 100 over the other treatments in comparison 100% recommended N+recommended PKZn. The highest number of panicles m^{-2} might be due to sufficient amount of nitrogen through nano urea at critical stage which would have maintained continuous supply of nitrogen, led to the meristematic activity and stimulation of cell elongation in plants which resulted in higher number of panicles m^{-2}. These were in close agreement with Jassim et al (2019). The total

Table 1. Effect of nano urea on yield attributes and yield of fine rice (Pusa Basmati-1121)

Treatments	Effective tillers/m^2	Number of grains/ panicle	1000-grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Recommended PKZN (0:25:15:20 kg/ha)	225.49	57.63	23.32	2673.62	3697.76
50% recommended N +recommended PKZn (25:25:15:20 kg/ha)	245.27	67.07	23.98	3568.01	4322.98
75% recommended N+ recommended PKZn (37.5:25:15:20 kg/ha)	255.92	67.87	24.21	3797.69	4712.40
100%r recommended NPKZn (50:25:15:20kg/ha)	256.97	69.42	24.36	4006.65	5100.12
Recommended PKZN(25:15:20kg/ha) +2FS nanourea each @ 2ml/liter of water	242.29	62.34	23.43	3567.99	4320.65
50% recommended N+ recommended PKZn (25:25:15:20 kg/ha) +2FS Nanourea each @ 2ml/liter of water	258.25	69.82	24.95	4182.12	5163.86
75%recommended N+ recommended PKZn (37.5:25:15:20 kg/ha)+2FS nano urea each @ 2ml/liter of water	258.65	69.89	24.98	4207.34	5185.66
100% recommended NPK Zn(50:25:15:20 kg/ha) +2FS nano urea each @ 2ml/liter of water	260.35	70.47	25.02	4215.09	5200.02
Recommended PKZN(25:15:20 kg/ha) +FS nanourea @ 4ml/liter of water	242.66	65.98	23.49	3588.98	4324.65
50%recommended N+ recommended PKZn (25:25:15:20 kg/ha) + FS nanourea @ 4ml/liter of water	257.73	67.98	24.57	4110.21	5151.63
CD (p=0.05)	14.07	2.50	1.02	208.44	387.00

number of grains panicle^{-1} might be due to the foliar spray of nano urea leading to more photosynthate assimilation and translocation of photosynthates from the source to the sink in addition timely supply of nitrogen stimulates the initiation of grain formation which helped to increase the number of grains panicle^{-1}. Nearly similar results were observed by Algym et al (2020). The number of filled grains panicle^{-1} be increased with the foliar application of nano urea fertilizer which might be due to the higher translocation of starch both from the active site of leaves and also straw to grain (sink) and also higher nitrogen supplied by nano urea throughout the growth stages. The increased amount of interception of photosynthetically active radiations and greater photosynthesis. Similar results were found by Gewaily et al (2019).

Grain and straw yield: The use of nano urea has a considerable impact on grain and straw yields (kg ha^{-1}) of rice (Table 2). Application of 100% recommended N + recommended PKZn+2 FS Nano Urea each @ 2 ml/litre of water (T_8) recorded significantly higher grain and straw yield which was at par with the application of 75% recommended N + recommended PKZn+2 FS nano urea each @ 2 ml/litre of water, 50% recommended N+ recommended PKZn +2FS nano urea each @ 2ml/liter of water, 50%recommended N+ recommended PKZn+FS nanourea @ 4ml/liter of water and 100%r recommended NPKZn, over the other treatments. Nano fertilizers increase rice grain yield it is mainly because of increasing growth of plant parts and metabolic process such as photosynthesis leads to higher photosynthates accumulation and translocation to the economic parts of the plant. It may be due to combined application of conventional fertilizer as basal dose and split dosage application of nano urea has been sprayed on plant surface leads to storage of remaining nitrogen in plant cells that may release slowly that can prevent the plant biotic and abiotic stress produces the high grain yield. These results were in close agreement with the findings of Kumar et al (2020). Increased straw yield with foliar spray of nano urea fertilizer might be due to nano fertilizer' quick absorption by the plant and easiness of translocation, which aided in better rates of photosynthesis and more dry matter accumulation, resulting in higher straw yield. Similar trend was observed by Khalil et al(2019).The primary reason for better performance of rice receiving two nano spray was due to nanopores and stomatal openings in plant leaves which facilitated nano material uptake and their penetration deep inside leaves leading to higher nutrient use

Table 2. Effect of Nano urea on economics of fine rice (Pusa Basmati-1121)

Cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	B:C ratio
43,061	80675	37,614	0.87
44,665	106745	62,080	1.39
44,865	113783	68,918	1.54
45,065	120237	75,171	1.67
44,935	106741	61,806	1.38
46,539	125263	78,724	1.69
46,739	126004	79305	1.70
46,939	126244	79,265	1.69
44,298	107337	63,039	1.42
45,902	123224	77,322	1.68

See table 1 for details

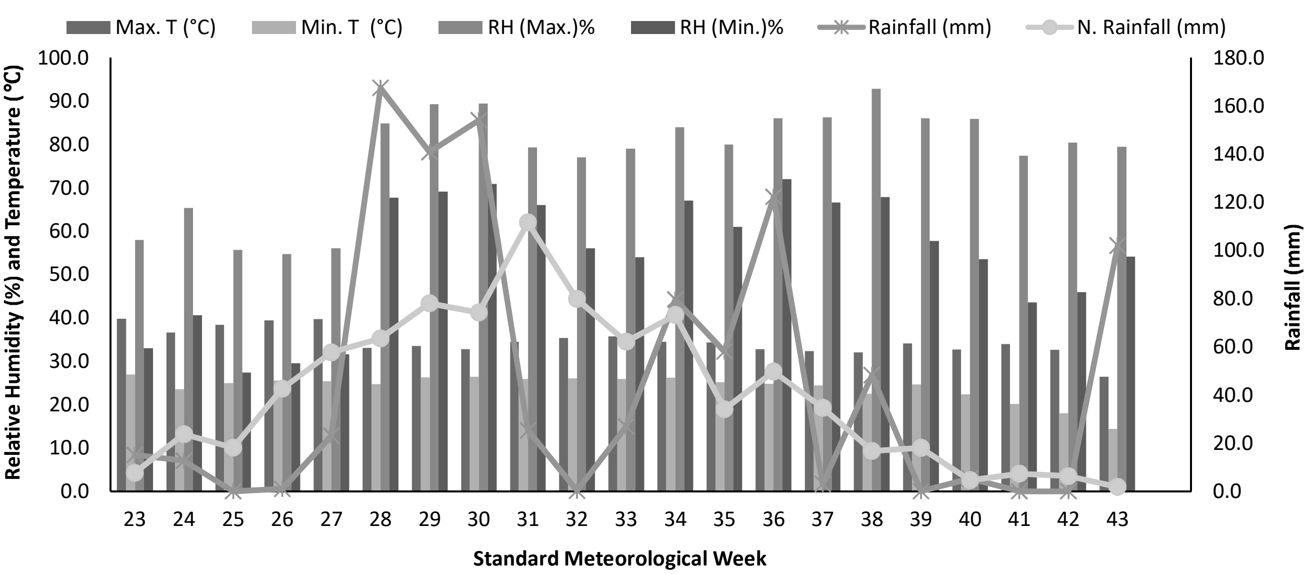

Fig. 1. Weather parameters recorded during crop growing season (*kharif* 2021)

efficiency(NUE).Precisely nano fertilizers have higher transport and delivery of nutrients through plasmodesmata, which are nano sized (50-60nm) channels between cells (Mahanta et al 2019).

Economics: The variations in economics of rice further led to marked variations in its relative economics (Table 2). The economic feasibility and usefulness of a treatment can be effectively adjusted in terms of B: C ratio and net returns. The treatment 75% recommended N+ recommended PKZn + 2 Foliar Sprays of Nano urea each @ 2ml/liter of water recorded numerically higher value for net returns to the tune of ₹ 79305 ha^{-1} followed by treatment 50% recommended N+ recommended PKZn + 2 foliar sprays of nano urea each @ 2ml/liter of water, 100% recommended NPKZn +2 urea each @ 2ml/liter of water and 100% recommended N:P:K:Zn (50:25:15:20 foliar sprays of nano $kgha^{-1}$) whereas the lowest net returns was observed in treatment (control) recommended PKZN(0:25:15:20 kg ha^{-1}) to the (₹37,614.15 ha^{-1})which was ultimately due to the significant difference in grain and straw yield of rice crop and cost of fertilizers incurred at different treatments. However, highest B:C ratio was in treatment 75% recommended N+ recommended PKZn + 2 foliar sprays of nano urea each @ 2ml/litre of water (1.70) which was closely followed by 50% recommended N+ recommended PKZn (25:25:15 kg ha^{-1}) + 2Foliar sprays of nano urea each @ 2ml/liter of water , 100% recommended NPKZn +2 foliar sprays of nano urea each @2ml/liter of water whereas the lowest B:C ratio was observed in treatment (control) Recommended PKZN(0:25:15:20 kg ha^{-1}) as 0.87 which might be due to variation in cost of cultivation and net returns. Similar trend was also observed by Kumar et al (2014).

CONCLUSIONS

Application of 100% recommended N + recommended PKZn +2 FS Nano Urea each @ 2 ml/litre of water recorded significantly higher grain and straw yield irrespective of B:C ratio. However with regard to net returns and B: C ratio, 75% recommended N+ recommended PKZn + 2Foliar Sprays of Nano urea each @ 2ml/liter of water recorded highest net returns and B:C ratio.

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REFERENCES

Algym AJK and Alasady MHS 2020. Effect of the method and level of adding NPK nanoparticles and mineral fertilizers on the growth and yield of yellow corn and the content of mineral nutrient of some plant parts. *Plant Archives* **20**(1): 38-43.

Anonymous 2019a. *Agricultural Statistics at a Glance*. Directorate of Economics and Statistics, Ministry of Agriculture, GovernmentofIndia.

Anonymous 2019b. *Digest of Statistics*. Directorate of Statistics and Economics, Jammu and Kashmir.

Anonymous 2019c. Annual Report *201718*. Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare Government of India.pp:1-3.

Carriger S and Vallee D 2007. More crop per drop. *Rice Today* **6**(2): 10-13.

Gewaily EE, Ghoneim AM, Khattab EA 2019. Nano silicon and nitrogen foliar spray affects the growth, yield and nutrients content of rice. *World Journal of Agricultural Sciences* **15**(6): 367-375.

Jassim RAH, Kadhem HN and Nooni GB 2019. Impact of levels and time of foliar application of nano fertilizer (super micro plus) on some components of growth and yield of rice (*Oryza sativa* L.) *Plant Archieves* **19**(1): 1279-1283.

Khalil MH, Abou AAF, Abdrabou RTH, Abdalhalim SH and Abdelmaaboud MSH 2019. Response of two maize cultivars (*Zea mays* L.) to organic manure and mineral nano nitrogen fertilizer under siwa oasis conditions. *Arab Universities Journal Agricultural Sciences* **27**(1): 299-312.

Kumar R, Pandey DS, Singh VP and Singh IP 2014. Nano-technology for better fertilizer use (Research Experiences at Pantnagar). *Research Bulletin no. 201*

Kumar Y, Tiwari KN, Singh T, Sain NK, Laxmi S and Verma R 2020. Nano fertilizers for enhancing nutrient use efficiency, crop productivity and economic returns in winter season crops of Rajasthan. *Annals of Plant and Soil Research* **22**(4): 324-335.

Mahanta N, Damble AS and Raj C 2020. Nutrient use efficiency through nano nitrogen. *Journal of Environment and Biology* **7**(3): 2839-2842.

Sinfield JV, Fagerman D and Colic O 2010. Evaluation of sensing technologies for on the go detection of macro nutrients in cultivated soils. *Computers Electronics Agriculture* **70**: 1-18.

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Varietal Response of Bio-Inoculants on Horticultural Traits and Microbial Population in Aubergine (*Solanum melongena* L.)

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Abstract: Field experiment was conducted to investigate the varietal response of bio-inoculants on horticultural traits and microbial population in aubergine (*Solanum melongena* L.) at Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu. The experiment was designed in randomized block design (factorial) with two factors i.e. varieties) and io-inoculants . The variety Punjab Raunak inoculated with consortia of all bio-inoculants had minimum days to 50% flowering (39.92), first picking (66.16), maximum plant height (88.65 cm), number of branches per plant (5.71), fruits per cluster (3.67), fruits per plant (53.73), fruit length (19.58 cm), fruit diameter (3.78 cm), fruit weight (74.17 g), total fruit yield per plant (6.82 Kg), and per hectare (261.66 Q/ha). With the exception of reducing sugar, ascorbic acid (24.46 mg/100g), total phenol content (34.81 mg/100g), and total sugar (4.78 mg/100g), the quality parameters showed considerable variation after inoculation with consortium treatment. The variety inoculated with the consortium also had the lowest incidence of the shoot borer (4.86 %) and fruit borer infestation (7.18 %) and phomopsis blight incidence (3.70 %). At various stages of the crop's growth, the total microbial load (CFU/ml) differed significantly. Under the application of consortia's bio-inoculant, Punjab Raunak recorded the highest bacterial count (27.60 CFU/ml), fungal count (22.77 CFU/ml),and actinomycetes count (22.01 CFU/ml).

Keywords: Bio-inoculants, Biotic-stress, Consortia, Microbial load, Varieties

The vegetables belonging to the *Solanaceae (*nightshade) family are among the major vegetables used in the world. Aubergine/eggplant belonging to this family is a long-duration and quite nutrient exhaustive crop. India is the second-largest producer of aubergine after China. In UT of J&K, it is an important crop with an area of 2.51 '000 ha with a production 45.62 '000 MT/ha (Anonymous 2018). High nutrient requirements of the vegetable crops along with the high vulnerability to the various bacterial, fungal or viral diseases are among the major concern for losses in yield and deterioration of soil health. To overcome this PGPR play a significant role in enhancing the plant growth by direct mechanisms such as fixation of atmospheric nitrogen, production of siderophores, solubilization of minerals or indirect mechanisms such as induction of disease resistance, stimulation of other beneficial symbiosis, xenobiotics degradation and antagonism against pathogens. PGPR likely to provide appropriate levels of both major and minor nutrients to plants, as well as other growth-regulating elements that improves the growth, yield, and nutritional quality in this crop also. Consortia of plant growth-enhancing rhizobacteria have proven to be more successful than single inoculation in encouraging plant development. Keeping in view the importance of PGPR/bio-inoculants a study was designed with following objectives to study the effect of different bio-inoculants on growth, yield and quality traits in aubergine and to identify most responsive aubergine varieties and bio-inoculants against biotic-stress.

MATERIAL AND METHODS

The experiment was carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu consecutively for two years, 2020-2021 and 2021-202. The climate of experimental site was subtropical, with hot, dry early summers followed by hot, humid monsoon seasons. The experiment comprised of three aubergine varieties *(Punjab Raunak (V_1), Pusa Purple Long (V_2), Punjab Sadabahar (V_3),* and five bio-inoculants treatments i.e *Pseudomonas fluorescens* (B_1)*, Bacillus* spp. (B_2), Phosphate solubilizing bacteria (PSB) (B_3), Consortia of all (B_4), and Control (B_5). The treatments were arranged in a randomized block design (Factorial). Nursery beds, with a comfortable size of 2 ×1.5 × 0. 15 m, were prepared for seed sowing. Seedlings of various eggplant varieties were raised in these nursery beds. Two methods were used for treatment (root dip and spray solution), during the month of March, seedlings with 4-6 uniformly sized leaves were carefully uprooted and kept in the shade till root dip was done. For the root dip solution, an overnight grown bacterial culture was diluted to 108 CFU/ml and different varieties of seedling roots were dipped for 5 minutes in a beaker containing bacterial solution before transplanting. The second treatment of foliar spray was given at the time of flower initiation. Data were recorded on days to 50% flowering, days to first picking, plant height (cm), number of branches per plant, number of fruits per cluster, number of fruits per plant, fruit diameter (cm), fruit length (cm), fruit weight (g), fruit yield per plant (Kg), fruit yield per hectare (q/ha), ascorbic acid content (mg/100g), total phenol content (mg/100g), total sugar (%), reducing sugar (%), shoot and fruit borer infestation (%), phomopsis blight incidence (%) and total microbial load (CFU/ml). The number of days to 50% flowering and days to first picking were recorded from the entire plot in each treatment. Ascorbic acid content and total phenol content were calculated by using the formula given by Rangana (1976) & Thimmaiah (1999). Total sugar and reducing sugar were calculated by using the formula given by Sadasivam and Manickam, (1992). Total microbial load i.e. enumeration of bacteria, fungi, and actinomycetes was done by the serial dilution- agar plating method.

RESULTS AND DISCUSSION

Growth and yield parameters: All the varieties, bio-inoculants, and interaction significantly affected growth and yield (Table 1). Punjab Raunak took a minimum number of days to 50% flowering (39.92) and first picking (66.16). Maximum days to 50% flowering (42.51) and first picking were recorded by Pusa Purple Long . Bio-inoculants also had significant results on days to 50% flowering and days to first picking. The minimum number of days to 50% flowering and first picking was 36.79 and 65.90 when the seedlings were dipped in consortia of all bio-inoculants (B_4). In un-inoculated control (B_5) maximum number of days for 50% flowering and first picking were 45.01 and 69.0. However, the interactions also varied significantly. The minimum days to 50% flowering (34.47) and first picking (64.11) was in V_1B_4 and maximum days to 50% flowering (46.78) and first picking (69.59) were in Pusa Purple Long under un-inoculated control (V_1B_5). The phosphorus through PSB increased the availability of nitrogen, which further increased cell division and cell differentiation. Thus, the plant came into flowering in early stages of its growth. Moreover, the induction of early flowering and picking might be due to the better nutritional status of the plant, and increased production of leaves might have helped to elaborate more photosynthetic efficiency and induced flowering by early initiation of the flower bud, resulting in earliness in fruit picking. These findings are in accordance with reports of Mandloi et al (2020) in peas and Singh et al (2017) in tomato. Maximum plant height was in Punjab Raunak (88.65 cm) and the minimum was found in Pusa Purple Long (78.52 cm). However, the maximum plant height (92.73 was in variety inoculated with consortia and minimum (73.94 cm) was under control treatment. Punjab Raunak recorded maximum plant height (97.74 cm) when inoculated with consortia of all (V_1B_4) and minimum plant height (70.96 cm) was in Pusa Purple Long under control treatment (V_3B_5). The increase in plant height might be due to the rapid multiplication of micro-organisms applied to the soil leading to a positive effect on the plant growth due to soil-plant-microbe interaction ultimately increasing the height of the plant (Nalini et al 2017). The phospho-bacteria helps in the conversion of un-available phosphorus form to available form, especially in the early growth phase, and augments the plant growth due to the bio-synthesis of growth-promoting substances in brinjal (Anburani and Manivannan, 2002).

The maximum number (5.71) of branches per plant was in Punjab Raunak (V_1) and a minimum number (4.96) was observed in Pusa Purple Long (V_2). The bio-inoculants also had significant effect. The variety treated with consortia recorded maximum number of branches per plant (5.94) and the minimum was recorded in the variety Pusa Purple Long under the control treatment (4.96). Moreover, interaction (varieties × bio-inoculants) also varied significantly. The maximum number of branches per plant (6.17) was achieved in the variety Punjab Raunak under the inoculation of consortium (V_1B_4). The significant increase in the number of branches per plant owes to the increased uptake of nutrients in the plant leading to enhanced chlorophyll content and carbohydrate synthesis. The seedling treatment in consortia increased the phosphates availability in soil which in turn helped in better proliferation of growth and uptake of other nutrients to a greater extent so, that there is enlargement in the cell size and cell division which might have helped in increasing the plant height and number of branches in eggplant. In agreement with our studies, the increase in plant height and the number of branches per plant under the influence of bio-control agents had also been reported by Ramakrishnan and Silvakumar, (2012) in tomato and Bindiya et al (2012) in Gherkin. Devi et al (2019) reported that the vegetative growth in brinjal plants treated with bio-control agents might be attributed to the improvement in the plant mineral concentration through better nitrogen fixation, increase in phosphorus uptake, and disease protection as well as growth promoting effects caused by the bio-control agents.

The number of fruits per cluster and the number of fruits per plant varied significantly in all the bio-control agent treatments. Among varieties, the maximum number (3.67) of fruits per cluster and maximum (53.73) of fruit per plant were found in Punjab Raunak. The minimum number of fruits per cluster (3.47) and per plant (47.55) were recorded in Pusa Purple Long (Table 1). Inoculation of consortial treatment to the variety showed maximum results in the number of fruits per cluster (3.81) and the number of fruit per plant (54.97). Punjab Raunak seedlings when dipped in consortia (V_1B_4) recorded a maximum number of fruits per cluster (3.98) and the Maximum number of fruits per plant (59.22). The highest number of fruits per cluster and the number of fruits per plant might be due to the increased growth components in this crop. These might have helped in producing a higher amount of carbohydrates which might have translocated from the source (leaf) to reproducing parts (sink) resulting in more fruit clusters and more number of fruits. Similar, results have been reported by Singh et al (2017) in tomato. The varieties had a significant effect on fruit length, fruit diameter, and fruit weight. The maximum fruit length (19.58 cm), fruit diameter (3.78 cm), and fruit weight (74.17 g) were observed in the variety Punjab Raunak (V_1). The bio-inoculants and their interaction with varieties had a significant effect on fruit weight and exerted non-significant effect on fruit length and fruit diameter. The maximum fruit weight (74.35 g) and minimum fruit weight (69.98 g) were in varieties inoculated with consortia of all and in the control treatment respectively. In the interaction effect, the maximum fruit weight (78.41 g) and minimum fruit weight (67.91 g) were found in Punjab Raunak inoculated with consortia treatment and under control treatment. The improvement in fruit characteristics under the influence of PGPR might be due to the better

Table 1. Effect of bio-inoculants on aubergine varieties for growth and yield parameters (Pooled data for two years**)**

Treatment	Days to 50 % flowering	Days to first picking	Plant height (cm)	Number of branches per plant	Number of fruits per cluster	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Total Fruit yield per plant (Kg)	Total Fruit yield (q/ha)
V_1	39.92	66.16	88.65	5.71	3.67	53.73	19.58	3.78	74.17	6.82	261.66
V_2	42.51	68.23	78.52	4.96	3.47	47.55	18.08	3.45	69.65	6.39	225.56
V_3	40.04	67.02	87.69	5.60	3.57	48.82	18.58	3.46	72.03	6.44	242.57
C.D. (p=-0.05) (V)	0.29	0.44	1.16	0.11	0.09	1.11	0.98	0.26	0.75	0.11	5.30
B_1	41.59	67.20	86.11	5.37	3.63	49.34	18.37	3.47	71.59	6.49	244.01
B_2	42.44	67.96	82.90	5.16	3.51	48.06	18.45	3.55	70.66	6.25	235.02
B_3	38.29	66.00	89.10	5.67	3.67	50.43	19.38	3.54	73.18	6.72	250.14
B_4	36.79	65.90	92.73	5.94	3.81	54.97	19.57	3.80	74.35	7.08	253.62
B_5	45.01	68.62	73.94	4.96	3.24	47.37	17.95	3.47	69.98	6.21	229.55
C.D. (p=-0.05) (B)	0.38	0.57	1.50	0.15	0.12	1.43	N.S.	N.S.	0.97	0.15	6.84
V_1 B_1	41.14	66.48	89.12	5.85	3.76	52.71	19.40	3.54	73.66	6.78	263.76
V_1 B_2	43.32	67.77	86.53	5.32	3.55	51.22	19.26	3.87	72.44	6.46	254.07
V_1 B_3	35.00	64.51	92.46	6.04	3.81	54.29	20.03	3.61	76.33	6.99	270.43
V_1 B_4	34.47	64.11	97.74	6.17	3.98	59.22	20.23	4.17	78.41	7.59	279.55
V_1 B_5	45.67	67.88	77.42	5.17	3.27	51.22	18.97	3.69	70.03	6.28	240.50
V_2 B_1	43.33	68.16	78.57	4.92	3.63	48.00	18.01	3.44	69.96	6.42	224.37
V_2 B_2	43.67	68.33	76.58	4.50	3.50	47.33	18.11	3.42	69.62	6.18	221.45
V_2 B_3	40.22	67.56	81.89	5.17	3.57	48.33	18.26	3.50	70.07	6.46	226.43
V_2 B_4	38.57	67.53	84.62	5.71	3.63	50.15	18.53	3.58	70.70	6.64	227.79
V_2 B_5	46.78	69.59	70.96	4.49	3.01	45.23	17.50	3.34	67.91	6.27	227.76
V_3 B_1	40.29	66.96	90.64	5.34	3.50	47.33	17.70	3.43	71.15	6.27	243.89
V_3 B_2	40.33	67.77	85.59	5.67	3.49	45.63	17.99	3.38	69.93	6.13	241.53
V_3 B_3	39.66	65.92	92.97	5.81	3.64	48.66	19.85	3.51	73.14	6.73	253.56
V_3 B_4	37.33	66.05	95.85	5.95	3.81	55.55	19.97	3.64	73.94	7.00	253.51
V_3 B_5	42.59	68.40	73.43	5.24	3.43	45.67	17.39	3.37	72.00	6.09	220.40
C.D. (p=-0.05) (V×B)	0.66	1.00	2.60	0.26	0.21	2.48	N.S.	N.S.	1.68	0.26	11.85

V_1: Punjab Raunak, V_2: Pusa purple long, V_3: Punjab sadabahar, B_1: *Pseudomonas fluorescens*, B_2: *Bacillus* spp., B_3: Phosphate solubilizing bacteria (PSB), B_4: Consortia of all, B_5: Control assimilation of plant's nutrients and better nitrogen utilization that enhanced the conversion of un-available phosphorus to available form and augment the plant growth due to the bio-synthesis of growth-promoting substances (Gajbhiye et al 2003).

The total fruit yield per plant and per hectare varied significantly in the varieties under the influence of bio-control agents. (Table 1) The maximum fruit yield per plant (6.82 Kg) and per hectare (261.66 q/ha) was in Punjab Raunak and the minimum total fruit yield per plant (6.39 Kg) and per hectare (224.09 q/ha) was depicted in Pusa Purple Long. Among the bio-inoculants, maximum fruit yield per plant (7.08 Kg) and per hectare (253.62 q/ha) was observed in the variety inoculated with consortia all. The variety under control treatment recorded minimum fruit yield per plant (6.22 Kg) and per hectare (229.55 q/ha). The interaction effects also had significant effects. Maximum total fruit yield per plant (7.59 Kg) and per hectare (279.55 q/ha) was found in Punjab Raunak inoculated with consortia of all treatments. The increase in fruit yield might be attributed to the fact that the consortia of all PGPR produced higher amounts of carbohydrates that might be trans-located from the source to the sink resulting in more healthy and marketable fruits. Singh et al (2017) reported an increase in tomato yield in response to growth-promoting substances due to higher absorption of N, P, and K, that might have favourably affected the chlorophyll content of the leaves resulting in increased synthesis of carbohydrates and build-up of new cells.

Quality traits : All the quality parameters i.e. ascorbic acid, total phenol, and total sugars except reducing sugar varied significantly among the varieties and their inoculation under the consortia of bio-inoculants. Punjab Raunak had highest

Table 2. Interaction effect of varieties and bio-inoculants on quality and biotic-stress traits (Pooled data for two years)

Treatment	Ascorbic acid content (mg/100g)	Total phenol content (mg/100g)	Total sugar (%)	Reducing sugar (%)	Shoot borer infestation (%)	Fruit borer infestation (%)	Phomopsis blight incidence (%)
V1	24.46	34.81	4.78	9.28	4.86	7.18	3.70
V2	22.56	24.87	5.06	8.15	6.33	8.13	4.03
V3	23.67	29.23	4.87	8.49	5.72	7.29	3.72
C.D (p=-0.05) (V)	0.26	0.42	0.22	N.S.	0.24	0.28	0.22
B1	23.67	29.73	4.71	9.92	5.13	7.59	3.80
B2	23.08	27.51	5.44	7.73	5.55	8.44	4.08
B3	24.29	31.80	4.28	9.30	5.78	6.71	3.59
B4	24.64	34.06	3.42	9.13	4.85	5.76	3.07
B5	22.15	25.10	6.65	7.11	6.86	9.17	4.56
C.D (p=-0.05) (B)	0.33	0.55	0.28	N.S.	0.31	0.36	0.28
V1 B1	24.88	35.22	4.91	10.04	4.66	7.25	3.87
V1 B2	23.92	33.12	5.19	8.37	5.15	8.16	4.12
V1 B3	24.94	36.65	4.45	9.47	4.55	6.27	3.48
V1 B4	25.18	38.59	3.33	10.03	4.48	5.09	3.02
V1 B5	23.49	30.50	6.01	8.49	5.45	9.15	4.05
V2 B1	22.78	24.92	4.58	9.04	5.68	8.22	3.77
V2 B2	22.11	21.92	5.83	7.86	5.37	9.00	4.25
V2 B3	23.39	27.14	4.12	8.45	6.82	7.12	3.72
V2 B4	23.77	30.71	3.53	8.74	5.49	6.29	3.14
V2 B5	20.79	19.69	7.22	6.64	8.28	10.04	5.27
V3 B1	23.45	29.05	4.66	10.69	5.05	7.31	3.76
V3 B2	23.22	27.50	5.29	6.96	6.14	8.17	3.86
V3 B3	24.54	31.61	4.28	9.98	5.99	6.75	3.56
V3 B4	24.97	32.88	3.40	8.63	4.58	5.92	3.06
V3 B5	22.19	25.12	6.71	6.19	6.84	8.33	4.36
C.D. (p=-0.05) (V×B)	0.58	0.95	0.49	N.S.	0.54	0.62	0.49

V_1: Punjab Raunak, V_2: Pusa purple long, V_3: Punjab sadabahar, B_1:*Pseudomonas fluorescens*, B_2:*Bacillus* spp., B_3: Phosphate solubilizing bacteria (PSB), B_4: Consortia of all, B_5: Control ascorbic acid content (24.46 mg/100gm), highest total phenol (34.81 mg/100gm) and minimum total sugar (4.78 %), (Table 2). Among bio-inoculates, the variety inoculated with consortia treatment had the highest ascorbic acid content (24.64 mg/100gm), highest total phenol (34.06 mg/100gm) and minimum total sugar (3.42 %). The maximum ascorbic acid (25.18 mg/100g), maximum total phenol (38.59mg/100g), and minimum total sugars (3.33 %) were observed in Punjab Rauank inoculated with consortia treatment. (V_1B_4). However, the minimum Ascorbic acid (20.79 mg/100g), minimum total phenol (19.69mg/100g), and maximum total sugars (7.22 %) were found in Pusa Purple Long under control treatment (V_2B_5). The increase in the secondary metabolites was apparently due to the enhanced mycorrhizal colonization and nutrient status of the plant (Hemashanpegan and Selvaraj 2011). The reducing sugar was not influenced by the varieties and inoculation.

Biotic stress traits: Shoot borer infestation, fruit borer infestation, and phomopsis blight incidence varied significantly among the varieties and their inoculation under the consortia of bio-inoculants. The variety Punjab Raunak has a minimum shoot borer (4.86 %), fruit borer (7.18 %) and phomopsis blight (3.70 %) incidence whereas, maximum shoot borer (6.33 %), fruit borer (8.13 %), and phomopsis blight (4.03 %) were in Pusa Purple Long (Table 2). Moreover, the bio-inoculants consortia of all treatments inoculated had minimum shoot borer (4.85 %), fruit borer (5.76 %), and phomopsis blight (3.07 %). Among the interactions, the minimum shoot borer infestation, fruit borer infestation, and phomopsis blight incidence were in Punjab Raunak inoculated with consortia of all. However, the maximum shoot borer infestation fruit borer infestation and phomopsis blight incidence were observed in Pusa Purple Long under un-inoculated treatment (Table 2). Dar et al (2017) reported that the Brinjal-85 and Local long recorded the lowest fruit and shoot infestation corresponding to low levels of total sugars both at the initial and final stages of crop growth. Khorsheduzzaman et al (2010) reported that susceptible genotypes contain a higher content of total sugars as compared to the resistant ones. Minimum incidence of *Phomopsis vexans* was in Punjab Raunak when inoculated with the consortia of different bio-inoculants. Thesiya et al (2019) also reported that among all the antagonistic evaluated by the dual culture method *T. virens*, *T. viride* and *P. fluorescens* showed strong antagonistic properties against *phomopsis vexans*.

Total microbial load (CFU/ml): Total microbial load (CFU/ml) comprising of bacteria, fungi, and actinomycetes

Table 3. Total microbial load (CFU/ml) in response to interactive effects of varieties and bio-inoculants on different stages of crop growth

Treatments	Bacteria (CFU/ml)			Fungi (CFU/ml)			Actinomycetes (CFU/ml)		
	Before transplanting	Fruiting stage	Harvesting	Before transplanting	Fruiting stage	Harvesting	Before transplanting	Fruiting stage	Harvesting
V_1B_1	16.89	24.40	21.77	13.18	21.88	18.07	12.02	16.86	11.56
V_1B_2	13.19	23.48	20.02	14.03	20.96	17.13	11.13	15.85	10.55
V_1B_3	15.62	25.57	22.81	14.32	22.05	20.21	12.24	20.55	13.27
V_1B_4	17.56	27.60	24.85	13.41	22.77	20.99	13.59	22.01	14.25
V_1B_5	12.29	22.81	19.67	12.25	20.44	16.54	13.25	14.74	11.44
V_2B_1	17.42	22.38	22.01	14.79	19.63	17.52	12.19	16.55	11.41
V_2B_2	13.54	22.33	21.86	11.79	18.72	15.25	10.25	15.88	11.00
V_2B_3	16.72	24.32	22.45	14.53	20.97	19.59	12.18	19.35	13.47
V_2B_4	20.70	26.61	23.94	16.38	21.44	20.13	13.44	20.98	14.18
V_2B_5	14.52	20.70	19.33	12.77	18.69	15.10	9.75	14.37	10.41
V_3B_1	20.35	23.37	22.24	15.75	20.67	19.20	11.71	16.48	11.86
V_3B_2	15.74	22.41	21.37	14.13	19.99	17.48	11.85	16.15	10.48
V_3B_3	20.07	24.86	22.44	16.39	21.39	19.86	12.46	19.52	13.45
V_3B_4	18.15	26.73	24.06	16.05	22.33	20.68	13.20	21.20	14.18
V_3B_5	14.73	21.22	20.06	13.25	19.07	16.74	9.82	15.45	10.52
CD (p=0.05)	N.S.	1.20	1.15	N.S.	0.52	0.86	N.S.	0.35	0.24

V_1: Punjab Raunak, V_2: Pusa purple long, V_3: Punjab sadabahar, B_1:*Pseudomonas fluorescens*, B_2:*Bacillus* spp., B_3: Phosphate solubilizing bacteria (PSB), B_4: Consortia of all, B_5: Control variates significantly at all three stages of crop growth (before transplanting, flowering stage, and harvesting) (Table 3). The total microbial load was non-significant before the transplanting of the crop and increased linearly up to the fruiting stage and was maximum at this stage and decreased again when the crop was harvested. Maximum bacterial count ranged between 12.29-20.70 CFU/ml before transplanting, 21.22-27.60 CFU/ml at the fruiting stage, and again 19.33-24.85 CFU/ml at the harvesting stage. Similarly, the fungal count ranged between 11.79-16.39 CFU/ml before transplanting and increased to a range of 18.69-22.77 CFU/ml at the fruiting stage and again came back down to 15.10-20.99 CFU/ml at harvesting time. Further, the actinomycetes count ranged between 9.75-13.59 CFU/ml before transplanting of the crop and increased up to 14.37-22.01 CFU/ml at the fruiting stage and again showed a decline to 10.41-14.25 CFU/ml. All the factors contributing to the microbial load was maximum in Punjab Raunak when inoculated with the consortia of all bio-inoculants. Naiman et al (2009) observed that the number of culturable rhizobacteria clones was significantly higher in the treatment inoculated with *Pseudomonas* than in the control. The plant's roots provide the soil micro-organisms with exudates that serve as substrates (carbohydrates) sources. These exudates initiate rhizospheric interaction and influence the soil microbial community. The rhizosphere interaction involving the plant roots, soil and microbes obviously changed the physical and chemical properties of the soil and in turn the entire microbial population of the environment (Innes et al 2004, Garbeva et al 2008, Bakker et al 2012).

CONCLUSION

Punjab Raunak seedlings inoculated with the consortia of all bio-agents proved to be superior towards growth and yield parameters besides mitigating the biotic stress efficiently.

REFERENCES

Anburani A and Manivannan K 2002. Effect of integrated nutrient management on growth in brinjal (*Solanum melongena* L.) cv. Annamalai. *South Indian Journal of Horticultural* **50**(4-6): 377-386.

Anonymous 2018. *Area and Production of Brinjal in Jammu & Kashmir*. National Horticulture Board, 188 p.

Akker MG, Manter DK, Sheflin AM, Weir TL and Vivanco JM 2012. Harnessing the rhizosphere microbiome through plant breeding and agricultural management. *Plant Soil* **360**: 1-13.

Bhushan A 2016. *Phenotypic stability in brinjal* (*Solanum Melongena* L.) Ph.D. Dissertation Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, India.

Bindiya Y, Srihari D and Babu JD 2012 Effect of organic manures and biofertilizers on growth, yield and nutrient uptake in Gherkin (*Cucumis anguria* L.). *Journal Research Angrau* **40**(1): 26-29.

Dar SA, Wani AR, Rather BA, Parey SH and Kandoo A 2017. Biochemical basis of resistance in brinjal genotypes against shoot and fruit borer (*Leucinodes Orbonalis*, Guenee). *Chemical Science Review and Letters* **6**(22): 1062-1073.

Devi LK, Chettri S, Sharma MPA, Jhajharia D and Singh KR 2019. Effect of bio-fertilizers and bio-control agents on growth and yield in off season brinjal under low cost polyhouse. *Current Journal of Applied Science and Technology* **34**(5): 1-5.

Gajbhiye RP, Sharma RR and Tewari RN 2003. Effect of biofertilizers on growth and yield parameters of tomato. *Indian Journal of Horticulture* **60**(4): 368-371.

Garbeva P, Van-Elsas JD and Van-Veen JA 2008. Rhizosphere microbial community and its response to plant species and soil history. *Plant Soil* **302**: 19-32.

Hemashenpagan N and Selvaraj T 2011. Effect of *Arbuscular mycorrhizal* (AM) Fungus and Plant Growth Promoting Rhizomicroorganisms (PGPR's) on medicinal plant *Solanum viarum* seedlings. *Journal of Environmental Biology* **32**(5): 579.

Innes L, Hobbs PJ and Bardgett RD 2004. The impacts of individual plant species on rhizosphere microbial communities in soils of different fertility. *Biology and Fertility of Soils* **40**: 7-13.

Khorsheduzzaman AKM, Alam MZ and Mian IH 2010. Biochemical basis of resistance in eggplant (*Solanum melongena* L.) to *Leucinodes orbonalis* Guen., and their correlation with shoot and fruit infestation. *Bangladesh Journal of Agricultural Research* **35**(1): 149-155.

Mandloi R, Waskel S, Jatav SK, Tambi KN and Agashe DR 2020. Varietal and phosphorus response on pod yield of pea (*Pisum sativum* L.). *International Journal of Current Microbiology and Applied Sciences* **10**: 213-221.

Naiman AD, Latrónico A García de Salamone IE 2009. Inoculation of wheat with *Azospirillum brasilense* and *Pseudomonas fluorescens*: Impact on the production and culturable rhizosphere microflora. *European Journal of Soil Biology* **45**: 44-51.

Nalini BS, Naik LK, Saba N, Prasad P and Ashiwini G 2017. Studies on the effect of microbial inoculants on growth and yield of capsicum (*Capsicum annuum* L.). *Journal of Pure and Applied Microbiology* **11**(2): 913-919.

Nanthakumar S and Veeraraghavathatham D 2000. Effect of integrated nutrient management on growth parameters and yield of brinjal (*Solanum melongena* L.) cv. PLR-1. *South Indian Horticulture* **48**(1-6): 31-35.

Ramakrishnan K and Selvakumar G 2012. Effect of biofertilizers on enhancement of growth and yield on tomato (*Lycopersicum esculentum* Mill.). *International Journal of Research in Botany* **2**(4): 20-23.

Rangana S 1976. *Manual of Analysis of Fruits and Vegetables Products*. Tata McGraw Hill Co. Pvt. Ltd., New Delhi. pp.77.

Sadasivam S and Manickam A 1992 In: *Biochemical Methods for Agricultural Sciences*, Wiley Eastern Limited, New Delhi, pp: 179-180.

Singh RK, Dixit PS and Singh MK 2017. Effect of bio fertilizers and organic manures on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.) Cv. Arka Vikas. *Journal of Pharmacognosy and Phytochemistry* **6**(5): 1793-1795.

Thesiya MR, Rakholiya KB, Shekhada MR and Patel PB 2019. In vitro evaluation of bioagents against *phomopsis vexans* (Sacc. & Syd.) harter, causing stem blight and fruit rot of brinjal (*Solanum melongena* L.). *World Journal of Pharmaceutical and Life Sciences* **5**(11): 142-144.

Thimmaiah SK 1999. *Standard Methods of Biochemical Analysis*. Kalyani Publishers. Pp. 287-288.

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Sustainable Round the Year Green Fodder Production Modules under Subtropical Conditions of Jammu

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Abstract: Round the year fodder production modules were established in an area of 2.5 ha at Instructional Livestock Farm Centre, R.S. Pura, SKUAST-Jammu. The area was allocated to different modules *viz*. Maize+Cowpea-Berseem+ Mustard module (area allotted 0.8 ha), Swankhi, Cowpea, Bajra-Berseem +Oats module (0.5ha), Sorghum-oats module (0.8 ha), perennial module viz. hybrid napier (0.35ha) and Para grass (0.05ha) along with boundary plantation of fodder trees and supplemental fodder module to feed fifty dairy animals during 2017-18 and 2018-19. Among seasonal fodder modules, maize+cowpea-berseem+mustard produced significantly highest system productivity including net returns, B:C ratio , monetary efficiency, LUE, production efficiency. Among perennial module, hybrid napier grass produced significantly highest system productivity, net returns, B:C ratio, monetary efficiency, production efficiency and energy productivity. However, supplemental module azolla provide feed every day. Thus integration of all sources of fodders ensured quality green fodder availability throughout the year besides improved soil fertility, sustaining monetary and production efficiency in long run.

Keywords: Fodder modules, Sustainability, Green fodder

Seasonal feed, fodder shortages and inefficient feed use by pastoralist and agro-pastoralist communities are the major challenges affecting livestock productivity in country, besides raising the cost of milk production to the tune of 60-70%. At present, India faces a deficit of 23.4%, 11.24% and 28.9% in the availability of dry fodder, green fodder and concentrates (ICAR-IGFRI 2021). The number of livestock population is growing rapidly @ 4.6 per cent (20th Livestock Census), but the grazing lands are diminishing gradually due to pressure on land for agricultural and non-agricultural uses (Ghosh et al 2019). In Jammu and Kashmir the devoted land to fodder is less than 4% (35.63 thousand hectare) of arable land with production of 64 lakh MT of green fodder and 35 lakh MT of dry fodder whereas against, the requirement of 139.13 and 58.53 lakh MT green and dry fodder. The assessment of feeds and fodders shows that a deficit of about 45% (including green and dry) in fodder and 85% in concentrate (feed) is being faced by J&K (ICAR-IGFRI 2021). There is no chance of horizontal expansion of land as the area under fodder cultivation is static and limited to about 4% of the cropping area for the last four decades. Besides this India faces a seasonal variation in the availability of fodder crops. Lush green fodder available in all months except during the months of May-June and November-December which are considered as lean period .Thus to meet the gap between demand and supply of the deficit and to lessened the variability in seasonal fodder the need of the time is to adopt the practices of fodder production that enhance productivity of fodder along with make the quality fodder accessible round the year. Keeping, above points in view the present investigation was undertaken with an objective to develop sustainable round the year green fodder production modules for feeding dairy animals.

MATERIAL AND METHODS

The experimental site where fodder block fully established was well drained clay loam in nature with neutral to slightly alkaline in soil reaction (7.15 to 7.9), oxidized soil organic carbon content varied from 0.6 to 0.64% with low in available N and medium in P & K respectively. The plan was executed and laid down by in an area of approximately 2.5 ha by making six blocks (A to F) of an area of 0.4 ha accordingly, each and every corner of land was kept under utilization of fodder as per the feasibility of an area. Different sources of fodder viz. seasonal fodders, perennial fodders grasses and trees and supplemental fodder azolla which is rich source of protein were tried. The data presented in the paper were collected for 2017-18 and 2018-19. In *Kharif* season fodders maize (*Zea mays*)+cowpea (*Vigna unguiculata L. Walp*.), swankhi *(Echinochloa frmentaceae)*, bajra (*Pennisetum glaucum),*cowpea (*Vigna unguiculata* L. *Walp*.), sorghum (*Sorghum bicolor L. Morlch*.) fodders were sown and in *rabi* season berseem (*Trifoloum alexandrinum)* +mustard (*Brasica compestris, var. Sarson*), berseem (*Trifoloum alexandrinum) +oats (*Avena sativa*), and oats (*Avena sativa*), were sown and in perennial fodders grasses like hybrid napier *(Pennisetum purpureum*), Paragrass (*Brachiaria mutica*) and in fodder tree spp. *Bauhinia variegate* and *Albizzia* spp were taken as boundary plantations 5m apart from each other. The supplemental fodder *Azolla pinnata* was grown from waste pits and drains . The seasonal fodder modules Maize+ cowpea- Berseem + mustard, Swankhi, Cowpea, Bajra-Berseem+Oats, Sorghum-oats were tested in blocks. The package and practice of subtropical Jammu region was followed. Staggered planting technique @ interval of 15 days was followed in annual cropping sequences. The supplementary information with respect to different fodder sequences with regard to dates of sowing and harvesting (Table 1). Initial composite surface soil samples (0-15 cm) were collected before land preparation of experimental field. Similarly, block wise surface soil samples also collected after harvesting of each plot, air dried, grounded and passed through 2 mm sieve were analyzed for soil reaction, organic carbon content and available N, P and K as per standard methods described by Jackson, (1973). System productivity (kg/ha/year) was calculated by adding produce of different seasons in a year. Land Use Efficiency (Tomar and Tiwari 1990). Production efficiency (Patil et al 1995). Energy budgeting (Lal et al 2003) were calculated. The data was analyzed by using software OPSTAT at probability level of 5%.

RESULTS AND DISCUSSION

Maize+Cowpea-Berseem+ Mustard modules (0.8ha): This module produced 1198q/0.80 ha/year of green fodder annually and supplied fodder in the July, September, December, January, February and April. Significantly highest system productivity of 149750 kg/ha/year, net returns Rs 114860.72, B:C ratio of 3.29, monetary efficiency of Rs 318.17/ha/day, production efficiency of 414.81 kg/ha/day

Table 1. Supplementary information w.r.t date of sowing and harvesting of different fodder modules for round the year fodder availability

Blocks	*Kharif*	*Rabi*	Area (ha)	Date of sowing		Date of harvesting					
				Kharif	*Rabi*	*Kharif*		*Rabi*			
						1st	2nd	1st	2nd	3rd	4th
A	Maize+Cowpea	Berseem+Mustard	0.4	1st May	1st Oct.	1st July-14th July	1st Sept.-6th Sep.	1st Dec.-7th Dec.	1st Jan.-17 Jan.	20th Feb.- 28 Feb.	1st April- 8th April
B	Maize +Cowpea	Berseem +Mustard	0.4	15th May	15th Oct.	15th July-31st July	3rd Oct.- 10th Oct..	8th Dec.-18th Dec.	18 Jan.-31 Jan.	01 March- 08 March	19th April- 23rd April
C	Swankhi	Berseem +Oats	0.2	1st June	15th Oct.	1st Aug. -4th Aug.	7 Sept.-9 Sept..	19th Dec.- 28Dec.	1Feb.-10 Feb.	09 March - 20 March	24th April- 30th April
	Bajra	Berseem+oats	0.2	1st June	15th Oct.	8th Aug.-13th Aug.	1st Oct.-2nd Oct.				
	Cowpea	Berseem+Oats	0.1	1st June	15th Oct.	5th Aug-7th Aug..	-				
D	Sorghum	Oats	0.4	15th June	30th Oct.	14th Aug.-31 Aug.	11th Oct.- 27Oct..	25th Dec.- 31 Dec.	21stMarch- 31st March	-	-
E	Sorghum	Oats	0.4	1st July	15thNov.	10th Sep. -30th Sept.	1st Nov.-20 Nov.	11 Feb.- 26Feb.	9th April-18th April	-	-
F	Perennial fodder Hybrid Napier		0.35	July	- -	1st May-31st May/1st June- 28th June	- -	28thOct- 31st Oct./ 21-27Nov	-	-	-
	Para grass		0.05	Aug		29th June-30th June	- -	28-30Nov.			
	Fodder trees		Boundary	July		-	-	31st Oct.			
	Supplemental fodder (Azolla)		Pits/ waste bodies	-		Daily (1 kg)round the year	-	-			

and energy productivity of 9.28kg/MJ (Table 2) was found in this system followed by sorghum + oats and swankhi, bajra, cowpea - berseem + oats respectively. It might be due to continuously diversified cropping of legumes along with cereals in this system for 361 days with highest LUE of 98.90%.The results are in collaboration of Luce et al (2020). This model also contributed and improved soil fertility by increasing organic carbon to the tune of 8%, available N 4-5%, available P 3-4 % and available K 2-3%, respectively (Table 3). Kumar and faruqui (2008) also found improved soil physico - chemical status of food-forage based system with respect to organic carbon (17%) and available N (12.7%) and P (27%) in 0–15 cm soil over initial level

Swankhi, Cowpea, Bajra-Berseem +Oats module (0.5 ha): This module produced 448q/0.50 ha/year of green fodder annually and supplied fodder in August, September, October, December, February, March and April. Among all annual fodder sequences, Swankhi, Cowpea, Bajra-Berseem +Oats model cropping sequence recorded significantly lowest system productivity of 89700kg/ha/year ,B:C ratio of 1.83 ,energy productivity of 6.53kg/MJ ,monetary efficiency of Rs 182.34 ha/day and production efficiency of 282.07 kg/ha/day, respectively (Table 2). This lowest productivity is due to use of sole crops of swankhi, bajra and cowpea in their respective blocks during *Kharif* season which drastically reduced the *Kharif* yield and thus effect total system productivity. Similar results were reported by Wang et al (2014). With respect to soil fertility soil organic carbon content, available N, available P and available K was improved to 11, 3, 1.5 and 2.5% over their initial level due to inclusion of legumes in the modules. Kakraliya et al (2018) also found the similar results

Sorghum-oats module (0.8ha): This module produced 993.07 q/0.80 ha/year of green fodder annually and provided fodder during August, September, October, November, December, February, March and April. This module produced system productivity of 124134 kg/ha/year, B:C ratio of 3.11, highest energy productivity of 10.80,monetary efficiency of Rs 303.09/ha/day and production efficiency of 400 kg/ha/day. The findings were in agreement of that of Gracia et al (2016). Contribution tosoil fertility was also found in this system, soil organic carbon was build up to 5-6%, available N up to 2-5%, available P up to 4-5% and available K up to 2-7%, respectively (Table 3).

Perennial fodder modules (0.4 ha): This module produced 581.85q/0.40 ha/year of green fodder annually during May, June, October, November. Among perennial grasses hybrid napier recorded significantly highest system productivity (154285 kg/ha), net returns (Rs 120425.71), B:C ratio (3.55), monetary efficiency (Rs 329.93/ha/day) and production efficiency (422 kg/ha/day) (Table 2). The results were in agreement with Bhakhar and Ram (2019). Among fodder trees Bahuinia varigata out yielded Albizzia spp in system productivity and also provide fodder during the time of scarcity. Under perennial sources organic carbon content increased up to 11%, Available N 6%, available P 5 %, and available K 10% respectively. Sarkar (2018) observed that growing perennial fodder crops build up soil fertility.

Supplemental fodder modules: Azolla was grown as supplemental fodder in the waste pits and contributed 365 kg

Table 2. Evaluation of different fodder modules on basis of productivity, economics and efficiency

Cropping sequence models	System productivity (kg/ha/year)	System cost of cultivation (Rs)	Total net returns (Rs)	B:Cratio	Energy productivity (kg/MJ)	Monetary efficiency (Rs/ha/day)	LUE (%)	Production Efficiency (kg/ha/day)
Maize+ cowpea- Berseem + mustard	149750	34889.28	114860.72	3.29	9.28	318.17	98.90	414.81
Swankhi, Cowpea, Bajra-Berseem+Oats	89700	31716.40	57983.60	1.83	6.53	182.34	87.12	282.07
Sorghum-oats	124134	30176.00	93,958	3.11	10.80	303.09	84.93	400.00
Perennial fodder	-	-	-	-				
Hybrid Napier	154285	33,860	120425.71	3.55	10.57	329.93	100.00	422
Para grass	74000	23,709	50,291	2.12	10.79	137.78	100.00	203
C.D	13519	-	-	-	-	-	-	-
S.E(m)+	4486	-	-	-	-	-	-	-
Fodder trees (20nos,)		-	120	-	0.76	0.33	100	0.33
Bauhinia variegata (10 No.)	80	-	-	-	-	-	-	-
Albizzia (10No.)	40	-	-	-	-	-	-	-
Supplemental fodder (Waste pits/drains)	365	-	365	-	5.80	1.00	100	1.00

Table 3. Changes in soil fertility as affected by round the year green fodder production

Blocks	*Kharif*	*Rabi*	Area (ha)	Soil pH		Organic carbon (%)		Average N (kg/ha)		Average P (kg/ha)		Average K (kg/ha)	
				Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
A	Maize+Cowpea	Berseem+Mustard	0.4	7.9	7.85	0-60	0.64	240	252	17.48	17.95	120	124
B	Maize +Cowpea	Berseem +Mustard	0.4	8.2	8.10	0.60	0.65	232	243	16.71	17.10	117	120
C	Swankhi	Berseem +Oats	0.2	7.9	7.80	0.62	0.69	239	247	17.82	18.08	125	128
	Bajra	Berseem+Oats	0.2										
	Cowpea	Berseem+Oats	0.1										
D	Sorghum	Oats	0.4	7.56	7.70	0.60	0.63	218	230	17.25	18.00	120	129
E	Sorghum	Oats	0.4	7.15	8.00	0.64	0.68	235	239	17.19	18.15	120	122
F	Hybrid Napier Para grass Fodder trees Supplemental fodder (Azolla)		0.35 0.05 Boundary Pits/waste bodies	7.80	8.00	0.62	0.69	241	256	18.18	19.10	110	121

in system productivity along with 5.80 in energy productivity and 1kg/ha/day in production efficiency. Kour et al (2020) found azolla supplementation in feeding regimen of crossbred cows is beneficial which is evident by increased milk yield, milk fat yield and improved benefit cost ratio.

CONCLUSION

The green fodder production models developed under Northwestern Himalayas which included diverse sources of fodders viz. annual, perennial grasses, fodder trees, supplemental fodder along with management techniques of staggered planting ensured the round year availability of quality fodder which may varies with the number of animals, and land holdings. Further modules with higher system productivity should be encouraged for sustained yield throughout year.

REFERENCES

Bhakar A and Ram H 2019. Hybrid napier grass a boon to forage production. *Indian Farming* **69**(02): 23-25.

Garcia SG, Baucells F, Feijoo G and Moreira MT 2016. Environmental performance of sorghum, barley and oat silage production for livestock feed using life cycle assessment. *Resource Conservation and Recycling* 111: 28-41

Ghosh PK, Mahanta SK, Singh JB, Kumar RV, Yadav VK and Kumar S 2019. Approaches towards fodder security in India. Studera press. India p 680.

ICAR-IGFRI 2021. Fodder resource development plan for J&K. ICAR-Indian Grassland and Fodder Research Institute, Jhansi.

Jackson ML 1973. *Soil chemical analysis*. pp. 165-167. Asia publication house, Bombay

Kakraliya SK, Singh U, Bohra A, Choudhary KK, Kumar S , Meena, RS and Jat ML 2018. Nitrogen and legumes: A meta-analysis. **In**: Meena RS et al (eds.), *Legumes for soil health and sustainable management*, © Springer Nature Singapore Pte Ltd. Pp: 277-314.

Kour M, Khan N, Singh R, Mahajan V, Amrutkar S and Kumar D 2020. Effect of azolla (*Azolla pinnata)* supplementation on milk Yield, composition and economics in crossbred HF cows. *International Journal of Current Microbiology and Applied Sciences* **9**(10): 2661-2666.

Kumar S and Faruqui SA 2008. Production potential and economic viability of food forage based cropping system under irrigated conditions. *Indian Journal of Agronomy* **54**(1): 36-41.

Lal B, Rajput DS, Tamhankar MB, Agarwal I and Sharma MS 2003. Energy use and output assessment of food-forage production system. *Journal of Agronomy and Crop Science* **189**(2): 57-62

Luce MS, Lemke R, Gan Y, Mcconkey BG, May W, Campbell C, Zentner R, Wang H, Krobel R, Fernandez M and Brandt K 2020. Diversifying cropping systems enhances productivity, stability, and nitrogen use efficiency. *Agronomy Journal* **112**(3): 1517-1536

Patil EN, Jowale S and Mahayan MS 1995. Production potential, economics and fertility status of soil as influenced by wheat - based cropping system. *Indian Journal of Agronomy* **40**(40): 544-548.

Sarkar D, Meitei BC, Das A, Ghosh PK and Mandal B 2018. Changes in soil organic carbon pools in long term trial with perennial fodder crops in acid soils of North-East India. *Grass and Forage Science* **73**(2): 473-481.

Tomar SS and Tiwari AS 1990. Production potential and economics of different cropping sequences. *Indian Journal of Agronomy* **35**(1, 2): 30-35.

Wang Z, Jin X, Bao X, Li X, Zhao J, Sun J, Christie P and Li L 2014. Intercropping enhances productivity and maintains the most soil fertility properties relative to sole cropping. *Plos One* **9**(12). e113984. 10.1371/journal.pone.0113984.

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Enhancement of Germination of *Berberis lycium* Royle. by Different Pre Sowing Seed Treatments

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Abstract: The study was carried out in the laboratory of the Department of Silviculture and Agroforestry, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan-173230 (HP) during 2017-2018. *Berberis lycium* seeds were obtained from plants growing in district Solan of Himachal Pradesh. The freshly harvested seeds were stratified in perforated poly bags. Three batches of seeds were stratified for 15, 30 and 45 days at four distinct temperature ranges *viz.,* 11-22˚C, +5˚C, 0±1˚C and -5˚C. Gibberellic acid (GA_3) was applied to seeds at three concentrations (100, 200 and 300ppm) with untreated seeds serving as control. Significant results were obtained when stratification duration and temperature were coupled with GA_3 treatments. Stratification period of 30 days (P_2) at 0±1˚C (T_3) combined with application of 200ppm GA_3 showed maximum germination percent (70.00%), germination energy (60.00%), mean daily germination (2.33) and peak value (4.30) while the minimal germination percent (26.67%), germination energy (21.67%), mean daily germination (0.89) and peak value (1.48) were observed in untreated seeds (control), stratified for 15 days (P_1) at +5˚C (T_2).

Keywords: Stratification, Dormancy, Germination, Growth regulators

According to IUCN (International Union for Conservation of Nature and Natural Resources) *Berberis lycium* (Kashmal) is having a vulnerable status of conservation. It occurs in the Himalayan region between the altitudes of 850-3500 meters amsl on moderate to steep slopes. It is an evergreen shrub belonging to the family Berberidaceae and is a vertical flowering bush that grows to a height of 3-4 meters, having a solid stem, which is enclosed in a slight fragile bark. The plant blooms from May to June and produces bright red/purplish coloured berries. In one kg of a seed lot, there are around 1,59000- 2,00000 seeds. Fruits of this plant are very nutritious and are rich source of vitamins, minerals, antioxidants, anthocyanin etc. Further the seeds have cancer suppressing properties. Like many other wild fruit species that are over exploited in nature which have not been domesticated yet, *Berberis lycium* also belongs to the same category (Sood et al 2013). It is utilized as fuel wood species as it owes high calorific value. Berberine present in rhizomes has marked antibacterial effects (Bhattacharjee 2008). The natural regeneration in this species through seed gives little success as the seeds show around 34.00 per cent germination. The main reason for the lower germination is seed dormancy (Kumari et al 2017). Considering the importance of this vulnerable shrub species with poor propagation by sexual approaches, the present study was undertaken to evaluate the effect of different stratified temperatures, periods of stratification and growth regulators, on seed germination of *Berberis lycium* Royle.

MATERIAL AND METHODS

The present investigation was at Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the year 2017-2018. The freshly harvested seeds of *Berberis lycium* collected from vicinity of Nauni in district Solan during the month of June 2017. The seeds were stratified with sand as a stratifying media. Stratification of seeds was done in perforated polythene bags in order to allow seed respiration. The seeds were kept moist during the entire stratification period. In November to December, 2017, three seed lots were kept for stratification for 15 (P_1), 30 (P_2) and 45 (P_3) days. Stratification of seeds were carried out at four different temperatures *viz.,* T_1 (11-22˚C), T_2 (+5˚C), T_3 (0±1˚C) and T_4 (-5˚C). After stratification, the seeds were further treated with gibberellic acid at three different concentrations *i.e.* GA_3 (100, 200, 300ppm), prior to sowing and the untreated seed lot was used as control. The observation on germination percent (as per ISTA rules), mean daily germination, peak value and the germination energy were recorded. The data generated from the investigation were subjected to OPSTAT software.

RESULTS AND DISCUSSION

The maximum seed germination in *Berberis lycium* Royle. was observed maximum when the seeds stratified at 0±1˚C for 30 days combined with application of 200ppm gibberellin (T_3×P_2×G_3) (70.00%) which was statistically at par when the seeds stratified in -5˚C for 45 days combined with application of 200ppm gibberellin (T_4×P_3×G_3) showed 66.67 per cent germination, 65.00 per cent germination in 0±1˚C for 45 days combined with the application of 300ppm gibberellin (T_3×P_3×G_4), 65.00 per cent germination in 0±1˚C for 15 days combined with the application of 200ppm gibberellin (T_3×P_1×G_3), 63.33 per cent germination in 0±1˚C for 45 days combined with the application of 200ppm gibberellin (T_3×P_3×G_3). Seeds treated with GA_3 enhance the performance and germination because GA_3 treated seed reduced the germination time, which could be due to more rapid uptake of water in seed treated with GA_3 than the control. GA_3 increasing the growth potential of embryo, during seed germination embryonic GA_3 is released that triggers the weakness of seed coat by stimulation of many genes which results in cell expansion as in *Arabidopsis thaliana* (Finkalstein et al 2008). Understanding the proper chemical mechanism of GA_3 transport in plant cells is a difficult task for scientists. The precise mechanism of gibberellic acid in plant development and seed germination remains a mystery. The appropriate elucidation of GA_3 transport mechanism is essential for the survival of plant species and successful crop production. Seed priming with GA_3 has been demonstrated to be a useful tool for activating metabolic germination processes and facilitating increments in physiological process during seed germination (Gupta and Chakrabarty 2013). The promotion of germination by GA_3 has been demonstrated in many seed species. Seed dormancy prevents seeds from germinating even when germination circumstances are ideal, such as enough water supplies and

Table 1. Interaction effect of stratification temperature, period and gibberellic acid (T×P×G) on germination percent of *Berberis lycium*

Gibberellic acid (ppm)	Interaction between(T×P×G)															
	T_1 (11-22˚C)				T_2 (+5˚C)				T_3 (0±1˚C)				T_4 (-5˚C)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Control	30.00 (33.15)	43.33 (41.15)	36.67 (37.21)	36.67 (37.17)	26.67 (31.06)	35.00 (36.36)	38.33 (38.23)	33.33 (35.18)	33.33 (35.20)	36.67 (37.24)	38.33 (38.21)	36.11 (36.89)	30.00 (33.15)	36.67 (37.21)	33.33 (35.10)	33.33 (35.15)
100	36.67 (37.24)	33.33 (35.24)	45.00 (42.10)	38.33 (38.19)	46.67 (43.07)	38.33 (38.19)	36.67 (37.19)	36.67 (37.08)	36.11 (36.84)	30.00 (33.15)	43.33 (41.05)	33.33 (35.09)	36.67 (37.19)	33.33 (35.15)	38.33 (38.18)	36.11 (36.84)
200	41.67 (40.18)	31.67 (34.17)	41.67 (40.18)	38.33 (38.18)	56.67 (48.82)	46.67 (43.06)	50.00 (44.98)	51.11 (45.62)	65.00 (53.74)	70.00 (56.82)	63.33 (52.72)	66.11 (54.43)	50.00 (44.98)	41.67 (40.18)	66.67 (54.81)	52.78 (46.66)
300	31.67 (34.22)	33.33 (35.20)	38.33 (38.23)	34.44 (35.88)	48.33 (44.03)	43.33 (41.14)	46.67 (43.03)	46.11 (42.73)	51.67 (45.95)	55.00 (47.86)	65.00 (53.74)	57.22 (49.18)	30.00 (33.15)	33.33 (35.20)	55.00 (47.86)	39.44 (38.74)
Mean	35.00 (36.20)	35.42 (36.44)	40.42 (39.43)		44.58 (41.74)	37.92 (37.86)	42.92 (40.86)		44.17 (41.49)	47.92 (43.77)	52.50 (46.43)		36.67 (37.12)	36.25 (36.94)	48.33 (43.99)	

CD (p=0.05) T= 2.61, P = 2.26, G = 2.61, T×P = 4.52, T×G = 0.22, P×G = 4.52, T×P×G = 9.04
Values in parenthesis are angular transformation

Table 2. Interaction effect of stratification temperature, period and gibberellic acid (T×P×G) on germination energy of *Berberis lycium*

Gibberellic acid (ppm)	Interaction between(T×P×G)															
	T_1 (11-22˚C)				T_2 (+5˚C)				T_3 (0±1˚C)				T_4 (-5˚C)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Control	25.00 (28.40)	31.67 (34.22)	30.00 (33.15)	27.78 (31.69)	21.67 (27.70)	28.33 (32.13)	33.33 (35.24)	27.78 (31.69)	28.33 (32.08)	25.00 (29.99)	33.33 (35.20)	28.89 (32.42)	25.00 (29.99)	30.00 (33.15)	28.33 (31.92)	27.78 (31.68)
100	25.00 (29.91)	26.67 (31.06)	35.00 (36.22)	28.89 (32.40)	33.33 (35.24)	23.33 (28.84)	31.67 (34.13)	29.44 (32.74)	23.33 (28.84)	23.33 (28.84)	38.33 (38.18)	27.78 (31.57)	28.33 (31.92)	23.33 (38.53)	36.67 (37.21)	29.44 (32.55)
200	36.67 (37.24)	23.33 (28.84)	30.00 (33.15)	30.00 (33.08)	48.33 (44.03)	38.33 (38.18)	48.33 (44.03)	45.00 (42.08)	55.00 (47.86)	60.00 (50.77)	56.67 (48.85)	57.22 (49.16)	43.33 (41.15)	31.67 (34.01)	58.33 (49.88)	44.44 (41.68)
300	23.33 (28.84)	26.67 (30.93)	28.33 (32.13)	26.11 (30.63)	36.67 (37.11)	36.67 (37.24)	40.00 (39.13)	37.78 (37.83)	40.00 (39.20)	43.33 (41.14)	55.00 (47.86)	46.11 (42.73)	28.33 (32.13)	28.33 (32.08)	50.00 (44.98)	35.56 (36.40)
Mean	26.67 (30.92)	27.08 (31.26)	30.83 (33.66)		35.00 (36.02)	31.67 (34.10)	38.33 (38.13)		36.25 (36.71)	37.92 (37.68)	45.83 (42.52)		31.25 (33.80)	28.33 (31.94)	43.33 (41.00)	

CD (p=0.05) T = 2.78, P = 2.41, G = 2.78, T×P = 4.81, T×G = 5.56, P×G = 4.81, T×P×G = 9.61
The values in parenthesis are transformed values (angular transformation)

Table 3. Interaction effect of stratification temperature, period and gibberellic acid (T×P×G) on mean daily germination of *Berberis lycium*

Gibberellic acid (ppm)	Interaction between(T×P×G)															
	T_1 (11-22˚C)				T_2 (+5˚C)				T_3 (0±1˚C)				T_4 (-5˚C)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Control	1.00	1.44	1.22	1.22	0.89	1.17	1.28	1.11	1.11	1.22	1.28	1.20	1.00	1.22	1.11	1.11
100	1.22	1.11	1.50	1.28	1.56	1.05	1.22	1.22	1.08	1.00	1.44	1.11	1.22	1.11	1.28	1.20
200	1.39	1.06	1.39	1.28	1.89	1.56	1.67	1.70	2.17	2.33	2.11	2.20	1.67	1.39	2.22	1.76
300	1.06	1.11	1.28	1.15	1.61	1.44	1.56	1.54	1.72	1.83	2.17	1.91	1.00	1.11	1.83	1.31
Mean	1.17	1.18	1.35		1.49	1.27	1.43		1.47	1.60	1.75		1.22	1.21	1.61	

CD (p=0.05) T = 0.09, P = 0.07, G = 0.09, T×P = 0.15, T×G = 0.17, P×G = 0.15, T×P×G = 0.30

Table 4. Interaction effect of stratification temperature, period and gibberellic acid (T×P×G) on peak value of *Berberis lycium*

Gibberellic acid (ppm)	Interaction between(T×P×G)															
	T_1 (11-22˚C)				T_2 (+5˚C)				T_3 (0±1˚C)				T_4 (-5˚C)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Control	1.79	2.42	1.92	2.04	1.48	2.00	1.96	1.82	2.13	2.10	2.38	2.21	1.81	2.30	1.82	1.97
100	2.22	1.95	2.58	2.25	2.75	1.71	2.11	2.19	1.55	1.70	2.65	1.97	2.06	2.19	2.29	2.18
200	2.21	2.02	2.45	2.23	3.32	2.69	2.79	2.93	3.44	4.30	4.04	3.93	2.75	2.37	3.41	2.84
300	2.11	1.75	2.29	2.05	2.38	2.35	2.99	2.57	2.99	3.52	3.43	3.31	1.88	1.90	3.27	2.35
Mean	2.08	2.04	2.31		2.48	2.19	2.46		2.53	2.90	3.12		2.13	2.19	2.70	

CD (p=0.05) T = 0.22, P = 0.19, G = 0.22, T×P = NS, T×G = 0.43, P×G = 0.37, T×P×G = 0.74

a proper temperature. GA_3 treated seeds breach the seed dormancy by either enhancing embryo development potential or weakening the seed coat, allowing the seeds radicle to burst through. The enhanced seed germination in *Berberis lycium* observed under GA_3 seed treatment might be due to increased cell elongation and cell division activities along with better supply of nutrients under the low temperature. The property of GA_3 to induced better and quicker germination (Dalip et al 2017). Similarly the effect of GA_3 has been reported by Garaniya and Bapodra (2015) in Abrus precatorius and Shreesty et al (2019) in *Carrisa carandus*.

CONCLUSION

The higher seed germination in *Berberis lycium* was observed after GA_3 seed treatment which is attributed to the increased cell elongation and cell division activities and better nutrition delivery from the seed at the low temperature. The interaction effect of stratification temperature, period and seed treatment with gibberellic acid revealed that when the seeds stratified at 0±1˚C (T_3) for 30 days interval (P_2) combined with soaking of seed in 200ppm gibberellic acid surpassed all other treatment combination.

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REFERENCES

Bhattacharjee SK 2008. *Handbook of Medicinal Plants*, Pointer Publishers, Jaipur, India, p 504.

Dalip WS, Singh S, Maharana D, Rout S and Patra SS 2017. Effect of Gibberellic acid (GA_3) different concentrations at different time intervals on seed germination and seedling growth of Rangpur lime. *Journal of Agroecology and Natural Resourse Management* **4**(2): 157-165.

Finkelstein R, Reeves W, Ariizumi T and Steber C 2008. Molecular aspects of seed dormancy. *Annual Review of Plant Biology* **59**: 387-415.

Garaniya N H and Bapodra A H 2015. Cow urine potential to remove seed dormancy of *Abrus precatorius* L. *The Indian Forester* **141**: 342-343.

Gupta R and Chakraborty S K 2013. Gibberellic acid in plant. *Plant Signal Behaviour* **8**(9): e25504.

Kumari A, Samant SS and Sharma S 2017. Seed germination behaviour of *Berberis lycium* Royle from Annikhad watershed area, Kullu (Himachal Pradesh). *The Journal of Indian Botanical Society* **96**(1&2): 18-27.

Shreesty P, Sharma TR and Nagar OP 2019. Effect of plant growth promoting rhizobacteria on seed germination, growth and survival of Karonda (*Carissa carandas* L.) seedlings. *International Journal of Current Microbiology and Applied Sciences* **8**(11): 1967-1978.

Sood P, Modgil R and Sood M 2013. *Berberis lycium* a medicinal plant with immense value. *Indian Journal of Pharmaceutical and Biological Research* **1**: 27-37.

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Effect of Post Emergence Herbicidal Combinations Tank Mixed with Zinc or/and Iron Sulphate on Growth and Straw Yield of Wheat Crop (*Triticum aestivum* L.)

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Abstract: Wheat (*Triticum aestivum*) is an important cereal crop of the world. Its straw is an important livestock feed source. Major biotic stress on wheat crop is the weeds. Wheat growing areas are also now suffering from deficiency of micronutrients. A field experiment was conducted at RRS, Bawal, India during *Rabi* season of 2018-19 to evaluate the post-emergence herbicidal combinations with Zn or/and Fe in wheat crop. Four herbicidal combinations *viz*. clodinafop + metsulfuron @ 60 g/ha, sulfosulfuron + metsulfuron @ 32 g/ha, mesosulfuron + iodosulfuron @ 14.4 g/ha, pinoxaden + carfentrazone @ (50 + 20g/ha) were evaluated with Zn, Fe and with both Zn as well as Fe. Growth parameters *i.e*. plant height, tillers per meter length of wheat and dry matter accumulation per meter row length of wheat increased significantly under the influence of herbicidal treatments over weedy check. Addition of iron and zinc to the herbicidal combinations resulted into increase in growth parameters of wheat. Application of combined (Zn + Fe) with herbicidal combinations enhanced the growth of wheat significantly over application of sole herbicidal combinations. Similar trend in increase in straw yield, biological yield and harvest index of wheat was observed. Highest straw yield, biological yield and harvest index was obtained under the influence of mesosulfuron + iodosulfuron @ 14.4 g/ha + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %).

Keywords: Growth parameters, Herbcidal combinations, Iron, Straw yield, Wheat, Zinc

Wheat (*Triticum aestivum* L.) plays very important role in attaining food security and is cultivated on an area of 30 mha in India having production and productivity of 97 mt and 3230 kg/ha, respectively (USDA-FAS 2018). Wheat straw has gained immense importance as livestock feed especially in north western India. Green revolution has caused reduction in production of wheat straw owing to short statured wheat. It has also led complex problem of both grassy and broad leaved weeds. Diverse type of weed flora attacks wheat due to diverse growing conditions and cultivation practices. Weed reduces the wheat yield by 30-40 % if not controlled. Among various weed management methods, chemical weed control is more efficient, less costly and less time consuming. Ready-mix of clodinafop + metsulfuron @ (75 g/ha + 0.2 % surfactant) reduces the grassy and broadleaf weeds density to very low level and results into comparable level of wheat grain yield to sequential application of clodinafop @ 60 g/ha and metsulfuron @ 4 g/ha and weed free without any phytotoxicity symptoms on the crop (Kaur et al2015). Herbicidal combinations (ready mix) of clodinafop + metsulfuron (Vesta), sulfosulfuron + metsulfuron (Total), fenoxaprop + metribuzin (Accord plus) and mesosulfuron + iodosulfuron (Atlantis) are very effective (WCE > 90 %) in wheat (Tiwari et al 2016). So, herbicidal mixtures are very effective in controlling complex weed flora in wheat.Second factor affecting wheat growth and yield is imbalanced fertilization and deficiency of nutrients specially micronutrients. Zn and Fe are essential micronutrients for plants. They play very crucial role in nitrogen fixation, energy transfer and protein synthesis, photosynthesis etc. (Alloway 2008). Foliar application of zinc and iron in wheat significantly increases straw yield of wheat (Zeidan et al 2010). Application of zinc either as seed soaked, soil applied or foliar application increases growth of wheat, straw yield and harvest index of wheat significantly (Mauriya et al 2015). Time of spray of micronutrients in standing field crops mostly coincides with the time of application of post-emergence herbicides. But very less information is available about the compatibility of herbicidal combinations with the zinc and iron sulphate. Keeping in mind the role of these micronutrients, this study was carried out.

MATERIAL AND METHODS

Field experiment was conducted at Choudhary Charan Singh Haryana Agricultural University (CCSHAU), Regional Research Station, Bawal (Rewari), India during *Rabi* season of 2018-19. The experimental soil was alkaline. Soil was low in organic carbon and available nitrogen; medium in available phosphorous, high in available potash; deficient in available zinc (0.56) and sufficient in available iron (4.51 ppm). Experiment was laid out in Randomized Block having 18 treatments, each replicated thrice. Wheat variety WH 1105 was sown as per recommendations. Crop was raised with recommended package of practices except weed management. Treatments of weed management were applied at 35 days after sowing (DAS) in different plots of size 6.0 m x 2.2 m. Treatments consist of sole application of four herbicidal combinations; as well as tank mixed with zinc or/and iron sulphate along with weedy check and weed free (Table 1). Data of crop growth parameters was recorded at different intervals of crop growth. Five plants were randomly selected and tagged in each plot and their heights were measured with the help of meter scale at 60, 90 and 120 days after sowing. Average of all five observations was calculated. Plant height (cm) was taken as length from ground surface level to the highest point of plant. Plants in 25 cm row length from the 3^{rd} line on either side in every plot were cut close to the ground at 60, 90 and 120 DAS. These samples were initially sun dried and then dried in oven at 65 ± 2^{0}C for 48 hours. After oven drying, the samples were weighted, converted into dry weight per meter row length by multiplying with four. The tillers were counted in one running meter row length measured with meter scale randomly placed at three spots in each plot at 60, 90 and 120 DAS. Both ends of one meter row distance were earmarked with sticks to record effective tillers per meter row length. The grain yield was deducted from biological yield to obtain straw yield and expressed in kg/ha. Before threshing, biological yield was recorded by weighing the crop biomass produced in each plot with the help of portable spring balance. The data was recorded in Kg/plot and converted into Kg/ha. Harvest index is a measure of effectiveness of translocation of carbohydrates from leaves to grains. It was determined using the following formula:-

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

Statistical analysis: All the experimental data for various crop parameters were statistically analysed by online computer programme OPSTAT (Sheoran et al 1998).

RESULTS AND DISCUSSION

Crop Growth

Plant height: The application of herbicidal treatments alone as well as tank mixed with Zn/Fe increased the plant height of wheat significantly as compared to weedy check. Among various treatments, application of herbicide mixtures with Zn and Fe sulphate results in significant variation in plant height in comparison to application of herbicide mixture alone. The maximum plant height of wheat was observed under mesosulfuron + iodosulfuron (14.4 g/ha) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$(0.5 %). The application of herbicide with either Zn or Fe alone could not make a significant improvement in plant height of wheat over treatment with herbicidal combination without Zn or Fe. Simultaneous application of zinc with herbicides improved plant height more than simultaneous application of iron. The possible reason for improvement in plant height with application of herbicides could be enhanced absorption of herbicides which resulted in inhibition of essential enzymes in weeds which caused less competition between crop plants and weeds. Mauriya et al (2015) reported that zinc influences various physiological and biochemical activity of the plant. Higher plant height with the application of zinc might be due to the fact that zinc is a constituent of various metabolites like chlorophyll, enzymes and hormones which affects plant cell enlargement and elongation. Zn and Fe have synergistic effect on plant growth and improved the plant growth as compared to their separate application (Zayed et al 2011). Competitive ability of wheat plants also increased due to application of micronutrients which proved advantageous for wheat plants. Sabeti (2015) reported that application of herbicides with fertilizers improves the wheat growth.

Dry matter accumulation: All the weed control treatments recorded significant increase in dry matter accumulation as compared to weedy check. The separate application of zinc and iron with herbicidal combinations resulted in insignificant improvement in dry matter accumulation but when applied simultaneously along with herbicides led to significant enhancement in dry matter accumulation /m.r.l. over sole application of herbicides. Maximum dry matter accumulation per meter row length was exhibited under the treatment mesosulfuron + iodosulfuron (14.4 g/ha) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %) followed by pinoxaden + carfentrazone (50 + 20 g/ha) + $ZnSO_4$(0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %). Among various herbicidal treatments, clodinafop + metsulfuron (60 g/ha) witnessed minimum dry matter accumulation/m.r.l. in wheat.

Weeds are primary competent of wheat for all the essential inputs required for dry matter accumulation. Micronutrients play an important role in crop growth. Zinc is required for formation and utilization of photosynthates and improves the dry matter yield (Sawan et al 2008). Fe is an important element in crops, because it is necessary for chlorophyll synthesis which leads to higher dry matter accumulation. Zinc and iron application at the same time could lead to higher dry matter as compared to using them separately (Kobraee and Shamsi 2011).

Number of tillers/meter row length (m.r.l.) of wheat: After application of treatments at 35 DAS, the number of tillers per m.r.l. differed significantly among various treatments and were significantly higher in all treatments than weedy check (Table 1). Highest number of tillers per m.r.l. were observed at 60 DAS. Among various herbicidal treatments, mesosulfuron + iodosulfuron (14.4 g/ha) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %) was most effective with maximum number of tillers per m.r.l. Data indicated that treatments of simultaneous application of zinc or iron with herbicidal combinations improved number of tillers per m.r.l. as compared to sole herbicide application; although insignificantly. Combined application of both zinc and iron with herbicidal combinations significantly improved number of tillers per m.r.l. as compared to sole herbicide application.

The application of micronutrients (Fe and Zn) tilted the crop-weed competition in favour of crop, leading to better crop growth and increase in number of tillers per meter row length. Foliar application of zinc and iron in wheat increases the number of tillers by increasing the chlorophyll content which leads to increase in photosynthetic process (Kandoliya et al 2018).Similar increase in number of tillers due to weed control by ready mix herbicidal combinations was reported by Pal et al (2016).

Straw yield, biological yield and harvest index: All weed management treatments employed in the present study exerted significant effect on straw yield of wheat in comparison to weedy check and reaped statistically equal straw yield to weed free. The addition of Zn or Fe individually to the herbicides improved the straw yield over sole application of herbicides. Combined application of herbicides with Zn and Fe (Zn + Fe) further augmented the straw yield. Among herbicides mesosulfuron + iodosulfuron (14.4 g/ha) was most effective and when applied with Zn + Fe attained maximum straw yield followed by pinoxaden + carfentrazone (50 + 20 g/ha) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %). The straw yield achieved under treatment of herbicides with sole application of Zn or Fe was statistically similar to straw yield harvested under herbicides + Zn + Fe. All

Table 1. Effect of herbicidal combinations and their tank mixtures with zinc or/and iron sulphate on crop growth

Treatment	Dose (g/ha)	Plant height			Dry matter			Number of tillers/m.r.l.		
		DAS			DAS			DAS		
		60	90	120	60	90	120	60	90	120
Clodinafop + metsulfuron	60	48.2	79.5	95.0	37.0	136.7	301.0	96.7	90.7	89.6
Sulfosulfuron + metsulfuron	32	48.8	79.8	96.1	37.4	138.1	305.3	98.0	92.3	91.9
Mesosulfuron + iodosulfuron	14.4	49.1	81.3	97.2	38.5	144.2	312.0	100.0	94.8	93.5
Pinoxaden + carfentrazone	50 + 20	47.6	80.1	96.5	37.9	141.0	308.5	98.7	93.7	92.9
Clodinafop + metsulfuron + $ZnSO_4$ + urea	60	49.7	81.3	97.7	38.8	143.3	311.1	100.3	93.1	92.1
Sulfosulfuron + metsulfuron + $ZnSO_4$ + urea	32	50.0	81.9	99.0	39.4	145.9	316.2	101.1	95.3	94.5
Mesosulfuron + iodosulfuron + $ZnSO_4$ + urea	14.4	50.6	83.2	99.5	40.3	149.5	321.2	102.8	97.0	96.2
Pinoxaden + carfentrazone + $ZnSO_4$ + urea	50 + 20	49.0	82.1	99.3	40.0	147.5	319.1	102.0	96.1	95.3
Clodinafop + metsulfuron + $FeSO_4$	60	49.1	80.8	96.6	38.1	140.3	308.4	99.3	93.0	92.1
Sulfosulfuron + metsulfuron + $FeSO_4$	32	49.2	81.2	97.7	38.6	142.3	312.1	100.0	94.8	93.8
Mesosulfuron + iodosulfuron + $FeSO_4$	14.4	49.9	82.4	98.8	40.0	147.8	319.0	102.7	96.0	95.4
Pinoxaden + carfentrazone + $FeSO_4$	50 + 20	48.0	81.7	98.3	39.5	144.0	314.9	101.3	95.7	94.9
Clodinafop + metsulfuron + $ZnSO_4$ + urea + $FeSO_4$	60	51.3	83.4	100.2	40.6	149.8	322.8	103.0	96.0	94.8
Sulfosulfuron + metsulfuron + $ZnSO_4$ + urea + $FeSO_4$	32	51.9	83.7	101.3	41.3	151.7	324.7	103.7	97.8	96.6
Mesosulfuron + iodosulfuron + $ZnSO_4$ + urea + $FeSO_4$	14.4	52.2	85.2	103.0	42.3	155.4	331.2	105.3	99.7	98.5
Pinoxaden + carfentrazone + $ZnSO_4$ + urea + $FeSO_4$	50 + 20	50.7	84.5	102.2	41.8	152.1	328.2	104.3	98.8	97.6
Weedy check	--	42.2	71.1	85.3	32.2	114.7	254.6	84.0	80.3	79.0
Weed free	--	51.3	83.3	99.9	40.6	150.1	322.1	103.3	97.7	96.5
C.D. (p=0.05)		3.0	3.8	4.7	3.1	10.4	16.6	5.1	4.7	4.6

Table 2. Effect of herbicidal combinations and their tank mixtures with zinc or/and iron sulphate on straw, biological yield and harvest index of wheat

Treatment	Dose (g/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Clodinafop + metsulfuron	60 g/ha	7918	12900	38.62
Sulfosulfuron + metsulfuron	32 g/ha	8052	13123	38.64
Mesosulfuron + iodosulfuron	14.4 g/ha	8064	13221	39.01
Pinoxaden + carfentrazone	50 + 20 g/ha	8062	13170	38.78
Clodinafop + metsulfuron + $ZnSO_4$ + urea	60 g/ha	8223	13447	38.85
Sulfosulfuron + metsulfuron + $ZnSO_4$ + urea	32 g/ha	8292	13600	39.03
Mesosulfuron + iodosulfuron + $ZnSO_4$ + urea	14.4 g/ha	8353	13731	39.17
Pinoxaden + carfentrazone + $ZnSO_4$ + urea	50 + 20 g/ha	8302	13624	39.06
Clodinafop + metsulfuron + $FeSO_4$	60 g/ha	8176	13347	38.74
Sulfosulfuron + metsulfuron + $FeSO_4$	32 g/ha	8284	13556	38.89
Mesosulfuron + iodosulfuron + $FeSO_4$	14.4 g/ha	8298	13631	39.12
Pinoxaden + carfentrazone + $FeSO_4$	50 + 20 g/ha	8296	13582	38.92
Clodinafop + metsulfuron + $ZnSO_4$ + urea + $FeSO_4$	60 g/ha	8548	14015	39.01
Sulfosulfuron + metsulfuron + $ZnSO_4$ + urea + $FeSO_4$	32 g/ha	8678	14240	39.06
Mesosulfuron + iodosulfuron + $ZnSO_4$ + urea + $FeSO_4$	14.4 g/ha	8705	14360	39.38
Pinoxaden + carfentrazone + $ZnSO_4$ + urea + $FeSO_4$	50 + 20 g/ha	8689	14291	39.20
Weedy check	--	6673	10268	35.01
Weed free	--	8433	13866	39.18
C.D. (p=0.05)		620	993	2.22

herbicidal treatments either alone or in blending with Zn and Fe individually or combined produced significantly more biological yield than weedy check and statistically equal biological yield to weed free. Maximum biological yield was obtained under the treatment of mesosulfuron + iodosulfuron (14.4 g/ha) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %).The harvest index varied from 35.01 per cent under weedy check to 39.38 per cent under the treatment of mesosulfuron + iodosulfuron (14.4 g/ha) + $ZnSO_4$ (0.5 %) + urea (2.5 %) + $FeSO_4$ (0.5 %). Harvest index of 39.18 per cent was attained for weed free.The results are in conformity with the results of Kumar et al (2014) and Punia et al (2017). Similar increase in the yield of wheat were reported by Kaur et al (2007) and Patel et al (2017).

Weeds compete with crop for the applied inputs and space, resulting into significant yield losses. The synergistic effect of tank mixing of herbicidal combinations with Zn and Fe increased yield of wheat. The herbicidal combinations exhibited their worth against weeds through selective mechanism while micronutrients (Zn and Fe) enhanced the efficacy of herbicidal combinations by improving growth of wheat plants directly through their physiological and biochemical action; and improving their competitive ability against weeds. The harvest index also followed same trend. Similar compatibility of herbicides and micronutrients were reported by Sabeti (2015). Martens et al (1978) also reported compatibility of herbicides with liquid fertilizers. Increase in biological yield and straw yield was also due to effect of zinc and iron on biochemical and physiological processes like photosynthesis and consequently growth of wheat (Mauriya et al 2015). Micronutrients especially, zinc and iron plays an important role in translocation of photosynthates which leads to increased grain or economic yield and higher harvest index (Marschner 1997).

CONCLUSION

All the herbicidal combinations recorded significantly higher straw yield and biological yield of wheat over weedy check. Addition of Fe to herbicidal combinations increased the growth and yield of wheat. Addition of Zn to herbicidal combinations further enhanced the growth and yield of wheat. Application of combined (Zn + Fe) to herbicidal combinations recorded significantly higher growth and yield of wheat. Therefore it is concluded that all the herbicidal combinations tested under study were compatible with Zn or/and Fe.

REFERENCES

Alloway BJ 2008. *Zinc in soils and crop nutrition*, 2nd Ed. International Zinc association publications, Brussels, Belgium.

Kandoliya RU, Talaviya BP and Kunjadia B 2018. Effect soil and foliar application of zinc and iron on growth of wheat plant in calcareous soil of Saurashtra region. *European Journal of Biotechnology and Bioscience* **6**(5): 86-90.

Kaur T, Brar LS and Walia US 2007. Effect of sulfosulfuron and mesosulfuron + iodosulfuron on weeds and wheat yield. *Indian Journal of Weed Science* **39**(1&2): 48-51.

Kaur T, Bhullar MS and Walia US 2015. Bio-efficacy of ready-mix formulation of clodinafop-propargyl + metsulfuron for control of mixed weed flora in wheat. *Indian Journal of Weed Science* **47**(2): 121-124.

Kobraee S and Shamsi K 2011. Determination of zinc, iron and manganese concentration and partitioning during reproductive stages of soybean grown under field conditions. *Research on Crops* **12**(3): 752-760.

Kumar S, Yadav RA, Pal V and Verma S 2014. Bio-efficacy of pinoxaden 5 EC in combination with broad leaf herbicides on weed species with relation to economics of wheat (*Triticum aestivum* L.). *Environment & Ecology* **32**(1): 154-158.

Martens AR, Burnside OC and Cramer GL 1978. Compatibility and phytotoxicity of herbicide-fertilizer combinations. *Agronomy Journal* **70**(6): 1089-1098.

Marschner H 1997. Functions of mineral nutrients. In *Mineral Nutrition of Higher Plants* (pp.313-363). Academic Press, London, UK.

Mauriya AK, Maurya DC, Maurya VK and Verma RK 2015. Effect of zinc application methods on yield attributes, yield and nutrient uptake in wheat (*Triticum aestivum*) varieties under sodic soil. *Indian Journal of Agronomy* **60**(1): 82-86.

Pal S, Sharma R, Sharma HB and Singh R 2016. Influence of different herbicides on weed control, nutrient removal and yield of wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **61**(1): 59-63.

Patel BD, Chaudhari D, Patel VJ, Patel HK, Mishra A and Parmar DJ 2017. Influence of broad spectrum herbicides on yield and complex weed flora of wheat (*Triticum aestivum* L.). *Research on Crops* **18**(3): 433-437.

Punia S, Yadav DB, Kaur M and Sindhu VK 2017. Post-emergence herbicides for the control of resistant little seed canarygrass in wheat. *Indian Journal of Weed Science* **49**(1): 15-19.

Sabeti P 2015. Evaluation the effect of micronutrients on herbicide mixture 2,4-D + MCPA, Bromoxynil + MCPA and Tribenoron-methyl efficacy in wheat (*Triticum aestivum*). *Biological Forum – An International Journal* **7**(1): 1855-1858.

Sawan ZM, Mahmoud MH and El-Guibali AH 2008. Influence of potassium fertilization and foliar application of zinc and phosphorus on growth, yield components, yield and fiber properties of Egyptian cotton (*Gossypium barbadense* L.). *Journal of Plant Ecology* **4**(1): 259-270.

Sheoran OP, Tonk DS, Kaushik LS, Hasija RC and Pannu RS 1998. Statistical Software Package for agricultural research workers. In: *Recent advances in information theory, statistics & computer applications* (pp. 139-143). Department of Mathematics Statistics, CCS HAU, Hisar.

Tiwari A, Verma BK, Tiwari A and Sharma JD 2016. Effect on growth, yield and economics of wheat (*Triticum aestivum* L.) as affected by different herbicides. *Research in Environment and Life Sciences* **9**(4): 490-492

USDA-Foreign Agricultural Service 2018. World Agricultural Production, Circular Series WAP8-18 August, 2018. https://apps.fas.usda.gov/psdonline/circulars/production.pdf.

Zayed BA, Salem AKM and El Sharkawy HM 2011. Effect of different micronutrient treatments on rice (*Oryza sativa*) growth and yield under saline soil conditions. *World Journal of Agricultural Sciences* **7**(2): 179-184.

Zeidan MS, Mohamed MF and Hamouda HA 2010. Effect of foliar fertilization of Fe, Mn and Zn on wheat yield and quality in low sandy soils fertility. *World Journal of Agricultural Sciences* **6**(6): 696-699.

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Cutting Frequencies and Foliar Application of Nutrients on Green and Seed Yield in Spinach Beet (*Beta vulgaris* var. *bengalensis*)

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Abstract: To assess the effect of cutting frequencies and foliar application of macro and micro nutrients on growth and seed yield in spinach beet (*Beta vulgaris* var. *bengalensis*) the experiment was carried out consecutively for two years at Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu. The experiment was designed in factorial RBD comprising of two factors i:e cutting frequencies and different combination of macro and micro nutrients. The crop with one cutting and 100% application of recommended dose of fertilizers +15 ppm micro nutrients+100 ppm of water soluble fertilizers had maximum seed yield per hectare (22.44q), improved germination (80.83%), highest seedling vigour index (1390.00) and maximum B:C ratio (1:4.30). Thus the crop given one cut produced maximum seed yield and better quality seed in spinach beet. The maximum green leaf yield per hectare (220.01q) was recorded in treatment combination with three cuts and 100% application of RDF+15 ppm micro nutrients+100 ppm of water soluble fertilizers. The maximum number of days to 50% flowering (143.06) was with three cuts and minimum (102.73) with no cut. The application of nutrients had no effect on 50% flowering.

Keywords: Cutting frequencies, Micronutrients, RDF, Seedling vigour index

Spinach beet (*Beta vulgaris* var. *bengalensis*; 2n=2x=18) originated in the Indo-Chinese region and is commonly known as “Indian Spinach”. It is a member of genus Beta, species *vulgaris* and family Chenopodiaceae. The forebear of palak is *Beta vulgaris* var. *maritima*. The palak growing states in India are Uttar Pradesh, West Bengal, Maharashtra and Gujarat. In Jammu division of J&K it is cultivated with a yearly production of 12360 MT over an area of 727 hectares (Anonymous 2020). Spinach's nutrients include a wide range of vitamins and minerals that can help to avoid deficiency disorders and meant to prevent the chronic diseases. The addition of nutrients and their uptake by the plants has a significant qualitative and quantitative impact on plant development and fruit yield (Rathore et al 2008), as a result the nutrient application has become one of the most important inputs in the leafy vegetable production which results in more green and seed yield (Tehelan and Thakral 2008, Tunctruk et al 2011). Micronutrients can aid spinach resistance to environmental stresses such as drought and salinity. To get lush green growth after each cutting, the nutrient application is necessary. Green leafy vegetables are obtained by trimming all of the leaves and new shoots and taking multiple cuttings during the growing season but crop without cut is generally recommended for best quality seed. Proper cutting management in this crop boosts green yield, number of branches, number of leaves, dry weight of leaves and stem *viz-a-viz* proper management of cutting with the application of nutrients boosts green and seed yield in spinach beet. Due to absence of any comprehensive study to overcome the hindrance in quality seed production, there was an urgent need to find out the effect of cutting frequencies and foliar application of macro and micro nutrients on growth and seed yield in spinach beet.

MATERIAL AND METHODS

The experiment was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu (2020-2021& 2021-2022). The climate of experimental area is sub-tropical, with hot and dry summers, hot humid rainy season and chilly winters. The experiment was laid out in factorial RBD replicated thrice with one factor as cutting frequencies and second as different doses of macro and micro nutrients. Plot size was kept at 3m × 3m.The Seeds of Jammu spinach beet-07 were sown at within row spacing of 20 cm and within plant spacing of 5 cm. The experiment was comprised of four cutting frequencies *viz.,* No cut (C_0), one cut (C_1), two cut (C_2) and three cut (C_3) and different doses of fertilizers *viz.,* recommended dose of fertilizers @ 90:60:60(A_0), recommended dose + 10 ppm micronutrients + 75 ppm of macronutrients (19:19:19) (A_1), recommended dose + 10 ppm micronutrients+100 ppm macronutrients (A_2), recommended dose + 15ppm micronutrients + 75 ppm macronutrients (A_3) and recommended dose + 15 ppm micronutrients + 100 ppm macronutrients (A_4). Data were recorded on plant height (cm), green leaf yield per plot (kg), green leaf yield per hectare (q), intervals between successive cuttings (days), days to 50% flowering, seed yield per plant (g), seed yield per plot (kg), seed yield per hectare (q), germination (%), seedling vigour index and cost benefit ratio. The germination percentage was tested by placing 50 seeds on Petri plates at 20-25^{0}C with 90-95 percent relative humidity. Seedling vigour index was calculated by using the formula that has been given by Abdul Baki and Anderson (1973). Intervals between successive cuttings was calculated by taking the number of days from the sowing to first cut from first cut to second and from second cut to third cut respectively. Number of days to 50% flowering was estimated from the entire plot in each treatment. B: C ratio was calculated by using the formula with net return divided by cost of cultivation. The treatment mean were separated at 5% level of significance for interpretation of the results.

RESULTS AND DISCUSSION

Growth and yield parameters: Beet leaf plants recorded maximum plant height (225.25 cm), when it was not given any cut. The recorded height was significantly more than other cuttings treatment. Similarly application of nutrients also increased the height of plants (Table 1). Maximum plant height (208.00 cm) was recorded in plants treated with RDF+15 ppm micronutrients+100 ppm macro nutrients. However the recorded height was at par with recommended dose + 15ppm micronutrients + 75 ppm macronutrients (A_3). Among the interaction studies, maximum plant height (228.72 cm.) was obtained when the crop was left without any cut and treated with RDF+15 ppm micronutrients+100 ppm macro nutrients. The least (168.84 cm) was observed when crop was treated with only RDF and cut thrice (Table -2). This can be due to pruning which encourages the development of the side shoots which resulted in bushy habit with decreased plant height (Bharad et al 2013). Singh et al (2018) reported that the tallest plants in fenugreek were recorded where no cutting was given. The decrease in plant height with three cuttings owes to curbing of vertical growth of the plants resulting in translocation of photosynthates to the leaves axils, thus encouraging the auxiliary branches. The increase in plant height in combination with nutrient application had also been reported by Vasudevan et al (2008) in fenugreek. The overall improvement in growth with nutrient application could be ascribed to the pivotal role played by the nutrients. The promotion of growth due to nutrient application had also been attributed to the increase in plasticity of the cell resulting in entry of water into the cell causing the cell elongation. These results were also supported by Gour et al (2009) in fenugreek and Singh et al (2012) in coriander.

The green leaf yield per plot and hectare varied significantly in response to the cuttings and the nutrient application individually and collectively. Maximum green leaf yield per hectare (220.01q) was in treatment with three cuttings (C_3) and minimum was recorded in treatment with one cut (C_0) (Table -1). Similarly the green leaf yield responded favorably towards the nutrient application. Maximum green leaf yield (per plot and per hectare) was

Table 1. Effect of cutting frequencies, foliar application of macro and micro nutrients on growth, seed yield and seed quality parameters

Treatments	Plant height (cm)	Green leaf yield/Plot (kg)	Green leaf yield/hectare (q)	Intervals between successive cuttings	Days to 50% flowering	Seed yield/plant (g)	Seed yield/plot (kg)	Seed yield/hectare (q)	Germination (%)	Seedling vigour index
C_0	225.25	0.00	0.00	0.00	102.73	22.84	2.51	22.31	80.33	1238.81
C_1	209.20	9.53	105.86	45.93	122.20	23.22	2.55	22.44	81.73	1365.01
C_2	204.40	15.49	172.15	75.60	132.33	19.86	2.19	19.39	78.73	1125.45
C_3	178.53	18.80	220.01	96.40	143.06	18.31	2.03	18.07	75.46	995.65
CD (p=0.05)	C=3.19	C=0.61	C=6.83	C=1.72	C=1.86	C=0.97	C=0.09	C=1.02	C=1.49	C=12.29
A_0	196.68	9.25	102.78	58.42	122.33	17.95	1.97	17.55	77.58	979.40
A_1	199.05	10.56	117.31	56.66	123.66	19.17	2.11	18.73	78.25	1087.20
A_2	201.86	11.16	124.04	54.33	125.33	20.07	2.28	20.29	78.58	1164.36
A_3	206.03	12.36	137.36	51.66	126.42	23.27	2.55	22.40	80.08	1288.18
A_4	208.00	12.69	141.04	51.16	127.66	23.94	2.65	23.26	80.83	1390.00
CD (p=0.05)	A=3.56	A=0.68	A=7.64	A=1.92	N.S	A=1.09	A=0.10	A=1.14	A=1.67	A=13.75

recorded with the application of RDF+15 ppm micronutrients+100 ppm macronutrients (12.69kg/plot and 141.04 q/ha). The combined effect of cutting frequencies and application of macro and micro nutrients also had the significant effect. Maximum leaf yield was with C_3A_4 which was at par with C_3A_3. Increased leaf yield with cuttings and nutrient application was also reported by Bharad et al (2013). The intervals in days between successive cuttings responded significantly in response to the cutting frequencies and the nutrient application. The first cutting took more number of days (45.93) as compared to the second and third cutting. Similarly the nutrient application of RDF+15ppm micronutrients+100 ppm macronutrients (A_4) took lesser number of days for producing the economic yield. However, was at par results with A_3. Among the interaction studies the minimum numbers of days were taken in treatment with three cuttings+RDF+15ppm micronutrients+100 ppm macronutrients (C_3 A_4) and C_3 A_3 (Table-3). Rafat et al (2017) also indicated that in fenugreek the growth and yield traits increased as the cuttings dates were delayed across the growing period.

Seed parameters: Minimum numbers of days taken by a crop for 50% flowering indicates its early maturity. Three cuttings delayed the flowering (Table 1) and crop took 143.06 days to came into 50% flowering. However, application of nutrients and their interaction with cuttings had no effect on 50% flowering. In fenugreek Krishnaveni *et al*. (2014) revealed significantly lesser number of days for flowering with no pinching. Similar results were also obtained by Vasudevan et al (2008). Seed yield per hectare (q) was significantly influenced by the cutting frequencies and nutrient application. Maximum seed yield per hectare was recorded in the treatments involving only one cut (23.22 g/plant, 2.55 kg/plot and 22.44 q/ha respectively). The application of nutrients also significantly favored the seed yield and maximum value of seed parameters was in A_4. Among interaction studies maximum seed yield was in treatment combination of one cutting followed by nutrient

Table 2. Interaction effect of cuttings and foliar application of macro and micro nutrients on spinach beet (Pooled data for two years)

Treatments	Plant height (cm)	Green leaf yield/Plot (kg)	Green leaf yield/ hectare (q)	Intervals between successive cuttings	Days to 50% flowering	Seed yield/plant (g)	Seed yield/plot (kg)	Seed yield/ hectare (q)	Germination (%)	Seedling vigour index
C_0A_0	225.50	0.00	0.00	0.00	99.00	18.65	2.05	18.24	79.00	1019.39
C_0A_1	223.76	0.00	0.00	0.00	100.33	19.19	2.11	19.46	79.67	1120.51
C_0A_2	223.01	0.00	0.00	0.00	103.66	22.17	2.43	21.63	80.00	1217.37
C_0A_3	228.41	0.00	0.00	0.00	105.00	26.23	2.88	25.59	81.00	1381.59
C_0A_4	228.72	0.00	0.00	0.00	105.66	27.23	2.99	26.63	82.00	1455.29
C_1A_0	202.01	7.77	86.36	50.00	119.33	18.62	2.14	18.21	80.33	1142.58
C_1A_1	203.09	8.97	99.70	47.00	121.33	20.51	2.26	20.08	81.66	1287.01
C_1A_2	209.09	9.37	104.18	45.00	122.00	22.90	2.52	22.39	81.69	1357.41
C_1A_3	214.87	10.34	114.88	44.33	123.33	26.59	2.96	24.67	82.00	1464.69
C_1A_4	216.93	11.18	124.22	43.33	125.00	27.47	3.02	26.84	83.00	1573.36
C_2A_0	197.69	11.86	132.73	80.00	130.00	18.29	2.07	17.86	77.00	920.35
C_2A_1	198.35	14.29	158.77	79.00	131.33	18.97	2.08	18.51	78.00	1053.49
C_2A_2	207.53	15.38	170.96	76.33	132.33	19.25	2011	18.81	78.67	1091.98
C_2A_3	208.77	17.47	194.14	70.67	133.66	21.02	2.31	20.53	79.00	1217.64
C_2A_4	209.71	18.46	205.18	72.00	134.33	21.77	2.39	21.27	81.00	1344.51
C_3A_0	168.84	17.37	193.03	103.66	141.00	16.27	1.78	15.87	71.67	823.39
C_3A_1	171.62	18.97	210.77	100.00	141.66	17.28	1.89	16.85	74.67	887.78
C_3A_2	177.14	19.89	221.03	96.00	143.33	18.79	2.06	18.36	75.33	991.41
C_3A_3	178.41	21.13	234.77	91.66	143.66	19.25	2.12	18.80	77.33	1088.82
C_3A_4	196.64	21.64	240.44	89.33	145.66	19.96	2.19	19.52	78.33	1186.85
CD (p=0.05)	7.13	1.37	15.28	3.84	N.S	2.18	0.21	2.28	N.S	27.50

Table 3. Economics of treatments depicting B:C ratio for foliage and seed yield of Jammu spinach beet

Treatments	Cost of cultivation (Rs/ha)	Green leaf yield/hectare	Seed yield/hectare	Green leaf yield (Rs/ha)	Seed yield (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
C_0A_0	110408	0	18.24	0	228000	228000	117592	1:1.06
C_0A_1	114925	0	19.46	0	243250	243250	128325	1:1.10
C_OA_2	123158	0	21.63	0	270375	270375	147217	1:1.90
C_OA_3	143158	0	25.59	0	319875	319875	176717	1:2.30
C_OA_4	148408	0	26.63	0	332875	332875	184467	1:2.40
C_1A_0	150408	86.36	18.21	86360	227625	313985	162577	1:1.08
C_1A_1	166075	99.70	20.08	99700	251000	350700	184625	1:1.10
C_1A_2	167325	104.18	22.39	104180	279875	384055	216730	1:2.90
C_1A_3	182908	114.88	24.67	114880	308375	423255	240347	1:3.10
C_1A_4	188908	124.22	26.84	124220	335500	459720	270812	1:4.30
C_2A_O	168408	132.73	17.86	132730	223250	355980	187572	1:1.10
C_2A_1	180075	158.77	18.51	158770	231375	390145	210070	1:1.60
C_2A_2	185075	170.96	18.81	170960	235125	406085	221010	1:1.90
C_2A_3	190908	194.14	20.53	194140	256625	450765	259857	1:3.60
C_2A_4	196908	205.18	21.27	205180	265875	471055	274147	1:3.90
C_3A_O	188408	193.03	15.87	193030	198375	391405	202997	1:1.07
C_3A_1	190075	210.77	16.85	210770	210625	421395	231320	1:2.10
C_3A_2	200075	221.03	18.36	221030	229500	450530	250455	1:2.50
C_3A_3	206908	234.77	18.63	234770	232875	467645	260737	1:2.60
C_3A_4	208808	240.44	19.52	240440	244000	484440	275632	1:3.10

Average sale price of green leaf=10/- per kg, Average sale price of seed=185/- per kg

application with RDF+15 ppm micronutrients+100 ppm macronutrients (C_1A_4) (26.84 q/ha). Singh et al (2013) also recorded maximum seed yield with one cutting that was at par with two cuttings. Lal et al (2003) revealed that seed yield considerably reduced with increased cutting levels. Similarly, Said-Al-Ahl and Omer (2009) observed significant increase in seed yield of coriander by foliar spraying with Zn alone or by Zinc and Iron combination.

The germination percentage (81.73%) and seedling vigour index (1365.01) were significantly higher when the crop was given with one cut (C_1). Among the macro and micronutrients combination RDF+15 ppm micronutrient+100 ppm (A_4) recorded more germination percentage (80.83%) and seedling vigour index (1390.00) as compared to control. However the interactions between cuttings and macro and micronutrients application showed non-significant effect towards the germination percentage, but it had significant effect on seed vigour. Maximum seedling vigour index (1573.36) was in treatment combination of C_1A_4 that was significantly more than other treatments.The improvement in seed quality might be due to the better mineral utilization of the plants accompanied with enhancement of photosynthesis and other metabolic activities and greater diversion of food material to the seed (Naga et al 2013). Similarly Islam et al (2019) reported that the highest germination in spinach when treated with nitrogen and phosphorus as compared to the control. The increase in this parameter may be due to involvement of nutrients in catalytic activity and breakdown of the complex substances into simple form like glucose, amino acids and fatty acids which in turn were reflected to enhanced seedling vigour index in coriander (Santosh 2012).

Economic studies: Among the various treatment combinations one cut with RDF+15 ppm micronutrient+100 ppm macronutrient fetched the highest net returns of 27081 due to maximum yield/ha, which resulted in cost benefit ratio of 1:4.30. Lal et al (2014) recorded maximum B: C ratio (2:7.2) with the application of 0.6% Zinc in coriander. Similar results were also obtained by Patil et al (2008). It can be concluded from the investigation that the combination of one cut+RDF+15ppm micronutrient+100 ppm macronutrient had maximum value for seed yield, quality and maximum B: C ratio.

REFERENCES

Anonymous 2020. *Area and Production of Rabi Vegetables in*

Jammu and Kashmir. Directorate of Farmers Welfare Jammu and Kashmir.

Abdul B and Anderson JD 1973. Vigour determination in soybean seed by multiple criteria. *Journal of Crop Science* **13**: 630-633.

Bharad SG, Korde SD, Pravina S and Baviskar MN 2013. Effect of organic manures and number of cuttings on growth, yield and quality of Indian spinach. *Asian Journal of Horticulture* **8**(1): 60-64.

Gour R, Naruka IS, Singh PP, Rathore SS and Shaktawat RPS 2009. Effect of Phosphorus and Plant Growth Regulators on Growth and Yield of Fenugreek (*Trigonella foenum graecum* L.) *Journal of Spices and Aromatic Crops* **18**(1): 33-36.

Islam MR, Khatun K, Mostarin T, Haq ME, Islam MN, Biswas BR and Afsun J 2019. Effect of nitrogen and phosphorus on the growth and seed yield of spinach. *Asian Plant Research Journal* **3**(1): 1-9.

Krishnaveni V, Padmalatha T, Padma SS and Prasad ALN 2014. Effect of pinching and plant growth regulators on growth and flowering in fenugreek (*Trigonella foenum-graecum* L.). *Plant Archives* **14**(2): 901-907.

Lal G, Mehta RS, Maheria SP and Sharma Y 2014. Influence of sulphur and zinc on growth and yield of coriander (*Coriandrum sativum* L.). *International Journal of Seed Spices* **4**(7): 32-35.

Lal S, Rana MK and Partap PS 2003. Seed yield of fenugreek genotypes as influenced by date of sowing and green cuttings. *Haryana Journal of Horticultural Sciences* **32**(3&4): 265-269.

Naga SK, Swain SK, Sandeep VV and Raju B 2013. Effect of foliar application of micronutrients on growth parameters of tomato (*Lycopersicon esculentum* Mill). *Discourse Journal of Agriculture Food Science* **1**(10): 146-151.

Patil BC, Hosamani RM, Ajjappalavara PS, Naik BH, Smitha RP and Ukkund KC 2008. Effect of foliar application of micronutrients on growth and yield components of tomato (*Lycopersicon esculentum* Mill). *Karnataka Journal of Agricultural Science* **21**(3): 428-430.

Rafat JG, Muhamad SR and Mustafa AR 2017. Effect of cutting dates on vegetative yield and its components on fenugreek (*Trigonella foenum-graecum* L.). *Euphrates Journal of Agriculture Science* **9**(4): 1-12.

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Rathore AC, Raizada A and Jayaprakash J 2008. Performance of Phalsa (*Grewia subinaequalis* Lin.) through integrated nutrient and canopy management on saline soils of the indo-gangetic plains. *Indian Journal of Soil Conservation* **36**(1): 42-47.

Said-Al AHL and Omer EA 2009. Effect of spraying with zinc and/or iron on growth and chemical composition of coriander (*Coriandrum sativum* L.) harvested at three stages of development. *Journal of Medicinal Food Plants* **1**(2): 30-46.

Santosh K 2012. Effect of micronutrients on quality of fruit and seed in tomato (Lycopersicon esculentum). *International Journal of Farm Sciences* **2**(1): 43-46.

Singh D, Singh PP, Naruka IS, Rathore SS and Shaktawat RPS 2012. Effect of plant growth regulators on growth and yield of coriander. *Indian Journal of Horticulture* **69**(1): 91-93.

Singh R, Bassi G. and Singh D 2013. Influence of sowing time and leaf cuttings on the seed yield and quality components of Palak (*Beta vulgaris* var. *bengalensis*). *Indian Journal of Agricultural Sciences* **83**(4): 410-414.

Singh S, Dhangrah VK, Singh V, Thenua OVS, Pal K and Shukla RD 2018. Nitrogen rate and cutting management for fenugreek green leaf and seed production. *International Journal of Bio-Resource and Stress Management* **9**(4): 523-526.

Tehelan SK and Thakral KK 2008. Effect of different levels of nitrogen and leaf cutting on leaf and seed yield of coriander (*Coriandrum sativum* L.). *Journal of Spices and Aromatic Crops* **17**(2): 180-182.

Tunctruk P, Colen AE and Tunctrunk M 2011. The effect of nitrogen and sulphur fertilizers on the yield and quality of fenugreek (*Trigonella foenum graecum* L.). *Turkish Journal of Field Crops* **16**(10): 69-75.

Vasudevan SN, Sudharshan JS, Kurdikeri NB and Dharmatti PR 2008. Influence of pinching of apical bud and chemical sprays on seed yield and quality of fenugreek. *Karnataka Journal of Agricultural Sciences* **21**(1): 26-29.

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Scientific Rationality and Adoption of Indigenous Soil and Water Conservation in Kolli Hills, Tamil Nadu, India

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Abstract: The tribal farmers of Kolli hills of Namakkal district in Tamil Nadu have unique insight in ITAPs (Indigenous Tribal Agricultural Practices) on soil and water conservation, that can be amalgamated with latest know-how for sustained agricultural development. There is a need to assemble, record, justify and refine those ITAPs before they antiquate. Hence, a study was performed by analyzing the rationality and the extent of adoption of the first-line selected ITAPs. About 9 ITAPs on soil and water conservation, in cluster villages of Kolli hills were recorded. The rationality was assessed by referring the selected nine ITAPs to the agricultural engineering scientists. After rationality analysis, they were test verified for their extent of adoption. All the nine selected ITAPs were found to be scientifically rational. Moreover, out of 9 number of selected ITAPs, 7 ITAPs were used by > 75 per cent and 2 ITAPs used by 50-75 per cent of the tribal farmers. This paper will help in culling out the appropriate indigenous technological package for soil and water conservation, thereby provoking the farmer-scientist interface.

Keywords: Rationality, Adoption, Indigenous Tribal agricultural practices, Soil and water conservation

India, with its long history had been a cradle of biological wealth, intellectual knowledge and spiritual wisdom. There is much indigenous knowledge in India, which are to be provoked. The Indigenous Knowledge is the information acquired over a period of time and transferred on heirloom orally. Warren (1991), rightly pointed out that the use and amalgamation of indigenous knowledge and latest know-how, assures the end user with appropriate need based technology.

In India, more than millions of years, primitive tribes have been living in forests and hills without having more than casual contacts with the populations of the open plains and the center of civilization. Likewise, history of Kolli Hills of Namakkal district of Tamil Nadu, is also closely linked with ancient Tamil literature. There are many legends and interesting myths associated with these hills. *Malayali* tribes relocated from the Kanchipuram (Plains) and settled in Eastern Ghats hill range of the Kolli Hills (Vedavalli et al 2002). The inhabitant *Malayali* tribes, of this area have been contingent towards utilization of various indigenous reserves and resources at least until last twenty years. Their contribution of towards the conservation of local flora and fauna in biological diversity had a significant role as natural resource managers. This local community is most directly involved in soil and water conservation too. But their rigid pattern of social structure and restricted social mobility kept off from scientific progress. Thus, there is an infinite need for the researcher to collate and rationalize the available ITAPs before they totally vanish. In addition, understanding and documenting farmers existing Indigenous knowledge in such farming systems, extent of usage of the ITAPs on soil and water conservation, with tradition/culture will be helpful for directing research towards participatory development and designing appropriate strategies for dissemination of suitable technologies to the farming community. Considering the above fact of indigenous tribal wisdom, a study on scientific rationality analysis and extent of adoption of Indigenous on soil and water conservation was carried out, at Kolli hills.

MATERIAL AND METHODS

This study was performed at Kolli Hills, situated at Namakkal district of Tamil Nadu in India with latitude of 11.248514 longitude of 78.338707 with an elevation of 1121.87 meters MSL. The soil type at Kolli hills is loamy and black soil. This hill is mainly occupied by Malayali tribes (98.8%), who are mainly depended on agriculture and forest resources for food. Kolli hills encompasses with 14 clusters of villages. Out of which seven cluster of villages (Pop.20541 and 3730 ITAP practicing farmers) were sort out for this research based on the geographical operation on agricultural farming systems. Twenty numbers of aged and experienced farmers were selected from each village, and informal interview was facilitated to collect indigenous practices associated with soil and water conservation. Thus, from seven cluster villages, 140 (20 from each cluster of villages) and experienced farmers were contacted. Apart from the tribal farmers, ITAPs were also gathered secondary sources *viz*., the locally functioning NGO namely M.S.Swaminathan Research Foundation (MSSRF), Agricultural colleges, Department of Agriculture and from earlier research. Finally, 28 ITAPs were considered for further analysis. Then the aggregated ITAPs were categorized systematically encompassing cropping systems and technological dimension. In the second phase, clubbing of cluster distinct practices, led to selection of 9 ITAPs related soil and water conservation. For rationality assessment, the selected 9 ITAPs were referred to the 50 agricultural engineering scientists, and asked to rate them on a four-point continuum ranging from 4 to 1. The rationality of each ITAP was evaluated by using the scoring procedure followed by Sakeer Husain (2010) and Venkatesan et al (2016) (Table 1).

Table 1. Scoring procedure to assess the rationality of indigenous technologies

Responses	Scores
Rational based on scientific evidence	4
Rational based on experience	3
Irrational based on experience	2
Irrational based on scientific evidence	1

The rationality of the individual ITAPs were computed based on the mean score, from the total score specified by all the agricultural engineering scientist. Then the ITAPs were categorized as rational (mean score of 2.5 and above) and irrational (mean score of less than 2.5).

After rationality analysis, ITAPs were further analyzed for extent of adoption, from the sample of thirty farmers, who were proportionately selected by random sampling from seven clusters of villages of Kolli hills. The ITAPs selected were depicted to thirty farmer respondents, one after another, with an enquiry about its adoption in the previous years. A score of one was allocated for the response 'Yes' and a zero score was allocated for the response 'No'. The adoption score was arrived by summing the score obtained for all the ITAPs, and the adoption quotient, which was calculated (Sundaramari et al 2003, Venkatesan et al 2016).

$$\text{Adoption Quotient} = \frac{\text{Number of ITAPs on soil and water conservation adopted}}{\text{Number of ITAPs on soil and water conservation applicable}} \times 100$$

With the adoption quotient, adoption of rational and irrational ITAPs by thirty farmer respondents were calculated. This methodology may help in further validation of

Table 2. Scientific rationality and adoption pattern of ITAPs on soil and water conservation

(n=30)

ITAPs on general agricultural practices	Rationality score	Adoption	
		No.	%
Length of the bench terraces in the upland area was determined based on the sloppiness of the field. Steeper the slope, the length of the terraces was smaller and conversely. The stone-bunds were raised along the rough contour lines and ploughing was done across the slope in the terraced bed, reduced soil erosion and thereby helped conservation of moisture.	3.54 R	28	93.33
Grasses like *Andropogan sp*. and *Chrysopogon zizanioides* (Vetiver) are grown on the bunds of the fields to check erosion. These grasses facilitate soil conservation. In addition, excessive growths of such grasses are fed to the cattle.	3.70 R	26	86.67
Agave sp. and *Euphorbia tirucali* are planted on the bunds and borders to check erosion. They serve to conserve soil and act as wind breaks.	3.56 R	20	66.67
Crops like Coconut (*Cocus nucifera*), Banana (*Musa sp.*), Jack (*Artocarpus heterophyla*) and Mango (*Mangifera indica*), are also grown on the bunds of wet and garden lands. In addition to conservation, the trees also give additional profit. Mixed cropping also serves to conserve soil and water.	3.20 R	26	86.67
Bench terracing was done by transforming relatively steep land into a series of level strips across the slope of the land. The field is prepared with a series of benches, burrowing the soil from upper part of the terrace and thereby filling the lower part. A good soil depth avoids exposure of unproductive soil during leveling.	3.53 R	25	83.33
Soil bunds and stone bunds are raised to a height of about 1 to 2 meters. Soil bunds are raised in red soil areas. The prime purpose of the soil bunds is conservation of soil and moisture.	3.51 R	24	80.00
Ditches are dug for the purpose of holding impounded water. This enriches the ground water and compensates the evaporation loss. Such conservation ditches also provide water for drinking purposes for both the tribes and their livestock. Trees and shrubs are grown around these ditches for the creation of micro-climate.	3.65 R	25	83.33
Heaping, minimum tillage and contour ploughing are also practiced for soil and water conservation.	3.70 R	24	80.00
Agave sp. serves for soil conservation due to soil binding characteristics.	3.65 R	17	56.67

indigenous knowledge of the farmers in soil and water conservation aspects.

RESULTS AND DISCUSSION

Out of 9 selected ITAPs on soil & water conservation,7 ITAPs on (1,2,4,5,6,7 and 8) and 2 ITAPs (3 and 9) were adopted by >75 per cent and 50-75 per cent of the tribal farmers respectively (Table 2). Moreover, all the selected ITAPs on soil and water conservation were found to be scientifically rational. The ITAP 1 was adopted by 93.33 per cent of the farmers, to prevent soil erosion and to conserve moisture in their own holding. ITAP 2 and ITAP 4 were followed by 86.67 per cent of the farmers, as both do have good scientific rationality. ITAP 5, on *bench terracing* and ITAP 7 on *digging ditches* were with the adoption of 83.33 per cent. Likewise, ITAP 6, on soil bunds and stone bunds and ITAP 8, on *Contour ploughing* were with the adoption of 80 per cent since they are the test verified and scientifically proven soil and water conservation methods followed in sloppy land. The finding is in accordance with earlier researchers (Ranjay et al 2008, Mihale et al 2009, Dey et al 2011, Sanjay Arora 2022).

CONCLUSION

The Indigenous Tribal Agricultural Practices on soil and water conservation was rationale and was adopted by more than 50 per cent of the tribal farmers. Hence there should be further research in the validation of those. The rich knowledge by the tribes in soil and water conservation should be amalgamated with scientific knowledge and diffused among other areas, with same edaphic and climatic factors.

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REFERENCES

Dey P and Sarkar AK 2011. Revisiting indigenous farming knowledge of Jharkhand (India) for conservation of natural resources and combating climate change. *Indian Journal of Traditional Knowledge* **10**(1): 71-79.

Mihale MJ, Deng AL, Selemani HO, Mugisha Kamatenesi M, Kidukuli AW and Ogendo JO 2009. Use of indigenous knowledge in the management of field and storage pests around Lake Victoria basin in Tanzania. *African Journal of Environmental Science and Technology* **3**(9): 251-259.

Ranjay K Singh and Amish K Sureja 2008. Indigenous knowledge and sustainable agricultural resources management under rainfed agro-ecosystem. *Indian Journal of Traditional Knowledge* **7**(4): 642-654.

Sakeer Husain A 2010. *Knowledge, adoption and perceived effectiveness of Indigenous Horticultural Practices in Kerala*. Ph.D. Dissertation, Gandhigram Rural Institute (DU),Gandhigram, Dindigul, India.

Sanjay Arora, Rajan Bhatt, Vikas Sharma and Manjeet S Hadda 2022. Environmental management indigenous practices of soil and water conservation for sustainable hill agriculture and improving livelihood security. *Environmental Management* DOI: 10.1007/s00267-022-01602-1.

Sundaramari M and Ranganathan TT 2003. *Indigenous Agricultural Practices for Sustainable Farming*. Agrobios (India) Publishers, Jodhpur, India, p311.

Vedavalli L, Oliver King EDI, Balasubramanian K and Balusamy S 2002. *Kolli Malai Makkal Padalgal*. Kalaigaan Padhipagam. p416.

Venkatesan P, Sundaramari M and Surya Rathore 2016. Scientific rationality and adoption of indigenous field bean (*Lablab purpureus (L.) Sweet*) cultivated by tribal farmers of Tamil Nadu. *Indian Journal of Ecology* **43**(1): 584-587

Warren DM 1991 *Using indigenous knowledge in agricultural development*. The World Bank, Washington DC, USA. Discussion paper-127: p 48.

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Effect of Integrated Nutrient Management on Growth and Yield of Stevia (*Stevia rebaudiana* Bertoni)

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Abstract: Field experiment was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu to study the integrated nutrient management technique suitable for increasing growth and yield in *Stevia rebaudiana* Bertoni. At the inception of the experiment, the soil was sandy-clay loam in texture, slightly alkaline in reaction having low status of available N with medium in available P and K. Application of vermicompost @ 1.5t/ha along with half of recommended dose of nitrogen(30kg N/ha) and Azotobacter significantly increased the growth and yield parameters over control and resulted in maximum plant height (66.17cm), number of branches per plant (24.87), number of leaves per plant (284.68), fresh leaf yield (23.35gm) and dry leaf yield per plant (5.98gm) compared to other fertilizer combinations, but it is at par with leaf yield in 30 kgN +vermicompost (VC) @1.5t/ha. Higher values of yield parameters are observed in vermicompost @ 1.5 t/ha in combination with 30 kg N and Azotobacter and 30kgN +vermicompost@1.5t/ha} with estimated dry leaf yield of 4.78q ha^{-1} and 4.32q ha^{-1}, respectively. Maximum contents of NPK in soil after harvest of crop were in FYM @ 12t/ha and Azotobacter followed by VC @ 3t/ha alongwith Azotobacter. Integrated nutrient management comprising the use of VC or FYM in combination with inorganic fertilizers and biofertilizer was best combination of nutrient management compared to sole application of organic or inorganic to increase the leaf yield in stevia under Jammu subtropics. The combination of organic, inorganic and biofertilizers is not only superior over application of manures or fertilizers alone for achieving higher growth and yield but also in maintaining the fertility status of soil.

Keywords: *Stevia rebaudiana,* Integrated nutrient management, Nitrogen, Azotobacter, Vermicompost

Widespread use of medicinal plants for health providing elements has generated bulk demand which cannot be met from their wild source. Cultivation of medicinal plants is the only alternative to conserve their natural diversity with sustainable supply. *Stevia rebaudiana* Bertoni,a sweet herb with low calorie sweetener, natural sweetener, cheeni tulsi or mau tulsi, a native of Northern Eastern Paraguay was introduced in India in last decade of 20^{th} century and is widely used for various purposes. Its leaves consist of two important secondary metabolites (steviol glycoside) namely stevioside and rebaudioside A and C which make it 30 times sweeter than cane sugar surprisingly without any calorie. The sweet compounds pass through the digestive process of the body without chemically breaking down, hence making safe food substance for consumption by people who need to regulate their blood glucose level. It is also used for treating cancer, obesity, hypertension, fatigue, depression and in cosmetics and dental problems. Stevia is in high demand due to its food and medicinal uses. Before undertaking its commercial cultivation, it is necessary to increase yield of economic part which is possible through fertilization and identification of superior lines among the existing population. Though the production can be increased by supplying the nutrient through chemical fertilizers alone but long term use of chemical fertilizers may result in deterioration of soil health. In this endeavour, a blend of organic and inorganic fertilizers (integrated nutrient management) is important not only for increasing yield but also for sustaining soil health (Larney and Hao 2007, Kumar et al 2007). The present study was proposed with the objective to study the effect of Integrated Nutrient management on the growth and yield of *Stevia rebaudiana.*

MATERIAL AND METHODS

The present investigation was carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu. The experiment was conducted under randomized block design with eight treatments and three replications. To meet the requirement of N through organic sources, the doses of manures [Farm yard manure (FYM) and vermicompost] were calculated based upon their individual nitrogen content. Nitrogen (N) was given in the form of urea and was applied with farm yard manure and vermicompost at the time of planting. *Azotobacter* was applied twice during the growth period of crop i.e., 200gm/acre at the time of planting and 200 gm/acre before onset of monsoon. The details of various treatments are in Table 1. Observations were recorded on 5 randomly selected plants per treatment in each replication. The observations were recorded for plant height (cm), number of branches per plant, stem diameter (mm), number of leaves per plant, fresh leaf yield per plant (gm), dry leaf yield per plant (gm), estimated fresh leaf yield per hectare (q), estimated dry leaf yield per hectare (q). After the termination of fertilization trial**,** concentration of major nutrients (NPK, %) was determined in the plants of each treatment using standard methods given by Subbiah and Asija (1956) (nitrogen), Olsen et al 1954 (phosphorus) and Jackson 1967 (potassium). The nutrient status of soil was also determined after the harvest of crop. The data was subjected to statistical analysis of randomized block design using OPSTAT package.

RESULTS AND DISCUSSION

Growth and yield parameters: The fertilization significantly influenced the growth and yield characters (Table 1). The results indicate that application of organic fertilizers is necessary to achieve good growth and yield. Use of chemical fertilizer shows improvement in growth and yield over control, but proved inadequate compared with Integrated Nutrient Management (INM) i.e. organic manures (vermicompost or FYM) in conjunction with inorganic and biofertilizer (Azotobacter). Among the different combinations of fertilizers and manures, application of vermicompost @ 1.5t/ha alongwith ½ of RDN (30kg N/ha) and Azotobacter (T_8) has significantly increased the growth and yield parameters over control (Table 1) and resulted in maximum plant height (66.17cm), number of branches per plant (24.87), number of leaves per plant (284.68), fresh leaf yield (23.35gm) and dry leaf yield per plant (5.98gm) compared to other fertilizer combinations, but is at par with leaf yield recorded in T_6{30kgN (½T_2) +VC @1.5t/ha}. Higher values of yield parameters are observed in T_8 (vermicompost @ 1.5 t/ha in combination with 30kg N and *Azotobacter*) and T_6 {30kgN (½T_2) +VC @1.5t/ha} with estimated dry leaf yield of 4.78q ha^{-1} and 4.32q ha^{-1}, respectively. Integrated nutrient management (vermicompost or FYM in combination with inorganic fertilizers and biofertilizer) was found better than application of organic or inorganic alone to increase the leaf yield in stevia under Jammu subtropics. The reason for higher growth under integrated nutrient management may be due to sustainable/continuous availability of nutrients especially nitrogen throughout the growth period coupled with lesser leaching losses of nutrients. Application of Azotobacter although increased the growth parameters but the increase is non-significant compared to treatment which don't received Azotobacter. The results are of Das et al (2007), Patil (2010), Liu et al (2011) and Kumar et al (2013) also recorded higher growth parameters in *Stevia rebaudiana* under combined application of manures, inorganic fertilizers and biofertilizer.

NPK uptake by plants and fertility status of soil after crop harvest: N, P and K concentrations (%) in plants though increased with the addition of manures and fertilizers but are not significantly different from each other and varies from 1.29-1.44, 0.27-0.32 and 2.23-2.41 per cent, respectively (Table 2). The increase in NPK concentrations (%) might be due to the efficient supply of macro and micro nutrients under integrated nutrient management *vis-a-vis* organic manures act as a source of plant nutrient and humus, which improves the soil physical condition by increasing its capacity to absorb and store water, improving aeration and favouring microbial activity, thereby making conditions favourable for nutrient uptake (Joy et al2005).After the harvest of the crop, the available N in soil is increased significantly due to fertilization

Table 1. Effect of fertilizers and manures on growth and yield parameter

Treatments	Plant height (cm)	Branches $plant^{-1}$	Stem diameter (mm)	Leaves $plant^{-1}$	Leaf yield $plant^{-1}$ (gm)		Estimated leaf yield ha^{-1}(q)	
					Fresh	Dry	Fresh	Dry
T_1 (Control)	48.08	11.86	8.34	157.73	12.82	3.03	10.25	2.42
T_2 [N@ 60 kg ha^{-1}(RDN*)]	59.09	18.19	8.82	216.56	17.88	4.76	14.30	3.81
T_3 [FYM @ 12 tha^{-1} +Azotobacter]	54.33	15.03	8.93	184.21	15.05	3.98	12.03	3.18
T_4 [VC @ 3t ha^{-1}+ Azotobacter]	56.58	18.08	9.30	214.72	17.57	4.53	14.05	3.62
T_5 [30 kg N (½T_2) + FYM @ 6 t ha^{-1}]	62.14	19.06	9.59	228.07	18.25	4.59	14.60	3.67
T_6 [30 kg N (½T_2) + VC @ 1.5 t ha^{-1}	65.25	24.25	10.31	274.62	22.28	5.41	17.82	4.32
T_7 [30 kg N (½T_2) + FYM @ 6 t ha^{-1}+ Azotobacter]	62.60	19.12	9.81	233.94	18.72	4.70	14.98	3.76
T_8 [30 kg N(½T_2)+VC @ 1.5 t ha^{-1}+ Azotobacter]	66.17	24.87	10.56	284.68	23.35	5.98	18.68	4.78
CD (p=0.05)	8.35	4.54	NS	31.41	3.52	0.64	2.82	0.51

*Recommended dose of nitrogen

Table 2. Effect of fertilizers and manures on NPK (%) concentration in plant and on soil fertility status after harvest of crop

Treatments	NPK (%) concentration in plant			Soil fertility status after harvest		
	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	1.29	0.27	2.23	197.73	14.10	154.94
T_2	1.32	0.29	2.32	255.50	14.62	157.91
T_3	1.28	0.28	2.34	262.07	17.14	168.02
T_4	1.36	0.29	2.38	254.77	15.32	160.34
T_5	1.39	0.30	2.30	244.84	15.06	159.81
T_6	1.42	0.30	2.41	248.15	16.12	161.23
T_7	1.40	0.29	2.39	247.26	15.31	160.35
T_8	1.44	0.32	2.40	250.49	16.18	160.83
CD (p=0.05)	NS	NS	NS	5.42	NS	NS
			Initial status	254.54	16.18	166.39

See Table 1 for treatment details

over control. Application of FYM @ 12t/ha and Azotobacter has resulted in increased available N (262.07 kg/ha) over the initial of 254.54 kg/ha (Table 2). However, T_8 and T_6 treatments, in which higher yields are obtained, the available N is recorded to be 250.49 kg/ha and 248.15kg/ha, respectively but are slightly lower (non-significant) than their initial status. Available P and K in soil are not significantly influenced by fertilization.

The increase in available N may be ascribed to mineralization of partially or fully immobilized N by farm yard manure in soil, nitrogen fixation by *Azotobacter*. The increase in N content could also be due to inability of micro-organisms to decompose the organic manures applied and make it available for the plant. These results are in close conformity with those reported by Joy et al (2005), Naik and Babu (2007), Kumar et al (2012) and Kumar et al (2013).

CONCLUSION

Combination of organic, inorganic and biofertilizers is superior over application of manures or fertilizers alone for higher growth and yield in *Stevia rebaudiana*. Application of vermicompost @ 1.5 t/ha along with 30kgN per hectare (½ of recommended dose) and *Azotobacter* is beneficial not only to increase the leaf yield but also in maintaining the fertility status of soil.

REFERENCES

Das K, Dang R, Shivananda TN and Sekeroglu N 2007. Comparative efficiency of bio-and chemical fertilizers on nutrient contents and biomass yield in medicinal plant *Stevia rebaudiana* Bert. *International Journal of Natural and Engineering Science* **1**(3): 35-39.

Jackson ML 1967. *Soil chemical analysis*, Prentice Hall Inc, New York, USA, pp 375.

Joy PP, Savithri KE, Mathew S, Thomas J and Kurien K 2005. Effect of sole and combined application of FYM and fertilizer on growth, yield and quality of blackmusli (*Curculigo orchioides*). *Journal of Medicinal and Aromatic Plant Sciences* **27**: 454-461.

Kumar A, Tripathi HP and Yadav DS 2007. Correcting nutrient for sustainable crop production. *Indian Journal of Fertilizers* **2**: 37-44.

Kumar MEC, Madusudhana MK, Reddy NVE and Rathod P 2012. Influence of organic manures and bio-fertilizer on yield and quality of stevia (*Stevia rebaudiana* Bertoni). *Plant Archives* **12**(1): 299-302.

Kumar R, Sharma S and Prasad R 2013. Yield, nutrient uptake, and quality of Stevia as affected by organic sources of nutrient. *Communications in Soil Science and Plant Analysis* **44**(21): 3137-3149.

Larney FJ and Hao X 2007. A review of compositing as management alternative for beef cattle feedlot manure in southern Alberta, Canada. *Bioresource Technology* **98**: 3221-3227.

Liu X, Ren G and Shi Y 2011. The effect of organic manure and chemical fertilizer on growth and development of *Stevia rebaudiana* Bertoni. *Energy Procedia* **5**: 1200-1204.

Olsen SR, Cole CW, Watenabe PS and Dean LA 1954. Estimation of available phosphorus in soil by extraction with $NaHCO_3$. *United States Department of Agriculture Circular* **939**: 19-33.

Naik MH and Babu RSH 2007. Feasibility of organic farming in guava (*Psidium guajava* L.). *Acta Horticulturae* **735**: 365-371.

Patil NM 2010. Biofertilizers effect on growth, protein and carbohydrate content in *Stevia rebaudiana* Bertoni. *Recent Research in Science and Technology* **2**(10): 42-44.

Subbiah BV and Asija GL 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25**: 259.

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Long-term Impact of Cotton Insecticide Resistance Management Programme: A Case Study from Punjab, India

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Abstract: An Insecticide Resistance Management (IRM) based Integrated Pest Management (IPM) programme was launched in 10 cotton-growing states of India in 2002, coinciding with the commercialization of Bt cotton in western and southern regions of the country. In Punjab, the IRM programme for rationalizing insecticide use was implemented from 2002 to 2013.A field study with IRM intervention and without IRM intervention was employed to compare the differences between IRM and non-IRM farmers in 2016, and a modified quasi-experimental difference-in-differences (DD) research design was used to compare changes between IRM and non-IRM farmers between 2004 and 2016 to account for biases over time due to seasonality and the widespread adoption of Bt cotton since 2004. In 2004, the IRM farmers' insecticide use (a.i.) in cotton area was less than 30% compared to non-IRM farmers. However, the difference in mean insecticide use (a.i.) per hectare farm per farmer between IRM and non-IRM farmers was only 10.3%, which was not significant. IRM farmers' mean number of insecticide applications was15% less than non-IRM farmers and the difference was significant but without any significant difference in yield compared to the non-IRM farmers. We revisited the study area of 2003–2004 in 2016 to find out the impact of the programme after the IRM intervention was withdrawn. We observed a significant reduction in insecticide use by volume and the number of applications both among the IRM trained and other farmers over time, but unlike in 2004, the differences between IRM and non-IRM farmers had not only flattened over time but also the non-IRM farmers had applied lesser number and volume of insecticides (a.i.) without any significant difference. The reduction in insecticide applications and active ingredients among both IRM and non-IRM can be attributed to the widespread adoption of Bt cotton and *Helicoverpa armigera* no longer being a key pest of cotton.

Keywords: Adoption, Environmental impact, Impact evaluation, Insecticide resistance management, Integrated pest management, Pesticide use

India is the world's leading cotton cultivating country. Cotton is cultivated on 13.3 million ha with a total production of 35.2 million bales (1 bale=170kg), but the productivity (491kg/ha; CCI 2022) is lower than the world average (772 kg/ha; USDA 2022). The major reasons for low productivity are both biotic and abiotic stresses. Prior to the commercialization of Bt cotton in 2002, the insecticide use in cotton accounted for 50% of the total pesticide use in Indian agriculture (Peshin et al 2014). The cotton insect pest management posed many challenges to cotton growers and entomologists. Despite heavy insecticide use, the cotton crop was ravaged by insect pest outbreaks, mainly bollworms, leading to the failure of the cotton crop. The cotton bollworm, *Helicoverpa armigera* (Hubner), a key pest of cotton, exhibited widespread resistance to cypermethrin, endosulfan, and chlorpyriphos (Kranthi et al 2002). To ameliorate this problem, the Insecticide Resistance Management (IRM) based Integrated Pest Management (IPM) programme was launched by the Central Institute for Cotton Research (CICR) under the cotton Mini Mission in 10 major cotton producing states in 2002. These 10 states accounted for 80% of the insecticide use in cotton (Russell, 2004). There have been studies reporting positive impacts of the IRM programme on reduction in insecticide use active ingredients (a.i.) and applications, saving on insecticide expenditure (ICAR 2007, Peshin et al 2009, Kumar et al 2012, Kranthi et al 2019). But these studies have measured immediate outcomes (short-term impacts), before the withdrawal of IRM programme intervention. Punjab-specific IRM module was validated by the Punjab Agricultural University (PAU), Ludhiana, India and is a part of its recommendation for cotton cultivation in Punjab. Peshin et al (2009) conducted a field study in 2003 and 2004 to find out the immediate outcome of the IRM programme in Punjab during the programme intervention. Peshin et al (2009) reported that the IRM programme implementation resulted in lesser insecticide use by weight (a.i.) and applications by the IRM farmers compared to non-IRM farmers. However, long- -

term impact evaluations are necessary to assess whether benefits are indeed sustained over time. Therefore, what has been the long-term impact of the IRM programme; we conducted an empirical field study in Punjab, India. The study area was revisited in 2016 and the comparison was made with 2004 data.

MATERIAL AND METHODS

Study area: Under the IRM project, Bathinda (30.2110° N, 74.9455° E), Mansa (29.9995° N, 75.3937° E), and Fazilka (30.4036° N, 74.0280° E) districts, covering 72% of cotton-growing areas, were selected for the field study in 2003 and 2004 for finding the immediate outcomes of the IRM programme in cotton. The study area was revisited in 2016 for conducting the field study

Sampling plan: A sample of 150 cotton farmers trained under the IRM programme and a control group of 60 cotton farmers were surveyed and the results were published in a peer-reviewed journal (Peshin et al 2009). For assessing the long-term impact of the IRM programme, the sampled farmers were revisited in 2016–2017.Because of sample attrition, only 172 of them could be contacted, and of the total contacted farmers, only 121 were cultivating cotton (IRM 92 and non-IRM 29) and the rest had shifted from cotton to rice cultivation and a few had given up farming and leased out their farms. An additional sample of 83 cotton farmers was drawn from six villages from the list of IRM and non-IRM cotton farmers prepared in 2003 and 2004. The new additions were from the same test and control farmers as in 2003–2004.The sample size comprised 27 villages and 204 farmers.

Empirical framework: Treatment and control groups with/without (Eq.1) and modified quasi-experimental difference-in-differences (DD) design were used to compare the differences between IRM and non-IRM cotton farmers and the changes between 2004 and 2016 (Eq.2). DD is a quasi-experimental design that makes use of longitudinal data from treatment and control groups to estimate a causal effect. DD was used to account for biases over time due to seasonality and the widespread adoption of Bt cotton since 2004.

$$\Delta Y = Y_t - Y_c \qquad (1)$$

Here, Y is the impact of IRM programmes, Y_t denotes the observations in the treatment group with IRM intervention, and Y_c denotes the observations in the control group without IRM intervention.

$$\Delta\Delta Y = (Y_{t2} - Y_{t1}) - (Y_{c2} - Y_{c1}) \qquad (2)$$

Here, Y represents the difference-in-differences between IRM and non-IRM cotton farmers, Y_{t1} and Y_{t2} denote the observations in the treatment group in 2004 and 2016, respectively, and Y_{c1} and Y_{c2} indicate the observations in the control group in 2004 and 2016, respectively.

Impact evaluation indicators: The following were the impact evaluation indicators of the IRM programmes:

Extent of adoption: It was measured as percent of farmers adopting a particular pest management practice. A score of "1"was for adoption and "0" otherwise.

Pesticide use by weight: Pesticide use by weight (a.i.) kg/ha was calculated by summing up the different pesticides applied by farmers and dividing it by the total area under cotton crop and mean pesticide (a.i.) applied/farmer/ha of farm.

Pesticide applications: It was the average treatment frequency of pesticides (herbicides, fungicides, insecticides, and bio-pesticides) applied to the cotton crop.

Proportion of pesticides (a.i.): The proportion of pesticides applied belonging to different hazard categories was measured by using the World Health Organization classification (Ia: extremely hazardous, Ib: highly hazardous, II: moderately hazardous, III: slightly hazardous, U: unlikely to present an acute hazard) (WHO 2020), and the proportion of probable and possible carcinogenic pesticides (a.i.) applied was determined based on the U.S. Environmental Protection Agency categorization (EPA 2018).

Field use environmental impact quotient (FEIQ) of pesticides: The methodology of Kovach et al (1992) was employed to measure the FEIQ of pesticides on consumers, workers, and ecology for comparing the pesticide use. The Cornell University reference EIQs were used for the calculation of FEIQ. The FEIQ was calculated by the formula of Kovach et al (1992).

$$FEIQ = EIQ \text{ of a pesticide} \times \% \text{ active ingredient} \times \text{dosage rate per ha} \qquad (3)$$

FEIQ was calculated by summing over the FEIQ of each active ingredient applied per ha.

Data collection: The structured interview schedule was developed for data collection from cotton farmers in face-to-face interviews in 2016 and 2017.

Statistical analysis: The data on differences between IPM and non-IPM farmers were analyzed with the help of two sampled *t*-test and *z*-test of proportions. Heckman (1979) two-step model was employed for identifying the sample bias and variables affecting pesticide applications. IBM SPSS 25 and Stata 12 were used for the analysis of the data.

Heckman's two-step selection model: Linear regression model does not account for endogeneity and sample selection bias. Many approaches to address endogeneity and self-selection of farmers, such as progressive/active farmers volunteering for training (Peshin et al 2009, Knook et al 2018), difference-in-differences, propensity score matching, and the Heckman correction model (Heckman 1979), are employed. We employed both the modified difference-in-differences to compare the differences between IRM and non-IRM cotton farmers between 2004 and 2016 and Heckman's two-step model to address the issue of sample selection bias.

The dependent variables in Heckman's two-step estimation model were farmers having participated in the IRM programme and the number of pesticide applications. The probability of participation in the IRM programme was estimated by using a probit model (Eq 4).

$P_i = \beta_0 + \beta_1 X_1 + ... + \beta_{15} X_{15} + \mu_1 > 0$ .... (4)

Here, P_i is the probability of participation of a farmer in the IRM programme ("1" for participation in IRM and "0" otherwise), β_0 is the intercept, and x_1 to x_{15} are explanatory variables. The explanatory variables entered in the selection model were age, education, family size, farming experience, farm size, the area under cotton crop, land leased-in, household members associated with farming, households having non-farm income, and distances of households to the nearest market, seed store, fertilizer store, pesticide shop, and agriculture office. The measurement of the variables is given in Table 1. β_1 to β_{15} are vectors of explanatory variables estimated. μ_1 is the normally distributed error term. From Eq. 4, we obtain the inverse Mills ratio (λ), which is used as a control in the outcome equation for correction of the sample selection bias, yielding estimates of the predictor of the outcome (Rejesus et al 2009).

$Y_i = \beta_0 + \beta_1 X_1 + ... + \beta_{14} X_{14} + \mu_1$ .... (5)

In Eq. 5, Y_i is the dependent variable (the number of pesticide applications in cotton crop) of the outcome equation, β_0 is the intercept, μ_1 is the error term, and x_1 to x_{14} represent predictors of the outcome equation, namely, age, education, family size, households with non-farm income, land leased-in, the area under cotton, total landholding, the distance of a household from the nearest pesticide store, purchase of a pesticide on credit, and sources of information about pesticides such as pesticide agents, package of practices of PAU, farmer's own experience, fellow farmers, and mass media. The measurements of these predictor variables are given in Table 1. β_1 to β_{14} are vectors of explanatory variables x_1 to x_{14}. The default value of a 5% significance level was adopted. The regression equations were run using Stata 12 software.

Binary logistic regression: Binary logistic regression model was applied to identify the independent variables influencing the dependent variables where the dependent variables were dichotomous (adoption of selected IPM practices). The result of this type of regression can be expressed as follows:

$$Ln\left[\frac{p}{1-p}\right] = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 ...... b_k x_k \qquad (6)$$

Here, p is the probability of an outcome, $\ln[p/(1-p)]$ is the log odds ratio or logit, b_0 is the y-intercept, b_1 to b_k represent the predictors in the equation. x_1 to x_k represent the independent variables given in Table 1.

RESULTS AND DISCUSSION

Descriptive statistics: There were no significant differences between the sampled IRM and non-IRM farmers with respect to their operational landholdings, age, literacy

Table 1. List of independent variables and their measurement

Independent variable	Measurement
Age	No. of years
Literacy	"1" for literate and "0" for illiterate
Education	No. of formal schooling years
Family size	No. of family members
Family members associated with farming	No.
Operational landholding	Ha
Owned landholding	Ha
Leased-in landholding	Ha
Leased-out landholding	Ha
Area under cotton	Ha
Farming experience	Number of years
Non-farm economic activity	"1" for non-farm and "0" for otherwise
Sources of information about pesticides	"1" for a particular source of information and "0" for not using that particular source of information
Bt and non-Bt	"1" for Bt and "0" for non-Bt
IRM training	"1" for IRM farmers and "0" for non-IRM farmers

rate, average formal schooling years completed, and possession of mobile phones (Table 2). The samples of IRM and non-IRM farmers matched on biophysical and personality variables.

Adoption of IPM practices: IPM practices adopted by the farmers were the cultivation of PAU-recommended Bt-cotton hybrids and other varieties resistant to sucking pests and cotton leaf curl virus (CLCV), which accounted for more than 50% of the total adoption (Table 3). Timely sowing, from April 1 to May 15,was done by more than 70% of the cotton growers, which resulted in the prevention of insect pest attack and diseases and thereby a better yield (PAU 2016). Cleaning of bunds to destroy the alternative host of cotton leaf curl virus and whitefly was done by 91% and 76% of the IRM

Table 2. Descriptive statistics for the IRM (treatment) and non-IRM (control) farmers

Parameter	IRM (n=141)	Non-IRM (n=63)	Difference
Average age of the respondent farmers (years)	43.8±0.95	44.1±1.65	0.3
Literate (%)	93	83	10
Average formal schooling (years)	9.2±0.31	8.7±0.78	0.5
Mobil phone (%)	93	86	7
Average family members of a household (No.)	6.7±0.21	6.8±0.32	0.1
Farm families exclusively dependent on on-farm income (%)	69	62	7
Farm families having non-farm income (%)	31	38	7
Average family members associated with farming (No.)	1.8±0.06	1.9±0.11	0.1
Average farming experience of respondents (years)	24.5±0.93	25.3±1.56	0.8
Average operational landholding	6.1±0.21	7.0±0.62	0.9
I. Owned (ha)	5.3±0.37	6.1±0.61	0.8
I. Leased-in (ha)	1.2±0.17	1.3±0.27	0.1
ii. Leased-out (ha)	0.4±0.22	0.4±0.10	0
Average area under cotton (ha)	2.01	2.37	
% area under cotton	32.95	33.86	0.91
Farm size[a](% farms)			
I. Marginal(<1ha)	6	3	3
I. Small (1–2 ha)	12	20	8
ii. Semi-medium (2–4 ha)	29	16	13
iii. Medium (4–10 ha)	38	37	1
iv. Large (>10 ha)	15	24	9
Sources of irrigation (% farms)			
I. Canal	98	97	1
I. Diesel pumps	67	71	4
ii. Electric pumps	51	49	2
Permanent hired labour (% farms)	41	43	2
Average distance from (km)			
Department of Agriculture office	13.3±0.420	19.8±1.184	6.5*±1.004
Seed retailer	11.7±0.513	16.0±1.128	4.3*±1.076
Fertilizer store	6.4±0.556	7.3±0.780	0.9±0.994
Pesticide retailer	12.1±0.413	15.6±1.071	2.7*±0.984
Nearest cotton sale point	12.9±0.413	12.9±0.413	1 2.7*±0.984
Commission agent	14.0±0.363	14.5±1.005	0.5±0.859
Cooperative store	3.3±0.345	3.9±0.671	0.9±0.686
Farm households cultivating cotton in 2016	79	83	3

Significant at p<0.05. ± Std. mean error

[a]Categorization of landholding as per the Government of India classification of farmers

and the non-IRM farmers, respectively. The recommendation not to grow okra, green gram, pigeon pea, castor, and *Sesbania bispinosa* in and around the cotton fields to reduce the build up of insect pests and diseases, especially tobacco caterpillar (*Spodoptera litura*), did not differ among IRM and non-IRM farmers. The surveillance to monitor insect pests such as jassids (*Amrasca biguttula*) and whitefly (*Bemisia tabaci*) was widely adopted. In case of jassids, the adoption of PAU-recommended ETL, along with farmers' own modifications of thresholds, was around 21% and 14% in the IPM and non-IPM villages. This was on the higher side in 2016, as the PAU and Department of Agriculture had employed scouts in 2016 to combat the whitefly infestation that devastated the crop in 2015. A small percentage of farmers had applied synthetic pyrethroids after September 15, 2016. Following the PAU recommendation, about 65% and 84% of the IRM and non-IRM farmers, respectively, did not apply synthetic pyrethroids after September 15 to minimize a resurgence of whitefly (PAU 2022). The sowing of non-Bt varieties/hybrids as a refuge to manage resistance to Bt toxins in bollworms over time was zero.

Factors affecting adoption of non-pesticide IPM practices: The socioeconomic and biophysical variables impacting the adoption of non-pesticide IPM practices were analyzed by running a binary logistic regression model. There was no uniformity in the predictors of adoption of different non-pesticide IPM practices (Table 4). In case of adoption of the PAU-recommended hybrids, the drivers of adoption were the area under cotton, family members associated with farming, and farmers trained under the IRM programme. Surprisingly, the IRM training was negatively impacting the cultivation of the PAU-recommended varieties/hybrids (Table 4).

Impact on pesticide use: Contrary to our hypotheses that IRM implementation would have had a long-term impact on the reduction of pesticide use by weight and applications, the results show otherwise. There is not much to differentiate between the IRM and the non-IRM cotton farmers. In cotton, the IRM farmers on average had applied more insecticide applications in Bt cotton hybrids, non-Bt varieties, and *desi* cotton and the difference was significant only in Bt cotton (t=2.486; p=0.014), which was cultivated by 95% of farmers on 92% acreage. The other cultivars were cultivated by a mere 5% of farmers. In non-Bt varieties, the non-IRM farmers had applied more fungicide applications and the difference was not significant (Table 5).

In cotton, the key pests reported were whitefly (*B. tabaci*), jassids (*Amrasca biguttula*), thrips (*Thrips tabaci*), wilt (caused by *Fusarium oxysporum* f. sp. *vasinfectum*), and Anthracnose (caused by *Colletotrichum lindemuthianum*). Pesticide use by weight (a.i.) among IRM farmers was marginally higher than non-IPM farmers by about 13%. The insecticide contributed 70% of the total pesticide use in cotton (Fig. 1). The impact of IRM on the environment and human health was estimated by FEIQ of pesticides applied by the IRM and non-IRM farmers and the use of the riskiest pesticides that have been reported to be probable and possible carcinogenic by the Environmental Protection Agency (EPA) of the United States (EPA, 2018). In cotton, insecticides contributed more than 75% of the total FEIQ in both the IRM and non-IRM villages, and organophosphates contributed around 66% and 61% in the IRM and non-IRM villages, respectively (Table 6). In the IRM and non-IRM villages, the contribution of probable (B) and possible (C) carcinogenic pesticides to the total pesticide use was 23.5%. However, FEIQ of pesticide use was more in the case of the IRM farmers.

Pesticide expenditure: In 2004, pesticide costs with regard to cotton accounted for 31% and 27%of the total cost of

Table 3. Adoption of IPM practices in cotton

Practice	IRM (n=141)	Non-IRM (n=63)	Difference
Cultivation of recommended Bt/hybrids resistant to sucking pests and CLCV	69	51	18
Timely sowing (April to May 15)[#]	72	77	–5
Cleaning of bunds to destroy alternate hosts of CLCV and whitefly	91	76	15
Bt cotton	94	94	0
Avoiding cultivation of alternate host crops of tobacco caterpillar	29	35	-6
Surveillance for monitoring insect pests	96	100	–4
Regular field visit	99	100	–1
Farmers' own thresholds for taking pesticide use decision	89	90	–1
Adoption of a threshold concept for Jassids	21	14	7
No synthetic pyrethroids applied after September 15	65	84	19

CLCV, cotton leaf curl virus
[#]Timely and late sowing (April to May): Cotton farmers who started sowing their cotton crop in April and completed sowing after May 15

Table 4. Factors affecting the adoption of non-chemical IPM practices in cotton

Practice	Coefficient (β)	SE	Wald	p value	Model summary
Cultivation of PAU-recommended hybrids/Bt					
Constant	0.923	0.449	4.220	0.040	–2 log likelihood 244.792 Nagelkerke'sR^2 = 0.149 χ^2= 5.402 df = 8 p = 0.714 Predicted percentage = 63.2
Family members associated with farming	–0.383	0.189	4.079	0.043	
Area under cotton	0.272	0.091	8.923	0.003	
IRM farmers	–0.853	0.329	6.718	0.010	
Timely date of sowing (upto 15th of May)					
Constant	2.219	0.400	30.742	0.000	–2 log likelihood 212.770 Nagelkerke's R^2 = 0.140 χ^2= 10.164 df = 8 p = 0.254 Predicted percentage = 73.9
Area under cotton	–0.124	0.059	4.479	0.034	
Distance from the seed store	0.052	0.026	4.154	0.042	
Distance from market/mandi	–0.102	0.031	11.078	0.001	
Timely and late sowing					
Constant	0.859	1.050	0.669	0.413	–2 log likelihood 132.762 Nagelkerke'sR^2 = 0.199 χ^2= 5.149,df = 8 p = 0.742 Predicted percentage = 87.3
Family members associated with farming	–0.795	0.315	6.370	0.012	
Area under cotton	0.216	0.064	11.271	0.001	
Age of the respondent	–0.051	0.021	5.711	0.017	
Late sowing (after 15th May)					
Constant	–3.628	0.587	38.256	0.000	–2 log likelihood 138.64 Nagelkerke'sR^2 = 0.119 χ^2= 11.695,df = 7 p = 0.111 Predicted percentage = 87.7
Distance from the cotton mandi	0.102	0.030	11.929	0.001	
Cleaning/weeding of bunds					
Constant	3.334	0.554		36.165	–2 log likelihood 144.260 Nagelkerke'sR^2 = 0.095 χ^2= 10.572,df = 1 p = 0.001 Predicted percentage = 87
Distance from the pesticide store	–0.089	0.029		9.747	
Avoiding cultivation of crops that are alternate hosts of insect pests around cotton crop					
Constant	–2.032	0.410	24.550	0.000	–2 log likelihood 217.772 Nagelkerke'sR^2 = 0.208 χ^2= 32.200,df = 3 p = 0.000 Predicted %age = 76.60
Operational land holdings	0.07	0.031	5.392	0.020	
Distance from the nearest agricultural market	–0.099	0.037	7.220	0.007	
Distance from the nearest pesticide retailer	0.154	0.039	15.972	0.000	

Cont...

Table 4. Factors affecting the adoption of non-chemical IPM practices in cotton

Practice	Coefficient (β)	SE	Wald	p value	Model summary
Pest surveillance and monitoring					
Constant	0.335	0.895	0.140	0.708	–2 log likelihood 40.980 Nagelkerke'sR^2 = 0.266 χ^2= 12.978,df = 2 p = 0.002 Predicted percentage = 97
Distance from Commission agent	0.245	0.089	7.603	0.006	
IRM farmer	18.502	1.009	0.160	0.002	
Not using synthetic pyrethroids after 15th September					
Constant	–2.027	0.537	14.235	0.000	–2 log likelihood 228.216 Nagelkerke'sR^2 = 0.114 χ^2= 16.841,df = 3 p = 0.001 Predicted percentage = 74.10
IRM trained farmer	–1.038	0.412	6.337	0.012	
Commission agent	0.050	0.026	3.789	0.052	
Farming experience	0.878	0.412	4.525	0.033	

Table 5. Average number of pesticide applications in cotton

Pesticide/crop	IRM farmers (n=141)	Non-IRM farmers (n=63)	Difference
Gossypium hirsutum L.			
Bt cotton hybrids	n=133	n=60	
Insecticides	8.46±0.279	7.37±0.339	+1.09* (14.8)
Fungicides[1]	0.79±0.091	0.83±0.168	-0.04 (4.8)
Herbicides[1]	0.42±0.050	0.53±0.080	-0.11 (20.1)
All pesticides	9.67	8.73	+0.94(10.8)
Non-Bt cotton varieties	n=9	n=6	
Insecticide	8.56±0.818	7.17±1.447	+1.39(19.4)
Fungicides[1]	0.11±0.111	0.67±0.333	-0.56*(83.6)
Herbicides[1]	0.56±0.176	0.50±0.341	+0.056 (11.2)
All pesticides	9.23	8.34	+0.89 (10.7)
G. arboreum L.			
Desi cotton	n=21	n=13	
Insecticide	7.14± 0.741	6.92±0.916	+0.22 (3.2)
Fungicides[1]	0.29±0.171	0.38±0.241	-0.09 (23.7)
Herbicides[1]	0.30±0.105	0.54±0.183	-0.24 (44.4)
All pesticides	7.73	7.84	-0.11 (1.4)

Notes: [1] Herbicides and fungicides were not components of the IRM programme but the data included to workout insecticide contribution to the total pesticide use in cotton. ± Std. mean error. *n* is the number of farmers out of a sample of 204 who had cultivated different cotton cultivars. Figures in the parentheses are the % differences with non-IRM farmers. *Significant at $p<0.05$.

cultivation in the IRM and non-IRM villages, respectively (Peshin et al 2009); this had come down to around 20% in 2016–2017, owing to reduction in pesticide applications since the commercialization of Bt cotton.

Sources of information: IRM cotton farmers were less dependent on pesticide retailers/pesticide industry sale agents compared to those in the non-IRM villages (Table 7). Although farmers have vast hands-on experience, they consult different sources for pest- and pesticide-related advice. The pesticide industry has a greater influence on farmers' pesticide use decisions compared to public sector extension agencies.

Factors affecting pesticide applications: Heckman's two-step model: The independent variable that determined the participation of farmers in the IRM programme was the distance of the household from the nearest market, whereas the distance of a village from pesticide stores negatively affected the participation in the IRM programme (Table 8). The variables causing a positive variation in pesticide use in the cotton were (i) area under cotton crop and (ii) influence of neighbour/fellow cotton farmers in pesticide use decision. There was no sample selection bias as the inverse Mills ratio was not significant (–0.682, p = 0.663), confirming that the estimates of impacts on pesticide applications are free of sample selection bias (Table 8). The other variables that caused variation in the pesticide applications at $p \leq 0.10$ were land leased-in and farm size.

Difference-in-differences between 2004 and 2016: Modified difference-in-differences (DD) model (Ashenfelter and Card 1985) was used to determine the change in pesticide use frequency between 2004 and 2016and to eliminate the seasonal effect and impact of Bt cotton cultivation over time. In 2004, none of the farmers had applied fungicides to cotton (Peshin 2005, Peshin et al 2009), but in 2016 the average fungicide use frequency was 0.79 and 0.83 in the IRM and non-IRM villages, respectively (Table

Table 6. Insecticide use by weight (a.i.) and FEIQ in cotton in 2016 (Cotton insect pests)

Pesticides applied to cotton	Insecticide use (a.i.) (kg/ha)		FEIQ/ha	
	IRM	Non-IRM	IRM	Non-IRM
Insecticides				
Acephate[C]	0.127	0.065	3.15	1.63
Alphamethrin[C]	0.005	0.003	NA	NA
Chlorpyriphos	0.000	0.014	0.00	0.36
Clothianidin	0.003	0.002	0.08	0.07
Cypermethrin[C]	0.000	0.001	0.00	0.05
Diafenthiuron	0.206	0.139	6.57	4.43
Dichlorvos	0.016	0.000	0.84	0.02
Dimethoate[C]	0.058	0.053	1.94	1.78
Dinotefuran	0.008	0.000	0.18	0.00
Ethion	0.423	0.472	18.28	20.41
Fenvalerate	0.015	0.002	0.61	0.07
Fipronil[C]	0.003	0.010	0.32	0.91
Flonicamid	0.051	0.056	0.45	0.49
Imidacloprid	0.073	0.172	2.69	6.31
Indoxacarb	0.001	0.000	0.02	0.01
Lambda-cyhalothrin	0.000	0.000	0.01	0.00
Monocrotophos	0.157	0.160	6.95	7.07
Pyriproxyfen	0.045	0.050	0.66	0.74
Quinalphos	0.000	0.003	0.00	0.12
Spinosad	0.006	0.002	0.09	0.04
Spiromesifen	0.021	0.001	0.59	0.04
Thiodicarb[B]	0.000	0.002	0.00	0.05
Thiamethoxam	0.123	0.093	4.10	3.09
Triazophos	0.614	0.426	21.87	15.17
β-Cyfluthrin	0.001	0.001	0.05	0.03
Insect growth regulator				
Chlorantraniliprole	0.005	0.003	0.09	0.05
Novaluron	0.000	0.011	0.00	0.15
Emamectin benzoate	0.001	0.007	0.02	0.19
Total	1.962	1.748	69.56	63.28

Notes: The superscripts "B" and "C" denote probable and possible carcinogenic pesticides, respectively. FEIQs do not include alphamethrin and *P. fluorescens* as their reference EIQs are not available. The total insecticide use does not include *P. fluorescens and neem based* formulations

Table 7. Sources of information about pesticide use (% farmers)[a]

Source	IRM	Non-IRM	Difference
Department of Agriculture	26	14	12
PAU	06	06	00
KVKs of PAU	04	02	02
Pesticide retailer/company	38	65	27
Package of practices of PAU	05	02	03
Commission agents	05	06	01
Own experience of the farmers	78	62	08
Progressive farmers	47	62	15
Newspaper	01	02	01
Radio	01	02	01
Television	00	02	02
Scouts of the PAU	06	02	04
Others	00	00	00

[a]Multiple sources of information: KVK, Krishi Vigyan Kendras; PAU, Punjab Agricultural University

6). A change was also observed in the use of botanical or biological pesticides. In 2004, none of the farmers had applied botanical or biological pesticides (Peshin 2005), but in 2016 the average use frequency of these pesticides was 0.20 and 0.22 in the IRM and non-IRM villages, respectively, though not recommended under IRM (Table 8). The farmers had applied these for multiple sucking pests.

In 2003, there was no significant difference between the mean frequency of pesticide use between IRM and non-IRM farmers, and after the intervention of the IRM programme, the IRM farmers reduced the use of insecticide applications by 2.36 in 2004 (Peshin 2005). In 2004, the average number of insecticide applications in the IRM villages was 13.1 compared to 15.1 in non-IRM villages, with a significant difference of 15.3% (t =2.1, $p \leq 0.05$). The pesticide use by weight (a.i.) applied by in the IRM and non-IRM villages was 5.602 and 8.032 kg/ha, respectively, with a difference of 30.25%. However, the mean insecticide applied per ha per farm by the IRM and non-IRM farmers was 5.455 and 6.083kg, respectively (Table 10). After the withdrawal of IRM intervention, the difference in insecticide use frequency between these two groups in 2016 was 0.9, which was not significant (Table 10). Besides, there were no significant differences in seed cotton yield and active ingredients of pesticides applied by the IRM and non-IRM farmers. But if we analyze the data using the modified DD model, the differences in pesticide applications and active ingredients of pesticides applied are found to be 2.9 applications and 0.746kg/ha, respectively. After the withdrawal of the IRM intervention, if we analyze the data using the DD methodology, the difference in mean pesticide applications is 2.9, which is significant.

Overall pesticide use has decreased since 2004, but that can be attributed to Bt cotton cultivation (Peshin 2005, Peshin et al 2007, Peshin et al 2021). The cultural pest management practices, such as timely sowing of the cotton crop having a high adoptability index (Peshin 2013) to avoid late season insect pest infestation, using seeds treated with chemicals, not applying or reducing the use of synthetic pyrethroids to avoid whitefly resurgence, were widely and equally adopted by both the IRM and non-IRM farmers in 2004 and 2016.Bt cotton has reached a 95% rate of adoption, yet pesticide use has consistently increased in Bt cotton since 2004, especially fungicides from zero (Peshin et al 2007, 2009) to 15% of total pesticides. The impact of the IRM programme at the national level, based on the project reports, is the reduction in insecticide use per hectare, which resulted in the saving of US$84/ha (US$1=Rs. 44 at 2005 rates) during 2002–2006 (ICAR, 2007; Peshin et al., 2009), US$46/ha (US$1=Rs. 50 at 2011 rates) during 2007–2011, and US$143/ha during 2012–2015 (US$1=Rs. 66 at 2015 rates) (Kranthi et al 2019). In a study commissioned by the Ministry of Agriculture and Farmers' Welfare, Government of India, the IRM programme resulted in saving on insecticides by US$44/ha at 2005 rates of US$1=Rs.44 (2002–2008), owing to a reduction in insecticide use by 30% and insecticide applications by 15% compared to farmers not covered under the IRM-based IPM programme (AFC 2010). The reduction in pesticide use and the increase in yields are estimated to have resulted in economic benefits of Rs. 968 million (US$16 million at Rs. 65=US$1) and Rs. 1983 million (US$33 million), respectively (AFC 2010). Similar trends of reduction in pesticide use from 31.2% to 26.8% were reported during the implantation phase of the IRM programme in Haryana (Kumar et al 2012). A peer-reviewed impact study of this programme by Peshin et al (2009) reported that 2 years of the IRM programme implementation (i.e., 2003 and 2004) resulted in 15% lesser insecticide applications and 30% lesser by weight (a.i.) by the IRM farmers compared to the

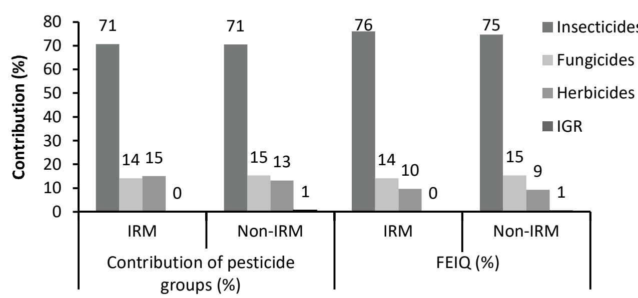

Fig. 1. Contribution of different groups of pesticides by weight and FEIQ

non-IRM farmers. This resulted in the benefit of US$24.05/ha (at 2005 rates: US$1 = Rs. 45), which is less than that reported by the CICR, the implementing agency of the IRM-based IPM programme in cotton. Our results show that the benefits have not sustained after the withdrawal of IRM intervention.

Table 8. Heckman's two-step estimates for sample bias and the factors affecting the pesticide use in cotton (Regression model with sample selection)

Variable	Coefficient	Standard error	*z* value	*p*>|*z*|
Pesticide application regression model				
Constant	8.840*	2.288	3.860	0.000
Age	–0.035	0.026	–1.350	0.176
Education	–0.095	0.083	–1.140	0.253
Family size	0.148	0.130	1.140	0.253
Households with non-farm income	0.960	0.734	1.310	0.191
Land leased-in	–0.259	0.147	–1.760	0.078
Area under cotton	0.491*	0.149	3.300	0.001
Total landholding	–0.138	0.076	–1.810	0.070
Distance of a household from the nearest pesticide store	0.062	0.050	1.240	0.215
Purchase of pesticides on credit	0.087	0.418	0.210	0.835
Sources of information about pesticides:				
Source pesticide agents	0.052	0.588	0.090	0.929
Package of practices of PAU	0.986	1.563	0.630	0.528
Own experience	0.145	0.745	0.190	0.846
Fellow farmers	1.171*	0.589	1.990	0.047
Mass media	–1.302	1.113	–1.170	0.242
IRM/non-IRM sample selection model				
Constant	1.055	0.680	1.550	0.121
Age	0.012	0.015	0.840	0.399
Education	0.040	0.021	1.900	0.057
Family size	0.000	0.058	0.000	0.999
Family members associated with farming	–0.006	0.161	–0.040	0.969
Land leased-in	–0.020	0.047	–0.420	0.675
Total landholding	–0.021	0.028	–0.760	0.447
Area under cotton	0.022	0.051	0.430	0.667
Farming experience	–0.016	0.014	–1.100	0.270
Households with non-farm income	–0.427	0.246	–1.740	0.082
Distance of farm household from:				
Seed store	–0.007	0.020	–0.370	0.709
Fertilizer store	0.030	0.021	1.480	0.138
Pesticide store	–0.300*	0.151	–1.980	0.048
Nearest market	0.293*	0.131	2.240	0.025
Agriculture office	–0.055	0.029	–1.920	0.055
Inverse Mills ratio	–0.682	1.566	–0.440	0.663
Rho	–0.211			
Sigma	3.233			

Notes:
1. Heckman's two-step model summary: The number of observations = 192; Wald $\chi^2(13)$ =31.34; $p>\chi^2$=0.005; IRM and non-IRM omitted because of collinearity.
2. Probit regression model summary: The number of observations = 192, LR χ^2 (14) = 58.33; $p>\chi^2$ = 0.000; loglikelihood = –92.340; pseudo R^2 = 0.24.
*Significant at $p\leq0.05$.

The IRM farmers using more pesticides was mainly driven by more outliers present among the IRM farmers compared to the non-IRM group. Peshin et al (2009) have highlighted that more active farmers having more landholding and better extension contacts were selected or volunteered in the IRM training programme in 2004. There were more outliers among the IRM farmers with respect to farm size and the number of pesticide applications. Besides, insecticides, for example, acephate and monocrotophos, were used for reducing boll shedding and as plant growth regulators. However, IRM farmers' use of the riskiest pesticide and dependence on pesticide retailers for pesticide advice was less compared to the non-IRM farmers. Many studies have shown that farmers acquire pesticide information and other technological information mainly through local contact (Koul and Cuperous 2007, Peshin 2005, Peshin et al 2009, Sharma et al 2015, Sharma and Peshin 2016). Dissemination and adoption are constrained by complexities, be it the use of pesticides according to good agricultural practices or cultivation of refuge requirements for Bt cotton; our results show that adoption was low in the case of the former and zero in the case of the latter.

CONCLUSION

The results confirm that bollworms, especially American bollworms, are no longer key pests of cotton in Punjab. This has resulted in a reduction of insecticide use in cotton, but on the other hand fungicide use has increased. The use of more insecticides by IRM farmers than non-IRM confirms that IPM programmes have a short-term positive impact on

Table 9. Mean frequency of pesticide applications against different pests of cotton in 2004 and 2016 (With sample attrition)

Pest	IRM			Non-IRM			DD
	2004 (*n*=147)	2016 (*n*=141)	Difference	2004 (*n*=60)	2016 (*n*=63)	Difference	
Cotton bollworm complex (main Bt target pests)	8.50	0.26	-8.24	11.15	0.25	-10.90	2.66
Tobacco caterpillar	1.55	0.00	-1.55	1.23	0.00	-1.23	-0.32
Whitefly/jassid	2.93	7.17	+4.24	3.01	6.08	+3.07	1.17
Thrips	0.00	0.36	+0.36	0.00	0.33	+0.33	0.03
Aphid	0.00	0.08	+0.08	0.00	0.15	+0.15	-0.07
Mite	0.00	0.17	+0.17	0.00	0.10	+0.10	0.07
Insecticides for growth	0.05	0.11	+0.06	0.02	0.13	+0.11	-0.05
Other insect pests	0.05	0.11	+0.06	0.00	0.11	+0.11	-0.05
Wilt	0.00	0.24	+0.24	0.00	0.13	+0.13	0.11
Anthracnose	0.00	0.20	+0.20	0.00	0.09	+0.09	0.11
Multiple sucking insect pests (botanical pesticides[a])	0.00	0.20	+0.20	0.00	0.22	+0.22	-0.02
Fungicide used for growth, flowering, and controlling fruit shedding	0.00	0.35	+0.35	0.00	0.58	+0.58	-0.23
All cotton pests	13.08	9.25	-3.83	15.41	8.17	-7.24	3.41

DD=Difference-in-differences.
[a]Organic and natural pesticides that are derived from plants and minerals

Table 10. Difference-in-differences impact of IRM programme (with sample attrition)

Parameter	2004			2016			DD
	IRM	Non-IRM	Difference	IRM	Non-IRM	Difference	
Mean pesticide applications (No.)	13.1 (6.58)	15.1 (6.55)	–2.0*	9.2 (3.57)	8.3 (2.95)	0.9	2.9*
Mean pesticide use by weight (a.i.)	5.455 (3.08)	6.083 (3.42)	–0.628	1.863 (1.06)	1.745 (1.04)	0.118	0.746
Yield (kg/ha)	2243 (849.1)	2296 (636.6)	–53	2099 (25.2)	1922 (578.4)	177	230
% area under Bt cotton	34.7	25.2	9.5	91.2	96.8	–5.6	15.1

*Significant at $p \leq 0.05$.
Note: Figures in the parentheses are standard deviations. DD, difference-in-differences

reducing pesticide use and these benefits are not sustained on a long-term basis. Both IRM and non-IRM farmers had cultivated Bt cotton on more than 92% and 95% cotton acreage, respectively, and had applied more pesticides on Bt cotton compared to *desi* and not Bt cotton, which is paradoxical. Glorified host-plant resistance that Bt cotton provides has not become a component of IRM/IPM strategies, unlike in a few countries such as the United States where it has become part of IPM to eradicate pink bollworm (Frisvold 2009). Thus, farmers are caught in "pesticide and genetic treadmill." IPM/IRM programming has to be a continuous process and not project or mini-mission-based projects implemented by the public sector and private sector.

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REFERENCES

AFC 2010. *Impact Evaluation Study of Mission-I and Mini Mission-II of Technology Mission on Cotton. Agricultural Finance Corporation* Ltd. India. http://afcindia.org.in/PDF/ research_reports/ Final%20Concise%20Report-141010.pdf (accessed 20 March 2020).

Ashenfelter O and Card D 1985. Using the longitudinal structure of earnings to estimatethe effects of training programmes. *The Review of Economics and Statistics*, 648e660.

CCI 2022. *Area, production and productivity of cotton in India from 1947-48 Onwards).* The Cotton Corporation of India Ltd. http://cotcrop.gov.in/statistics.aspx#area. (Accessed 30 August 2022.)

EPA 2018. Chemical Evaluated for Carcinogenic Potential Annual Cancer Report 2018. U.S Environmental Protection Agency Office of Pesticide Programme. http://www.epa.gov/pesticide-reevaluation

Frisvold GB 2009. Can transgenic crops and IPM be compatible? In: Peshin, R., Dhawan, A.K. (Eds.), *Integrated Pest Management: Dissemination and Impact*, Vol.2. Springer, Dordrecht.pp 555–579.https://doi.org/10.1007/978-1-4020-8990-9_19

Heckman J 1979. Sample selection bias as a specification error. *Econometrica* **47**: 153-162.

ICAR 2007. *Insecticide resistance management in cotton pests*: Success story. DARE/ICAR annual report.Directorate of Information and Publications of Agriculture (DIPA), Indian Council of Agricultural Research, New Delhi, India.p. 24.

Knook J, Eory V, Brander M and Moran D 2018. Evaluation of farmer participatory extension programmes. *The Journal of Agricultural Education and Extension* **24**(4): 309-325.

Koul O and Cuperus GW 2007. Ecologically based integrated pest management: Present concept and new solutions. In: Koul O, Cuperus G (Eds.), *Ecologically Based Pest Management.* CAB International, Oxfordshire. pp. 1–17.

Kovach J, Petzoldt C, Degni J and Tette J 1992. A method to measure the environmental impact of pesticides. New York's Food. Life. Sci. Bull. 139. New York Agricultural Experiment Station, Geneva, New York. http://dspace.library.cornell.edu/ bitstream/1813/5203/1/FLS-139.pdf (accessed 26 March 2020).

Kranthi KR, Jadhav DR, Kranthi S, Wanjari RR, Ali SS and Russell DA 2002. Insecticide resistance in five major insect pests of cotton in India. *Crop Protection* **21**(6): 449-460.

Kranthi SR, Kranthi K, Rodge C, Chawla S and Nehare S 2019. Insect resistance to insecticides and Bt cotton in India. In: Peshin, R, Dhawan A (Eds.), *Natural Resource Management: Ecological Perspectives.* Sustainability in Plant and Crop Protection. Springer, Cham.https://doi.org/10.1007/978-3-319-99768-1_11

Kumar R, Monga D, Jat SL, Indoria AK, Chauhan R and Kranthi KR 2012. Impact evaluation of insecticide resistance management strategies in cotton under Technology Mini-Mission on Cotton (*Gossypium hirsutum*). *Indian Journal of Agricultural Sciences* **82**(10): 852-857.

PAU 2016. *Package of Practices for Crops of Punjab: Kharif*. Punjab Agricultural University, Ludhiana. http://web.pau.edu/content /pf/pp_kharif.pdf(accessed 15 March 2017).

PAU 2022. Package of Practices for Crops of Punjab: Kharif. Punjab Agricultural University, Ludhiana. http://web.pau.edu/content/ pf/pp_kharif.pdf (accessed 13 September 2022).

Peshin R 2005. *Evaluation of dissemination of' insecticide resistance management technology in cotton crop in Punjab*. Ph.D. dissertation, Punjab Agricultural University, Ludhiana, India.

Peshin R 2013. Farmers' adoptability of integrated pest management of cotton revealed by a new methodology. *Agronomy for Sustainable Development* **33**(3): 563-572.

Peshin R, Dhawan AK, Vatta K and Singh K 2007. Attributes and socio-economic dynamics of adopting Bt-cotton. *Economic and Political Weekly* **42**(52): 73-80.

Peshin R, Dhawan AK, Kranthi K and Singh K 2009. Evaluation of the benefits of an insecticide resistance management programme in Punjab in India. *International Journal of Pest Management* **55**(3): 207–220.

Peshin R, Kranthi K and Sharma R 2014. *Pesticide use and experiences with integrated pest management programmes and Bt cotton in India*. In: Peshin R, Pimentel D (Eds.), *Integrated Pest Management.* Springer, Dordrecht. pp 269–306. https://doi.org/10.1007/978-94-007-7802-3_11

Peshin R, Hansra BS, Singh K, Nanda R, Sharma R, Yangsdon S and Kumar R 2021. Long-term impact of Bt cotton: Empirical evidence from North India. *Journal of Cleaner Production,* **312**: 127575.

Rejesus RM, Palis FG, Lapitan AV, Chi TTNand Hossain M 2009. The impact of integrated pest management information dissemination methods on insecticide use and efficiency: Evidence from rice producers in South Vietnam. *Applied Economic Perspective Policy* **31**(4): 814-833.

Russell D 2004. Integrated pest management in less developed countries pp. 141-208. In: Horowitz AR, Ishaaya I (Eds.). *Insect Pest Management: Field and Protection Crops*. New Delhi, India: Springer.

Sharma R and Peshin R 2016. Impact of integrated pest management of vegetables on pesticide use in subtropical Jammu, India. *Crop Protection* **84**: 105-112.

Sharma R, Peshin R, Shankar U, Kaul V and Sharma S 2015. Impact evaluation indicators of an integrated pest management programme in vegetable crops in the subtropical region of Jammu and Kashmir, India. *Crop Protection* **67**: 191-199.

USDA 2022. C*otton world markets and trade,* United States Department of Agriculture Foreign Agricultural Service. https://apps.fas.usda.gov/psdonline/circulars/cotton.pdf

WHO 2020. The WHO recommended classification of pesticides by hazard and guidelines to classification 2019. Geneva, World Health Organization. http://www.who.int/ipcs/publications/ pesticides_hazard_2019.pdf

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Weather/Crop Ecology-What Influences *Spodoptera litura* Population

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Abstract: The pheromone trap catches of *Spodoptera litura* in groundnut crop ecosystem from 2012 to 2021 are studied with an intention to enumerate the incidence pattern. The pheromone traps with spodolure were installed in AICRP on groundnut at MARS, UAS, Dharwad during *kharif* season (June to November). The trap collections from 26th to 44th SMW is considered for analysis. The peak trap collections (male moths trapped) varied between 32 to 37 SMW. The correlation studies on average of total trap catch from 2012 to 2021 exhibited a significant negative and positive relation respectively with maximum temperature and RH (both morning and evening). Despite of good rainfall and favorable RH, *Spodoptera* population was almost nil during 2016 and 2019 *kharif* season, indicating along with the weather some other factor might play crucial role in deciding the pest population on groundnut crop.

Keywords: *Spodoptera litura*, Pheromone trap, Weather parameter

Groundnut is an important oil seed crop grown on 31.5 million ha worldwide with a total production of 53.6 million metric ton and an average productivity of 1.831 metric t/ha (FAOSTAT, 2020). *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae), has been causing immense damage to various crops including groundnut across India. This insect has been considered as a pest of national importance due to its wide host range and development of proper monitoring system is very much important to develop integrated management practices (Ranga Rao et al 1991). It has been estimated that an infestation level of one larva per plant at seedling/flowering stage may result up to 20 % yield loss in groundnut. The severe infestation can cause 30 to 40 % loss in pod formation. The pheromone traps offer one of the best sampling tools for flying adult insects and has been using commonly for pest surveillance. The interaction between pheromone trap collections and prevailing weather during the period in any area for a fairly long period of time can be used for development of models to predict the seasonal pest incidence (Agarwal and Mehata 2007). Further, studies at ICRISAT indicated that the groundnut crop is vulnerable to damage and defoliation up to 50 days after emergence and needs to be contended. However, at later stage of the crop, when defoliation is severe and more than 50 per cent immediate protection measures have to be taken. The pest has already developed resistance to many insecticides (KiranGandhi et al 2016, Babu and Singh et al 2022). With this in background an attempt was made to enumerate the factors deciding Spodoptera population on groundnut.

MATERIAL AND METHODS

The *S. litura* male moth catches in sex pheromone trap from 2012 to 2021 (10 years) during *kharif* season were considered for this study. A weekly total was obtained from daily average catches of male moths in three pheromone traps located exclusively in groundnut field with a distance of 100 m between traps located at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The lures were replaced once in every 15 days throughout the season. The sleeve traps with commercially available *S. litura* pheromone (Z,E)-9,11-tetradecadienylacetate and (Z,E)-9,12-tetradecadienyl (at the ration of 10:1) and the quantity of the chemical present was 0.84mg per lure. Male moths trapped from 26 to 44 standard meteorological week (=SMW) were considered for analysis. The average weekly total number of moths trapped and the average weather parameters of the corresponding SMW are considered for analysis. The weather variables such as maximum and minimum temperature, morning and evening relative humidity and total weekly rainfall were considered as independent variables.

RESULTS AND DISCUSSION

The peak trap catches of *Spodoptera* male moths from the year 2012 to 2021 varied and corresponded between 31st to 37th SMW (Table 1). The *Spodoptera* incidence was low during this decade bearing the year 2012, 2015 and 2021. The incidence was almost nil during 2019 and 2016 irrespective of prevailed favorable weather parameters. The peak trap catches of 292, 148 and 197 moths/trap/week were recorded during 2012-2016, 2017-2021 and 2012-2021, respectively. This indicated that there was decreasing trend in Spodoptera incidence especially 2017 onwards (Table 2). There was no much change in the prevailing weather. However, there was a slight increase in the RH, an important factor deciding Spodoptera population. Morning and Evening RH had positive correlation with pest population at one or two weeks prior to the incidence. Chattopadhyay et al (2019) observed that maximum and minimum temperature ranging from 26-27^{0}C and 21-22^{0}C and morning RH of 90 per cent, a week prior to incidence are critical weather parameters causing the outbreak of *S. litura* in soybean. The prevailed weather was almost similar year to year but corresponding moth collection exhibited variation. It may be difficult to predict the appearance of Spodoptera using pheromone trap catch and prevailed weather factors.

The number of male moths trapped were correlated with corresponding weather parameter such as maximum and minimum temperature, morning and evening Relative Humidity and rainfall. The average total trap catches from 2012 to 2016 was not significant with any weather parameters. However, trap catch between 2017 to 2021 exhibited significant negative and positive relation respectively with maximum temperature and evening RH. Similarly, it was positive and significant with morning RH. The average total trap catches from 2012 to 2021 exhibited significant negative and positive relation respectively with maximum temperature and morning and evening RH (Table 3). The increased temperature probably might have reduced the *Spodoptera* population. The higher moisture positively would have supported Spodoptera population growth and multiplication. The relative humidity ranging from 89 to 92 per cent supported the higher population and growth of *Spodoptera* and negative relation with temperature was also reported in the past by Selvaraj et al (2010). *Spodoptera* population growth is positively supported by higher relative humidity, however, almost nil population was recorded in 2016 and 2019, despite of very favorable RH ranging more than 90, which could not support *Spodoptera* population and this needs to be addressed. There may be few other ecological factors such as environmental resistance and also the changing cropping pattern in the region that may also play vital role in deciding *Spodoptera* population in particular crop ecology. However, pheromone trap may be advocated to design momentary management strategy based on monitoring result and number trapped / unit time (Nayak and Pradhan 2021).

Table 1. Pheromone trap catches of *Spodoptera litura* (2012 to 2021)

SMW	No. of adult male moths trapped/week										Mean
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
26	28	0	0	0	33	9	0	3	36	13	12
27	45	0	0	0	42	13	7	4	70	17	20
28	62	0	6	3	24	28	17	4	83	21	25
29	93	0	9	16	25	32	26	4	162	100	47
30	138	5	11	27	20	48	39	0	196	112	60
31	139	37	30	41	17	113	97	1	223	144	84
32	220	78	61	56	21	171	158	0	217	195	118
33	374	45	89	79	5	89	71	0	164	214	113
34	648	56	105	645	4	69	60	0	130	256	197
35	624	85	126	424	0	54	46	1	82	293	174
36	382	39	181	314	0	45	45	0	49	335	140
37	297	18	263	206	0	33	28	1	36	246	113
38	240	30	218	138	0	21	19	1	27	185	88
39	151	146	174	91	0	12	5	0	19	75	67
40	153	188	77	59	0	7	0	0	6	40	53
41	79	9	23	21	0	3	0	0	4	2	14
42	28	0	6	7	0	0	0	0	0	2	4
43	13	0	6	0	0	0	0	0	0	1	2
44	2	0	6	0	0	0	0	0	0	0	1

Table 2. Prevailing weather and corresponding trap collection during the period from 2012-2021

SMW	Period	Number of male moths trapped /week/trap			Maximum temperature (°C)			Minimum temperature (°C)			Morning relative humidity (%)			Evening relative humidity (%)			Rainfall (mm)		
		2012 to 2016	2017 to 2021	2012 to 2021	2012 to 2016	2017 to 2021	2012 to 2021	2012 to 2016	2017 to 2021	2012 to 2021	2012 to 2016	2017 to 2021	2012 to 2021	2012 to 2016	2017 to 2021	2012 to 2021	2012 to 2016	2017 to 2021	2012 to 2021
26	25th to 1st July	12	12	12	28.2	28.4	28.3	20.7	21.0	20.8	90	90	90	71	71	71	24	21	23
27	2nd to 8th July	17	22	20	27.5	28.1	27.8	20.7	20.8	20.7	90	92	91	72	75	73	22	29	25
28	9th to 15th July	19	31	25	27.3	26.9	27.1	20.7	20.5	20.6	91	91	91	77	82	80	29	33	31
29	16th to 22th July	29	65	47	26.8	26.6	26.7	20.9	20.8	20.9	92	91	91	77	83	80	31	50	40
30	23th to 29th July	40	79	60	26.2	26.6	26.4	20.6	20.7	20.7	93	91	92	79	80	79	47	30	38
31	30th Jul to 5th August	53	116	84	26.5	26.9	26.7	20.4	20.6	20.5	92	91	92	78	83	80	49	46	48
32	6th to 12th August	87	148	118	26.2	26.9	26.5	19.8	20.6	20.2	89	91	90	71	82	77	24	96	60
33	13th to 19th August	118	108	113	26.6	26.4	26.5	19.8	20.4	20.1	89	92	90	72	85	78	11	35	23
34	20th to 26th August	292	103	197	27.9	27.6	27.8	20.3	20.4	20.3	90	91	91	71	80	75	23	12	17
35	27th to 2nd September	252	95	174	27.5	27.6	27.5	20.1	20.4	20.3	92	92	92	74	79	77	29	15	22
36	3rd to 9th September	183	95	139	27.9	28.1	28.0	19.1	20.5	19.8	87	91	89	66	78	72	16	45	30
37	10th to 16th September	157	69	113	27.8	28.6	28.2	20.5	20.2	20.4	92	91	91	73	74	73	28	20	24
38	17th to 23rd September	125	51	88	26.8	28.2	27.5	19.4	20.3	19.8	87	90	89	71	76	73	18	22	20
39	24th to 30th September	112	22	67	28.3	28.8	28.6	19.6	20.2	19.9	86	91	89	65	76	71	33	32	32
40	1st to 7th October	95	11	53	28.7	30.4	29.6	20.1	20.4	20.3	91	89	90	69	71	70	24	41	33
41	8th to 14th October	26	2	14	29.6	29.9	29.8	19.8	20.5	20.2	88	91	90	60	69	65	18	34	26
42	15th to 21st October	8	0	4	31.1	29.5	30.3	18.3	20.0	19.2	73	90	81	40	70	55	31	59	45
43	22nd to 28th October	4	0	2	28.9	29.5	29.2	18.1	18.9	18.5	75	83	79	49	67	58	33	20	27
44	29th Oct to 4th November	2	0	1	29.7	29.8	29.8	17.6	17.8	17.7	77	79	78	50	60	55	0	1	1

Table 3. Relation between trap catches and weather parameter

Moth catches	Temperature		Relative humidity		Rainfall
	Maximum	Minimum	Morning	Evening	
Moth catch (2012-2016)	-0.244	0.167	0.359	0.318	-0.105
Moth catch (2017-2021)	-0.762**	0.389	0.490*	0.786**	0.382
Moth catch (2012-2021)	-0.476*	0.291	0.497*	0.539*	0.015

REFERENCES

Agarwal R and Mehata SC 2007. Weather based forecasting of crop yields pests and diseases-IASRI Models. *Journal of the Indian Society of Agricultural Statistics* **61:** 255-263.

Babu RS and Singh B 2022. Resistance in *Spodoptera litura* (F.) to insecticides and detoxification enzymes. *Indian Journal of Entomology* 1-5. https://doi.org/10.55446/IJE.2022.519.

Chattopadhyay N, Balasubramanium R, Attri SD, Kamaljeet R, Gracy J, Khedikar S and Karmakar C 2019. Forewarning if incidence of *Spodoptera litura* (Tobacco caterpillar) in soybean and cotton using statistical approach. *Journal of Agrometeorology* **21**(1): 68-75.

FAOSTAT 2020, FAO Statistics, Food and Agriculture Organization of the United Nations, Rome, Italy.

Received 10 September, 2022; Accepted 15 September, 2022

Kiran Gandhi B, Patil RH and Srujana Y 2016. Field resistance of *Spodoptera litura* (Fab.) to conventional insecticides in India. *Crop Protection* **88:** 103-108.

Nayak P and Pradhan K 2021. *Biorational Pesticides: Semiochemicals and Insect Growth Regulators.* Recent Trends in Insect Pest Management, pp 83-99, Vol -5, AkiNik Publications, New Delhi

Ranga Rao GV, Wightman JA and Ranga Rao DV 1991. Monitoring *Spodoptera litura* (F) (Lepidoptera: Noctuidae) using sex attractant traps: Effect of trap height and time of the night on moth catch. *International Journal of Tropical Insect Science* **12:** 443-447.

Selvaraj S, Adiroubane D, Ramesh V and Narayanan AL 2010. Impact of ecological factors on incidence and development of tobacco cut worm, *Spodoptera litura* Fabricius on cotton. *Journal of Biopesticides* **3**(1): 043-046.

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Diversity and Foraging Behaviour of Pollinators on *Sesamum indicum* L.

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Abstract: The experiment was carried out at different altitudinal gradients of Jammu for two consecutive years (2017 and 2018) to study the diversity and foraging behaviour of various pollinators on flowers of *Sesamum indicum* L. The study documented twenty-six (26) species of native pollinators from four major families viz., Apidae, Megachilidae, Halictidae and Sphingidae visiting flowers of *S. indicum* in all the study areas. Megachilid bees, Honey bees, Halictid bees, Ceratina bees, Amegilla bees, Xylocopa bees and Bumble bees were the dominant pollinators, in a decreasing order. Shannon-Weiner Diversity Index and Simpson Index was H= 3.12 and D= 1.80, respectively which indicates high richness of species of entomoforagers among various families. The abundance of various pollinators revealed polynomial pattern of distribution indicating almost even distribution of insects among various pollinator groups with domination of a few groups in terms of flower visitation. Average length of foraging bout was found higher in megachilid bees and honey bees whereas in other cases, moderate foraging bouts were recorded.

Keywords: *Sesamum indicum*, Foraging, Diversity, Native bees, Megachilid bees

Sesame (*Sesamum indicum* L.), belonging to the family Pedaliaceae, is a popular and ancient oilseed crop that has successfully signified its irreplaceable role in human nutrition. Sesame seeds are used to extract oil, and also used for edible purposes at the very same time (El Khier et al 2008). The crop is cultivated in various regions of the world on an area of over 2.023 million hectares. Asia covers about 70% of the world's sesame crop followed by Africa which covers about 26% of the global acreage under this crop. China and India are its largest producers followed by Myanmar and Sudan (Anonymous 2020). About 225 million years ago, the co-evolution of flowering plants and their respective pollinators started (Maiti and Maiti 2011). The flower structure of sesame facilitates cross-pollination wherein, the rate of cross-pollination ranges between 0.5 to 65%, depending on various factors viz., insect activity, environmental conditions, and availability of other vegetation (Rakesh and Lenin 2000). Out of the total pollination activities, more than 85% of activities are performed by insects (Hoshiba and Sasaki 2008) wherein, 80% of the total insect pollination is contributed by bees (Thapa 2006) which serve as the best pollinators. Ashri (2007) reported the rate of cross-pollination between 2.7 and 51.7% in Nigeria. In addition to increasing the yield, cross-pollination also helps to raise quality through a more unified ripening period and an earlier harvesting time. Keeping these facts in view, the present experiment was carried out to study the diversity and foraging behaviour of various pollinators on flowers of *S. indicum* in Jammu, India.

MATERIAL AND METHODS

In different farmers' fields across various landscapes viz., plain areas of Dhiansar in Samba district (32.3750°N, 74.5501°E); steep rainfed landscapes of Sunderbani area in Rajouri district (33.0434°N, 74.4674°E) and elevated rainfed areas of Bajalta in Udhampur district (32.7667°N, 74.9667°E), the present experiment was conducted from July to mid-September (2017 and 2018). Selected patches of *S. indicum*, a widely grown important oilseed of this region, were monitored regularly at peak flowering period (August-September) during the daytime at hourly intervals. Different insect foragers visiting *S. indicum* were collected with aerial nets and stored in insect vials. For visual observation, crops with large number of freshly opened flowers were selected for recording the foraging behaviour and bouts of bees. Line transect method of sampling technique was administered wherein; each line transect was approximately 30 m long. Three different pockets were selected for visual observation with linear distance of 3m within a field. Activity of entomo-foragers was monitored from morning to evening at every hourly interval based on snapshot observation of five minutes in each hour. Distance between visual fields was taken under consideration while continuing the observation. Data generated on foraging activity from each visual field was pooled in order to obtain a consolidated picture of pollinator activity on *S. indicum*. The collected insects were identified with the help of dichotomous taxonomic keys. Based on observation and record of number of individual foragers, various diversity indices were worked out in order to study the magnitude of pollinator diversity and species richness in the field. The following parameters were used to calculate the species richness and species diversity from the observed data.

Shannon-Wiener diversity:

$$H = \sum_{i=1}^{s} pi \, ln \, pi$$

Where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations and s is the number of species.

Simpson index:

$$D = 1 / \sum_{i=0}^{n} pi^2$$

Where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and n is the number of species.

The data generated over two years was pooled for statistical analysis using SPSS 20.0 to compare differences in frequency of occurrence and most dominant insect pollinator of this crop.

RESULTS AND DISCUSSION

A total of twenty-six species of native pollinators belonging to four major families viz., Apidae, Megachilidae, Halictidae (Order- Hymenoptera) and Sphingidae (Order-Lepidoptera) were recorded visiting the flowers of *S. indicum* in the study areas (Table 1). Versatility in foraging insect guild and efficient supply-utilization of available resources to establish a strong plant-pollinator interaction in *S. indicum* was depicted through the generated data in the present study. In all the areas under study, seven species of Megachilid bees viz., *Megachile bicolor, M. lanata, M. hera, M. disjuncta, M. carbonaria, M. cephalotes* and *M. conjuncta* were recorded as the dominant pollinators which was succeeded by three species of honey bees viz., *Apis dorsata*, *A. mellifera* and *A. indica* and five species of Halictidae viz., *Nomia iridipennis, N. curvipes, N. elliotii, N. westwoodi* and *Lassioglossum* sp. Diurnal visitation pattern of insect foragers revealed peak activity time between 1100 to 1300 hours (Fig. 1). Spatial distribution amongst various solitary bee foragers of *S. indicum* revealed the availability of pollinating bees in Jammu region for this important crop. Except for *M. carbonaria* and *N. westwoodi* which were not recorded from Jammu plains, all the other species of Megachilidae and Halictidae along with *Apis* sp. and *Ceratina* sp. were found in all the landscape types. Both the species of *Xylocopa* were not recorded from high altitude sub temperate zone of Sunderbani. *Amegilla* spp. and *Bombus* spp. visited

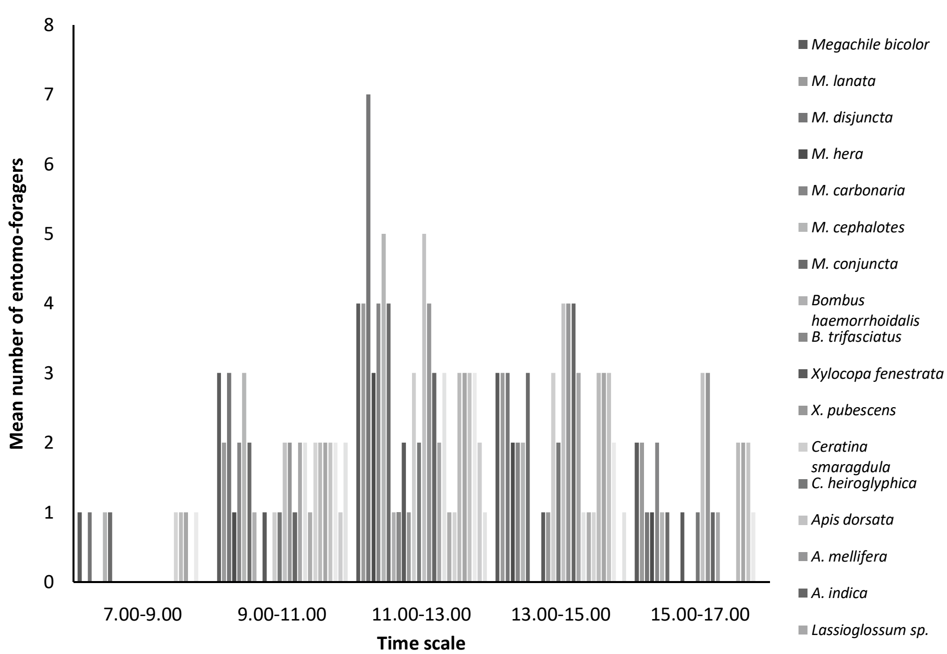

Fig. 1. Diurnal flower visitation pattern of various solitary bees on *S. indicum* in Jammu region

these flowers in almost all the landscape types wherein *A. confusa* was not recorded foraging on *S. indicum* flowers in high altitude area of Sunderbani and *B. trifasciatus* was not recorded from the plains of Jammu (Table 1). Striking plant-pollinator interaction was recorded between the study plant and the flower visitor pool. Whitish-pink tinge colour of flower petals with upside-down bell-shaped structure in morphology, could easily help in visual navigation cue for entomoforagers. Ample content of nectar, and profuse pollen collectively encouraged the visitation of entomo-foragers. Group wise foraging behaviour helped in separating the proficient pollinators from large flower visitor pool recorded from these plants. Species richness of the pollinators of *S. indicum* calculated through Shannon-Weiner Diversity Index was H= 3.12 and through Simpson Index was D= 1.80, which indicated high richness of species of entomoforagers among various families. Abundance of various major flower visiting insects showed polynomial pattern of distribution indicating almost even distribution of insects among various solitary bee groups with domination of a few groups in terms of flower visitation (Fig. 2). Average length of foraging bout, when calculated, was higher in megachilid and honey bees whereas in other cases moderate foraging bouts were recorded (Fig. 3). Of all these insects, megachilid bees and honey bees were the most efficient pollinators as they inserted tongues deep in the flower to collect nectar as compared to other bees which mostly collected nectar from side of the flowers, thereby, acting as nectar thieves. Sesame flowers were of whitish-pink tinge with upside-down bell-shaped structure in morphology. Megachilid bees and honey bees entered the flower to collect nectar and pollen rewards, whereas *Xylocopa* and *Amegilla* sp. collected nectar from sides of the flower. Megachilid bees commenced activities early in the morning at 7.30 am and maximum abundance

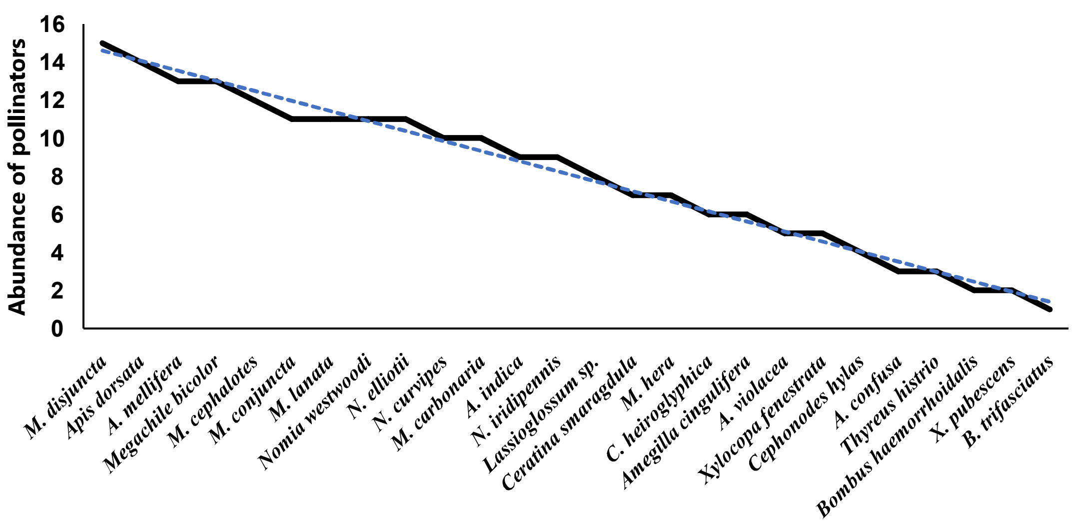

Fig. 2. Distribution of various solitary bee foragers in *S. indicum*

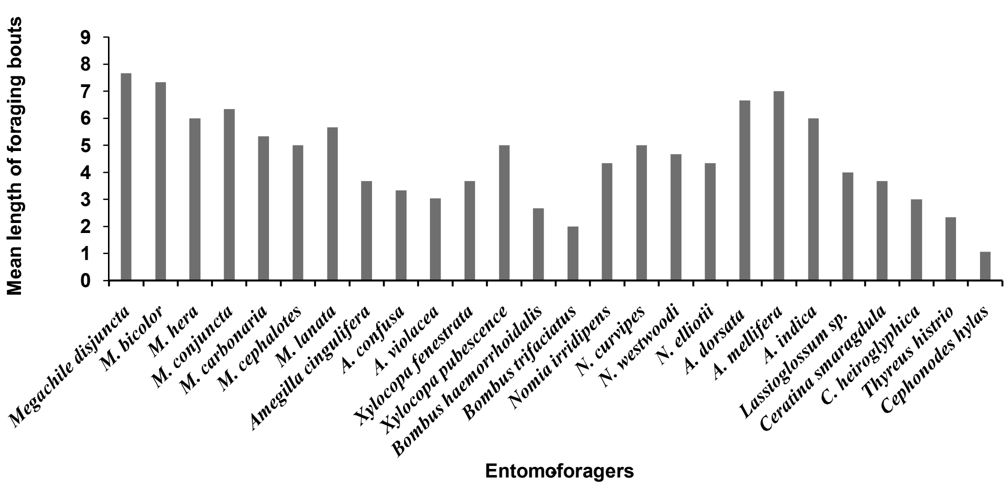

Fig. 3. Comparative pattern of mean foraging length of various bees in flowers of *S. indicum*

was observed between 1100 hrs to 1300 hrs, thereafter the population declined and continued up to 1700 hrs in the evening. In almost all the cases of such major insect visitors, while foraging, their body was found to rub the pollen loaded anthers intensely resulting in a heap of pollen adhered in the ventral parts which were brushed against the rough stigma head of the next flower while foraging in the next, ensuring successful and efficient sternotribic (carrying pollen chiefly on the sterna region of body) pollination. Pashte and Shylesha (2013) also recorded twenty-two species of native pollinators on *S. indicum* among which seventeen species belonged to order Hymenoptera. Kamel et al (2013) collected twenty-nine entomo-foragers on sesamum wherein Hymenoptera was the dominant order with eighteen species. Moreover, Sajjanar and Eswarappa (2015) mentioned the maximum activity of pollinators on sesame during mid-morning hours which is in corroboration with our present study. Abrol et al (2012) observed similar trend in pollinator activity. This strengthens the findings of current study to justify the effective role of native bee guild in pollination of *S. indicum* in this region. Participation of honeybees in crop pollination has been established since pre-historic era of agriculture. In this study too, three species of honeybees, both wild and domesticated, were good foragers on the flower of *S. indicum*, resulting in successful pollination program for this crop.

Table 1. Insect visitors recorded from sesame, *Sesamum indicum* flowers from various landscapes in Jammu

Insect morpho species	Landscape type		
	High altitude sub temperate zone	Elevated land	Plain
Family -Apidae			
Amegilla cingulifera Cockerell	+	+	+
Amegilla confusa Smith	-	+	+
Amegilla violacea Lepeletier	+	+	+
Xylocopa fenestrata Drury	-	+	+
Xylocopa pubescens Spinola	-	+	+
Bombus haemorrhoidalis Smith	+	+	+
Bombus trifasciatus Smith	+	+	-
Apis dorsata Fabricius	+	+	+
Apis mellifera Linnaeus	+	+	+
Apis indica Fabricius	+	+	+
Thyreus histrio Fabricius	-	+	+
Ceratina (Pithitis) smaragdula Fabricius	+	+	+
Ceratina (Pithitis) heiroglaphica Smith	+	+	+
Family -Halictidae			
Nomia iridipennis Smith	+	+	+
Nomia curvipes Fabricius	+	+	+
Nomia elliotii Smith	+	+	+
Nomia westwoodi Gribodo	+	+	-
Lassioglossum sp.	+	+	+
Family -Megachilidae			
Megachile bicolor Fabricius	+	+	+
Megachile lanata Fabricius	+	+	+
Megachile cephalotes Smith	+	+	+
Megachile disjuncta Fabricius	+	+	+
Megachile conjuncta Smith	+	+	+
Megachile hera Bingham	+	+	+
Megachile carbonaria Smith	+	+	-
Family -Sphingidae			
Cephonodes hylas Linnaeus	+	+	+

CONCLUSION

The present study documented the activity of twenty-six species of native pollinators on sesame wherein Megachilid bees were the most dominant pollinators with maximum length of foraging bouts. The peak pollinator activity was recorded between 1100 to 1300 hours. Moreover, the elevated landscape type of Bajalta had the highest species richness of entomo-foragers followed by plain area of Dhiansar and elevated area of Sunderbani, respectively. Present study holds its key importance here, exploring, exploiting and promoting available native bee pollinators of the crop-growing area. Entomophily among zoophilly and in turn, melittophily amongst entomophily has been always regarded as centre of research interest. In Jammu and Kashmir, such kind of explorative research are taking pace with the present study and this, in turn, is also paving way for a new arena of plant-pollinator interaction and pollinator conservation, securing food and nutritional safety, at the same time, assuring reduction of pollinator deficiency in the changing world with climate change.

REFERENCES

Abrol DP, Shankar U, Chatterjee D and Ramamurthy V 2012. Exploratory studies on diversity of bees with special emphasis on non-*Apis* pollinators in some natural and agricultural plants of Jammu division, India. *Current Sciences* **103**(7): 780-783.

Ashri A 2007. Oilseed Crops, pp 231-89. In: Singh R J (ed). *Genetic Resources, Chromosome Engineering and Crop Improvement*. CRC Press, Boca Raton, FL, USA.

Anonymous 2020. Agricultural statistics at a glance. https://eands.dacnet.nic.in/PDF/AgriculturalStatisticsaaGlance 2020

El Khier MKS, Ishag KEA and Yagoub AEA 2008. Chemical composition and oil characteristics of sesame seed cultivars grown in Sudan. *Research Journal of Agriculture and Biological Sciences* **4**: 761-766.

Hoshiba H and Sasaki M 2008. Perspective of multi-modal contribution of honey bee resources to our life. *Entomological Research* **38**: 15-21.

Kamel SM, Blal AH, Mahfouz HM and Said M 2013. The most common insect pollinator species on sesame crop (*Sesamum indicum* L.) in Ismailia Governorate, Egypt. *Arthropods* **2**(2): 66-74.

Maiti PK and Maiti P 2011. *Biodiversity: Perception, Peril and Preservation*, New Delhi, India.

Pashte V and Shylesha AN 2013. Pollinator diversity and their abundance on sesamum. *Indian Journal of Entomology* **75**(3): 260-262.

Rakesh K and Lenin JK 2000. Insect pollinators and effects of cross pollination on yield attributes of sesame (*Sesamum indicum* L.). *Indian Bee Journal* **62**: 80-88.

Sajjanar SM and Eswarappa G 2015. Sesame (*Sesamum indicum* L.) crop insect pollinators with special reference to the foraging activity of different species of honeybees. *Journal of Agriculture and Veterinary Science* **8**(11): 09-14.

Thapa RB 2006. Honey bees and other insect pollinators of cultivated plants: A review. *Journal of the Institute of Agriculture and Animal Science* **27**: 1-23.

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Integrated Management of *Callosobruchus maculatus* (Fab.) in Mung bean Stored as Seed

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Abstract: Bruchids causes quantitative and qualitative losses estimated to about 87 to 100 per cent within storage duration of 3-6 months. In order to manage the bruchid, *Callosobruchus maculatus* in stored mung bean seed studies were conducted at Punjab Agricultural University, Ludhiana. Five Kg mung bean seeds were treated with treatment combinations of neem oil (0.50-1.50%) and dharek (*Melia azedarach* L.) kernel powder (1.00-3.00%), later packed in deltamethrin 2.8 EC (0.025-0.075%) treated jute bags after release of 20 pairs of freshly emerged adults of *C. maculatus*. In order to optimize the test process conditions these bags were stored for 6 months under ambient laboratory conditions i.e. temperature (29.5 to 31.0°C) and relative humidity (43 to 75%) to observe seed damage (%), weight loss (%), colour change, moisture content (%), protein content (%) and germination (%) at an interval of 2, 4 and 6 months in disposable sets. The optimized condition was compared with zerofly bags, existing PAU recommendation along with untreated control. Numerical optimization showed that if mung bean seeds treated with neem oil (0.55%), dharek kernel powder (2.21%) and packed in deltamethrin 2.8 EC (0.055%) treated jute bags, may be stored safely for 2.50 months. The optimized conditions showed least seed damage (0.01%) and seed weight loss (0.01%) along with less colour change (2.14), moisture content (10.15 %) and maximum protein content (27.12%), seed germination (89.67%). Moreover, zerofly bags and metallic bin stored seeds also proved to be effective to store mung bean seeds.

Keywords: Mungbean, Botanicals, Deltamethrin, *Callosobruchus maculatus*, Quality parameters

Among various pulse crops, mung bean, *Vigna radiata* (L.) is an important crop that fits well in diverse cropping systems and is cultivated during summer and *Kharif* seasons across Northern India. The production of this crop has increased over the years but still relies on other countries for meeting its domestic need. One of the reason behind this is the post-harvest losses due to insect pest which alone may account to 10-50 per cent. Among various stored grain insects, Bruchids belonging to the order Coleoptera have been associated with the seeds of leguminous plants. The bruchid, *Callosobruchus maculatus* (Fabricius) is a cosmopolitan and polyphagous pest of economically important legume crops such as cowpea, lentil, mung bean and black gram. This insect pest has been can cause quantitative and qualitative losses estimated to about 87 to 100 per cent within storage duration of 3-6 months, leading to lesser returns to small scale farmers (Ojiako and Adesiyun 2013). Control of this insect pest can be achieved by synthetic chemicals. However due to hazards caused by these chemicals to plants, man and the environment there has been a move to search for alternative using plant materials such as bio pesticides to control *C. maculatus* (Yusuf et al 2011). Due to non-phytotoxic and easy bio-degradable, plant derivatives have a great potential in pest management. Thus, the present study was planned with an objective to develop an integrated management approach for pulse beetle in mung bean stored for seed purpose.

MATERIAL AND METHODS

The present investigations were conducted at Punjab Agricultural University (PAU), Ludhiana to study the integrated effect of different practices to manage *C. maculatus* in mung bean stored for seed purpose. The recommended mung bean var. TMB 37 were procured from the Farm of Director (Seeds), PAU, Ludhiana and dharek (*Melia azedarach* L.) kernels were obtained from Agroforestry Research Farm, PAU, Ludhiana which were tray dried, later grounded into fine powder by using electric mixer grinder. The neem oil and jute bags were procured from local market. The mung bean seeds used for conducting the experiments were disinfested at 60ºC temperature for an hour to make them free from any other insect infestation. The rearing of *C. maculatus* was also done on 100 gm disinfested mung bean seeds by releasing 10 pairs of adults in a jar and kept in an incubator at 29±2ºC and 70±5% relative humidity to get the pure culture for the experiments. After 48 hours, these adults were removed and the grains were kept as such for about 25 days for the emergence of adults and were used for conducting the experiments. The neem oil (0.50-1.50%)

and *M. azedarach* kernel powder (1.0-3.0%) were used to treat mung bean seeds along with deltamethrin 2.8 EC (0.025-0.075 %) was used to treat jute bags. The experiments were conducted using 3 factors Box-Behnken design of RSM for all the selected treatments (Design-Expert software version 8.0.3.1, Stat-Ease Inc., Minneapolis, U.S.A). The independent variables with three different levels viz. -1, 0 and +1 (Table 1) which formed a total of 27 different

Table 1. Independent variables and their levels

Independent variables	Symbol		Levels	
	Coded	Un-coded	Coded	Un-coded
Deltamethrin 2.8EC	X_1	A	-1 0 +1	0.025% 0.050% 0.075%
Neem Oil	X_2	B	-1 0 +1	0.50% 1.00% 1.50%
Dharek kernel Powder	X_3	C	-1 0 +1	0.50% 1.00% 1.50%
Storage Periods (months)	X_4	D	-1 0 +1	2.00% 4.00% 6.00%

Table 2. Quality of mung bean seeds for response surface analysis

Process variables				Product quality responses					
Deltamethrin 2.8 EC (%)	Neem oil (%)	Dharek kernel powder (%)	Storage methods (Months)	Seed damage (%)	Seed weight loss (%)	Colour Change	Moisture content (%)	Seed germination (%)	Protein content (%)
0.025	0.50	2.00	4	0.2	0.13	3.67	10.20	88.67	24.10
0.075	0.50	2.00	4	0.0	0.0	2.31	10.30	88.33	26.88
0.025	1.50	2.00	4	0.0	0.0	3.37	10.10	84.00	25.24
0.075	1.50	2.00	4	0.0	0.0	3.27	10.40	84.00	24.65
0.050	1.00	1.00	2	0.0	0.0	2.65	10.30	88.00	25.32
0.050	1.00	3.00	2	0.0	0.0	3.11	10.70	89.67	26.27
0.050	1.00	1.00	6	0.1	0.05	2.24	10.40	79.00	24.04
0.050	1.00	3.00	6	0.0	0.0	2.46	10.20	78.00	21.11
0.025	1.00	2.00	2	0.0	0.0	2.25	10.20	88.00	26.19
0.075	1.00	2.00	2	0.0	0.0	2.27	10.20	87.33	25.77
0.025	1.00	2.00	6	0.0	0.0	2.44	10.80	77.00	23.64
0.075	1.00	2.00	6	0.0	0.0	2.88	10.80	76.67	25.85
0.050	0.50	1.00	4	0.0	0.0	2.99	10.20	88.00	26.61
0.050	1.50	1.00	4	0.0	0.0	2.84	10.20	83.67	25.14
0.050	0.50	3.00	4	0.0	0.0	3.20	10.30	89.00	24.10
0.050	1.50	3.00	4	0.0	0.0	3.90	10.10	83.00	23.00
0.025	1.00	1.00	4	0.0	0.0	3.48	10.20	87.33	23.64
0.075	1.00	1.00	4	0.0	0.0	3.30	10.40	86.33	24.90
0.025	1.00	3.00	4	0.0	0.0	3.50	10.20	86.00	21.48
0.075	1.00	3.00	4	0.0	0.0	2.22	10.20	86.00	25.26
0.050	0.50	2.00	2	0.0	0.0	2.14	10.10	89.67	26.04
0.050	1.50	2.00	2	0.0	0.0	2.96	10.25	87.66	26.24
0.050	0.50	2.00	6	0.0	0.0	2.42	10.30	80.33	24.90
0.050	1.50	2.00	6	0.0	0.0	4.20	10.20	73.33	25.94
0.050	1.00	2.00	4	0.0	0.0	2.64	10.20	86.33	28.35
0.050	1.00	2.00	4	0.0	0.0	2.92	10.20	85.33	25.50
0.050	1.00	2.00	4	0.0	0.0	2.39	10.10	86.00	25.32

combinations (Giles et al 2004) having three replicates of the center point (Table 2). Later 5 kg mung bean seeds were exposed to selected treatment combinations for each bag and 20 pairs of freshly emerged adults of *C. maculatus* were released into it. These bags were kept for 6 months for storage studies under ambient conditions i.e. temperature (29.5 to 31.0°C) and relative humidity (43 to 75%). Various observations such as grain damage (%) based on 1000 grains, grain weight loss (%) as per given by Adams and Schulten (1978), colour change measurement by using Colour Reader CR-10 Konica Minolta Sensing Inc. with the equation given by Gnanasekharan et al (1992), moisture content (%) in grains by hot air oven method (AOAC 1984), protein content (%) by using AOAC (2000) and germination as per the equation given by Patel (2001) were recorded for mung bean seeds at regular interval of 2, 4 and 6 months in disposable sets. The design was taken from response surface designs and it fulfills most of the requirements needed for optimization of the best method for the management of insects with targeted goals of less seed damage, less weight loss, less change in colour, less moisture content, more protein content and more germination of mung bean seeds. The best treatment (optimized condition) was compared with zerofly bags, existing PAU recommendation (7cm layer of sand on top of mung bean seeds stored in metallic bins) along with untreated control.

RESULTS AND DISCUSSION

The experimental data related to management of *C. maculatus* in mung bean stored for seeds were presented in Table 2. F-value and the final equation of the fitted model for the selected parameters is depicted in Table 3 and 4 along with the R^2 values. The regression models for colour change, moisture content (%), protein content (%) and germination (%) were significantly high witnessing high correlation coefficient (R^2 = 0.81, 0.79, 0.80 and 0.98, respectively). None of the models showed significant lack of fit (P > 0.01), indicating that all the second-order polynomial models correlated well with the measured data. All the parameters showed high adequate precision. The studies indicated closer the value of R^2 to the unity, the better the empirical model fits the actual data.

Seed damage and seed weight loss (%): The seed damage ranged from 0.0 to 0.2% and seed weight loss ranged from 0.0 to 0.13% in various experimental combinations of deltamethrin, neem oil, dharek kernel powder along with the storage period (Table 2). There was no seed damage at 2, 4 and 6 months of storage in various combinations except where jute bags were treated with 0.025

Table 3. Statistically analyzed data for the selected responses

Source	F-value			
	Colour change	Moisture content (%)	Seed germination (%)	Protein content (%)
Fitted model	Quadratic	Quadratic	Quadratic	Quadratic
A-Deltamethrin (%)	1.23 (0.289)	0.84 (0.378)	0.92 (0.355)	7.58 (0.017)**
B- Neem oil (%)	2.40 (0.147)	0.00 (1.000)	135.52 (<0.0001)**	0.55 (0.474)
C- Dharek kernel powder (%)	2.51 (0.139)	0.052 (0.823)	0.073 (0.7909)	6.62 (0.024)**
D- Storage period (months)	20.64 (0.0007)*	27.72 (0.0002)*	734.99 (<0.0001)**	9.98 (0.008)*
AB	3.85 (0.073)	0.00 (1.000)	0.059 (0.813)	3.18 (1.001)
AC	10.18 (0.008)*	0.63 (0.443)	0.51 (0.490)	1.78 (0.207)
AD	1.10 (0.315)	0.00 (1.000)	0.059 (0.813)	1.93 (0.189)
BC	0.86 (0.373)	0.63 (0.443)	1.41 (0.257)	0.04 (0.848)
BD	1.06 (0.323)	0.63 (0.443)	12.60 (0.004)**	0.20 (0.665)
CD	0.05 (0.832)	1.41 (0.257)	3.61 (0.082)	4.21 (0.063)
A^2	3.21 (0.098)	3.64 (0.080)	7.92x10-^{3} (0.931)	0.69 (0.421)
B2	3.46 (0.088)	5.82x10^{-3} (0.940)	7.92x10-^{3} (0.931)	0.59 (0.458)
C2	0.43 (0.525)	0.37 (0.553)	2.87 (0.116)	8.34 (0.014)*
D2	0.069 (0.797)	9.32 (0.010)*	107.29 (<0.0001)**	0.090 (0.769)
Std. Dev.	0.32	0.13	0.988	0.95
C.V. %	11.24	1.22	0.937	3.80

The data in parenthesis are the p-values
*significant at 1 %level of significance (p<0.01),** significant at 5 %level of significance (p<0.05)

and 0.050% deltamethrin and mung bean seeds were treated with neem oil (0.50 & 1.00%) and dharek kernel powder (2.00 & 1.00 %) at 4 and 6 months of storage, respectively (Table 2). Sharma et al (2019) also observed that neem oil @ 10ml/kg seed completely inhibited the oviposition, adult emergence and seed damage, which may be due to growth disruption and repellant property of azadirachtin present in neem (Schmutterer 1990). Zafar et al 2018 concluded that neem powder to be effective which also corroborates with the present findings where additional doses of dharek powder did not show any effect on insect mortality, while lower dose of neem oil proved to be effective (Table 2).

Colour change: The effect of the independent variables on colour change ranged from 2.14 to 4.20 irrespective of the experimental combinations (Table 2). The effect of storage period was significantly positive witnessing that the increase in storage period leads to more change in colour of mung bean seeds. There was non-significant effect of deltamethrin 2.8 EC, neem oil and dharek kernal powder on colour change. Ogendo et al (2004) also observed that the grain colour and odour were unaffected by the botanicals. The fitted model was quadratic and linear term of storage period as well as product term of deltamethrin and dharek kernel powder was significant and negative on colour change of mung bean seeds. The storage period (month) witnessed the significantly higher effect in comparison to other treatments with F-value (20.64) (Table 3). Therefore, there exists positive relationship between storage period on colour change. The regression equation for the colour change of mung bean seed is shown in Table 4.

Moisture content (%): The moisture content ranged from 10.10 to 10.80% irrespective of the experimental combinations (Table 2). Maximum moisture content was observed at six months of seed storage, when jute bags were treated with 0.025 & 0.075% deltamethrin 2.8 EC and mung bean seeds treated with 1.00% neem oil and 2.00% dharek kernel powder, while, minimum moisture content in the mung bean seeds were observed at 2 months of storage in various combinations of deltamethrin, neem oil and dharek kernel powder. The effect of storage period was significantly positive witnessing that the increase in storage time leads to more change in moisture content of mung bean seeds. This fluctuation in moisture content might be due to the variation in an atmospheric humidity, as the seeds are hygroscopic in

Table 4. Adequacy of model fitted

Parameters	Fitted models	Model equation	R^2	P value
Colour change	Quadratic	$=2.66-0.10*A+0.14*B-0.15*C+0.42*D+0.32*AB-0.51*AC+0.17*AD+0.15*BC-0.17*BD-0.035*CD+0.25*A^2+0.26*B^2-0.091*C^2+0.037*D^2$	0.81	0.01
Moisture content (%)	Quadratic	$=10.20+0.033*A+0.000*B+8.333\times10^{-3}*C+0.19*D+0.000*AB-0.050*AC+0.000*AD-0.050*BC-0.050*BD-0.075*CD+0.10*A^2+4.167\times10^{-3}*B^2-0.033*C^2+0.17*D^2$	0.79	0.02
Protein content (%)	Quadratic	$=25.39+0.75*A-0.20*B-0.70*C-0.86*D-0.84*AB+0.63*AC+0.66*AD+0.092*BC+0.21*BD-0.97*CD-0.34*A^2+0.31*B^2-1.18*C^2+0.12*D^2$	0.80	0.01
Germination (%)	Quadratic	$=85.89-0.19*A-2.36*B-0.055*C-5.50*D+0.085*AB+0.25*AC+0.085*AD-0.42*BC-1.25*BD-0.67*CD-0.027*A^2-0.027*B^2+0.52*C^2-3.15*D^2$	0.98	<0.0001

Table 5. Optimum values of process parameters and responses for mung bean stored as seeds

Process parameters	Target	Experimental range		Optimum values
		Minimum	Maximum	
Deltamethrin (%)	Range	0.025	0.075	0.055
Neem oil (%)	Range	0.50	1.50	0.55
Dharek kernel powder (%)	Range	1.00	3.00	2.21
Storage period (Months)	Range	2	6	2.39
Responses				
Colour change	Minimize	2.14	4.20	2.14
Moisture content (%)	Minimize	10.10	10.80	10.15
Germination (%)	Maximize	73.33	89.67	89.67
Protein content (%)	Range	21.11	28.35	27.12

The desirability level was 0.975

nature and they absorb moisture from atmosphere. Similar results were obtained by Beedi et al (2018) and Angelovic et al (2018). There was non-significant effect of deltamethrin 2.8 EC, neem oil and dharek kernel powder on moisture content. Based on F-value, the storage period witnessed the significantly higher effect in comparison to other treatments (Table 3). The regression equation for the moisture content is shown in Table 4.

Germination (%): Seed germination varied from 73.33 to 89.67 % irrespective of the experimental combinations (Table 2). The maximum seed germination was at 2 months of storage where jute bags were treated with deltamethrin @ 0.050% and seeds were treated with 1.00 & 0.50% neem oil and 3.00 & 2.00% dharek kernel powder, followed by different experimental combinations used for different months of storage. The effect of neem oil and storage period was significantly negative witnessing that the increase in neem oil percentage and storage period reduced the germination percentage of mung bean seeds. There was non-significant effect of deltamethrin 2.8 EC and dharek kernel powder on germination percentage. The fitted model was quadratic and linear term neem oil, storage period, product term neem oil and storage period and quadratic term storage period was negative on seed germination percentage. The neem oil percentage and storage period witnessed the significantly higher effect in comparison to other treatments (Table 3). Rath et al (2013) observed that the germination of green gram seeds was inhibited with neem oil treatment and the same was observed in case of shoot and root length, fresh and dry weights. The study indicated that the plant protectors like neem oil is to be administered in very low concentrations and for shorter duration since higher concentration and duration is affecting all the germination parameters significantly. Kadam et al (2013) also observed that neem oil @ 5ml/kg seed inhibit the seed germination up to 80.33% at 9 months of storage period. However, a decline in germination percentage was observed in all the treatments with advancement in the storage period, which may be attributed to the phenomenon of ageing and due to depletion of food reserves, decline in synthetic activity (Beedi et al 2018)

Protein content (%): The protein content ranged from 21.11 to 28.35 % (Table 2). The maximum protein content was at 4 months of storage when jute bags were treated with deltamethrin 2.8 EC @ 0.050% and seeds were treated with neem oil @ 1.00% and dharek kernel powder @ 2.00 %, while minimum at 6 months of storage when jute bags were treated with deltamethrin 0.050% and seeds were treated with neem oil @ 1.00% and dharek kernel powder @ 3.00 %. The effect of storage period was significantly negative witnessing that the increase in storage period leads to decrease in protein content of mung bean seeds (Table 3). There was positive significant effect of deltamethrin 2.8 EC treated jute bags on protein content, which may be due to that the seeds stored in the treated bags remain unaffected with the insect attack and there was negative significant effect of dharek kernel powder on protein content of mung bean seeds, which showed that dharek kernel powder may affect the seed properties. There was non-significant effect of neem oil percentage on protein content, which corroborates with the study conducted by Sharma et al (2022).

Optimum treatment conditions for the storage of mung bean seed and its comparison with zerofly bag as well as metallic bin stored mung bean seeds: The various independent parameters for storage of mung bean seeds were optimized using numerical optimization technique (Table 5). There was negligible seed damage and weight loss were found in almost all the experimental combination, so they were not taken for optimization. Thus, the main criteria for various responses to be undertaken for optimization include minimum colour change, minimum moisture content, maximum germination and protein content to be in the range. In order to optimize deltamethrin for treating jute bags, while neem oil and dharek powder for treating mung bean seed to enhance their storage life, an equal importance was given to all the parameters and responses. The zone of optimization for various parameters

Table 6. Comparison between different storage practices used to store mungbean seeds

Process parameters	Responses					
	Seed damage (%)	Seed weight loss (%)	Colour change	Moisture content (%)	Germination (%)	Protein content (%)
Optimum values of D:NO:DKP:SP (0.055:0.55:2.21:2.50)	0.01	0.01	2.14	10.15	89.67	27.12 (0.11)
Zerofly bag (2 months)	0.40	0.26	1.38	10.30	91.00	26.35 (2.94)
Metallic drum stored seed (2 months)	0.00	0.00	2.17	10.40	95.00	27.11 (0.15)
Untreated control (2 months)	2.00	0.41	1.95	10.90	78.50	25.98 (4.30)

D= Deltamethrin, NO= Neem Oil, DKP= Dharek Kernel Powder, SP= Storage period
* values in parenthesis are the percent change in protein over period of time
Fresh sample: Protein= 27.15% , Moisture content = 10.20%, Germination: 97%

depicts that the 0.055% deltamethrin 2.8 EC for treating jute bags and 0.55% neem oil as well as 2.21% dharek kernel powder for seed treatment, under these conditions mung bean seed may store for 2.50 months witnessing optimized predicted values i.e. colour change (2.14), moisture content (10.15%), germination (89.67%) and protein content (27.12%) with desirability of 0.975. Thus, the optimized values show that mung bean seeds may be stored for 2.50 months without much change in tested responses. The optimum values of seed damage (0.01 %) and seed weight loss (0.01 %) in treated combinations was compared with zerofly bag, metallic bin, untreated control stored mung bean seeds for 2 months indicated that there was 0.40, 0.00, 2.00 % seed damage and 0.26, 0.00, 0.41% seed weight loss, respectively, which corroborates with study conducted by Ahmad et al (2015), where use neem leaf powder showed strong detrimental effect on pulse beetle in mung bean. Zerofly bags showed good response against test insect, similar results were observed by Mutungi et al (2014), where triple layered hermetic bags halted multiplication of *C. maculatus.* Similarly, the results of metallic bin stored pulses by using top sand layer was similar to Swamy et al (2018). The moisture content in seeds stored with optimized parameters was 10.15%, while 10.30, 10.40 and 10.90 % observed in zerofly bag, metallic bin with sand layer and untreated control stored seeds, respectively (Table 6) which is the safe limit as per observed by Kadam et al (2013). Mutungi et al (2014), also observed that the moisture content of grain stored in triple layered hermetic bags and PP bags remained below 12%. The moisture content in control bags also remained stable which may be due to atmospheric conditions. Seed germination was 89.67, 91.00, 95.00 and 78.50% in treated seeds with optimized parameters, zerofly bags, metallic bin with sand layer and seed stored under untreated control, respectively at 2 months of storage. The same has been reported by Rath et al (2013), where germination of green gram seeds were inhibited with neem oil and by Mutungi et al (2014) that germination of mung bean stored in PICS (triple layered hermetic) bags dropped marginally to 84.19% whereas in pigeon peas dropped 78.42% after six months of storage and was not affected when seed stored by using sand layer (Swamy et al 2018). The change in protein content was very less in treated seeds with optimized parameters followed by metallic drum, zerofly bag and untreated control stored mung bean seeds at 2 months of storage (Table 6). There was very less reduction of protein content was observed in untreated control, which may be due to the eggs, egg cases, excretory products left behind on removal of larval, pupal and adult stages of *C. maculatus* before analysis and corroborates with the study conducted by Sharma et al 2022.

CONCLUSION

The response surface methodology was appropriate for optimization of process conditions for storage of mung bean seeds. The optimized conditions for storage of mung bean seed were found to be deltamethrin 2.8EC @ 0.055% for treating the jute bags along with mung bean seed treated with neem oil @ 0.55% as well as dharek kernel powder @ 2.21% and thus, seed may be stored for 2.39 months. Under these conditions, optimal values of responses were for colour change-2.14, moisture content-10.15%, germination-89.67% and protein content-27.12%. The use of insecticides for treating the seeds during storage created various issues like development of pest resistance, resurgence and residue effects on grains besides ill effects on human and animal. Thus, the ecofriendly pest management strategy is the only solution to avoid above said situations. In view of that neem oil and dharek kernel powder used to treat mung bean seeds and deltamethrin used to treat empty gunny bags against *C. maculatus* under laboratory conditions. The use of zerofly bags and metallic drum stored seeds also proved effective to store mung bean seeds. The finding of present work revealed that mung bean seeds may be stored for 2.50 months without much change in tested responses.

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REFERENCES

Adams JM and Schulten GM 1978. Losses caused by insects, mites and micro-organisms. In: KL Hartis and CJ Lindblad (eds), *Post-harvest Grain Loss Assessment Methods*, Minsota, pp. 83-93.

Ahmad K, Adnan M, Khan MA, Hussain Z, Junaid K, Saleem N, Ali M, Basir A and Ali A 2015. Bioactive neem leaf powder enhances the shelf life of stored mungbean grains and extends protection from pulse beetle. *Pakistan Journal of Weed Science and Research* **21**: 71-81.

Angelovic M, Kristof K, Jobbagy J, Findura P and Krizan M 2018. The effect of conditions and storage time on course of moisture and temperature of maize grains. *BIO Web of Conferences* **10**: 6, DOI:10.1051/bioconf/20181002001.

AOAC 1984. *Official Method of Analysis*. Association of Official Analytical Chemists Washington DC.

AOAC 2000. Official method of Analysis. Association of official analytical chemists, Washington, DC.

Beedi S, Macha SI, Gowda B, Savitha AS and Kurnallikar VK 2018. Effect of seed priming on germination percentage, shoot length, root length, seedling vigour index, moisture content and electrical conductivity in storage of kabuli chickpea cv., MNK – 1 (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry* **7**: 2005-2010.

Giles HF, Wagner J and Eldridge M 2004. *Design of experiments. In Extrusion: The Definitive Processing Guide and Handbook* (2nd ed.). Plastics Design Library. Elsevier Press, pp. 303-305.

Gnanasekharan V, Shewfelt RL and Chinnan MS 1992. Detection of colour changes in green vegetables. *Journal of Food Science* **57**: 149-154.

Kadam UK, Palande PR, Shelar VR and Bansode GM 2013. Potential of Different Azadirachtin Based Products in Reducing Infestation of Chickpea by Pulse Beetle. *PKV Reseach Journal* **37**: 69-73.

Mutungi C, Affognon H, Njoroge A, Baributsa D and Murdock LL 2014. Storage of mung bean (*Vigna radiata* [L.] Wilczek) and pigeonpea grains (*Cajanus cajan* [L.] Millsp) in hermetic triple-layer bags stops losses caused by *Callosobruchus maculatus* (F.)(Coleoptera: Bruchidae). *Journal of Stored Products Research* **58**: 39-47.

Ogendo JO, Deng AL, Belmain SR and Musandu AAO 2004. Effect of insecticidal plant materials, *Lantana camara* L. and *Tephrosia vogelii* Hook, on the quality parameters of stored maize grains. *Journal of Food Technology in Africa* **9**: 29-36.

Ojiako FO and Adesiyun AA 2013. Assessment of the curative potency of some plant materials on cowpea seeds with established infestation of *Callosobruchus maculatus* (Fabricius) (Coleoptera:Chrysomelidae: Bruchinae). *Journal of Biology, Agriculture and Healthcare* **3**: 83-93.

Patel CS 2001. *Bionomics and non-chemical control measures of pulse beetle, Callosobruchus maculatus (Fabricius) in stored Indian bean*. M.Sc. (Agri.) Dissertation, Gujarat Agricultural University, NAU, Navsari, India.

Rath BB, Sudhakar P and Mohanty BK 2013. Studies on effect of neem oil and teprosyn on the germination parameters of *Vigna radiata* (L.), wilczek. *International Journal of Current Science* **8**: 67-73.

Schmutterer H 1990. Properties and potential of natural pesticides from neem tree, *Azadirachta indica*. *Annual Review of Entomology* **35**: 251-297.

Sharma DK, Alam MS, Saini MK and Bhatia S 2022. Evaluation of Some Botanicals, Thermal Treatment and Packing Materials Against Pulse Beetle *Callosobruchus chinensis* L. in Chickpea. *Indian Journal of Entomology* 1–6, DOI:10.55446/IJE. 2021.141.

Sharma R, Devi R, Yadav S and Godara P 2019. Biology of pulse beetle, *Callosobruchus maculatus* (F.) and its response to botanicals in stored pigeonpea, *Cajanus cajan* (L.) grains. *Legume Research* **41**(6): 925-929.

Swamy SVSG, Wesley BJ, Raja DS and Vishnuvardhan S 2018. Feasibility of sand layer technique for small scale storage of pulses seed. *Journal of Entomology and Zoology Studies* **6**: 428-431.

Yusuf AU, Dike MC, Adebitan SA and Ahmed BI 2011. Comparative efficacy of seven plant products on the cowpea bruchid, *Callosobruchus maculatus* development and damage. *Journal of Biopesticides* **4**: 19-26.

Zafar U, Mamoon-Ur-Rashid M and Shah M 2018. Entomotoxicity of plant powders against pulse beetle (*Callosobruchus chinensis*) on stored mung bean (*Vignia radiata*). *Journal of Entomology and Zoology Studies* **6**: 1637-1641.

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Relative Abundance of Mustard Aphid *Brevicoryne brassicae* (Homoptera: Aphididae) on Mustard, *Brassica juncea* (L.)

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Abstract: Field experiment was conducted during the years 2018-19 and 2019-20 at Entomology Farm of Faculty of Agriculture, Wadura campus, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu & Kashmir, India to ascertain the aphid incidence in mustard, *Brassica juncea*. The incidence of aphid started from the 12th standard week (6.37 aphids/20 plant) and reached its peak in 16th standard week *viz*., 127.36 aphids/20 plantsand declined in 22nd standard week (8.54 aphids/20 plants). Negative correlation was found between aphid population and maximum and minimum temperatures. Positive correlation was found between aphid population and rainfall and significantly positive correlation was observed between aphid population and morning relative humidity and evening relative humidity. Two species of predators, *Coccinella septumpunctata* and *Hippodamia variegata*, were observed feeding on mustard aphid. *C. septumpunctata* appeared in 12th standard week (0.05 population/20 plants)and *H. variegata* in 13th standard week (0.15 population/20 plants) and the population reached its peak at 16th standard week viz., 4.05 and 2.35 population/ 20 plants for *C. septumpunctata* and *H. variegata*, respectively that coincided with the peak population of aphids. *B. brassicae* population exhibited significantly positive correlation with *C. septumpunctata* and *H. variegata.*

Keywords: Population dynamics, *Brevicoryne brassicae*, *Coccinella septumpunctata, Hippodamia variegata*

Mustard, *Brassica juncea* (L.) Czern and Coss is an important oilseed crop of Cruciferae family and constitute major source of edible oil for human consumption and cakes for animals. Every effort is being made to raise yield of this crop by adopting modern agricultural practices, such as the use of high yielding varieties, heavy manuring and assured irrigation in order to meet the growing demands of oils. These composite efforts are, however, nullified if crop is not protected from the ravages of insect-pests. The crop is damaged at various stages of plant growth by more than a dozen of insect pests *viz*; mustard sawfly (*Athalia lugens proxima* Kulg.), painted bug (*Bagrada cruciferarum* Kirk.), mustard aphid (*Brevicoryne brassicae*.), cabbage leaf webber (*Crocidolomia binotalis* Zeller), flea beetle (*Phyllotreta cruciferae* Geoze) and leaf miner (*Phytomyza horticola* Meign). The mustard aphid (*Brevicoryne brassicae*) (Homoptera: Aphididae) is the most serious and destructive pest and major limiting factor for mustard cultivation (Biswas and Das 2000). The infestation of this pest varies with place and also depends upon the environmental factors. This pest caused substantial losses in many crops and causes about 35-75 % reduction in the yield of mustard (Singh and Sharma 2012). The infestation also led to 6% reduction in oil contents (Singh et al 2007). The loss caused by aphids is due to direct feeding on leaves, inflorescence and stems as well as indirectly by transmitting diseases (Liu and Yue 2001). The ecological approach to the pest management suggests using pesticides only when and where necessary. Therefore, for ensuring an effective and economical management of this serious pest, the present studies were undertaken to study population fluctuations in relation to weather parameter. These studies will provide an opportunity to face the pest challenge by manipulating sowing time, varietals selection; correct timing of pesticidal application besides other management practices.

MATERIAL AND METHODS

The field experiment was conducted at Entomology Farm of College of Agriculture, Wadura Campus, SKUAST-K, India during 2018-19 and 2019-20. The mustard crop variety, KS 101 "Gulcheen" was sown manually on 2nd week of October in 2018 and 2019, in lines@ 5kg /ha on a plot of 10×12 m^2 about 3 cm deep in furrows, keeping the row to row and plant to plant distances as 30 and 10cm, respectively. Half of the recommended dose of nitrogenous fertilizer (60 Kg N/ha) and full dose of phosphatic fertilizer (60 Kg P_2O_5/ha) and potasic fertilizer (40 Kg K_2O/ha) were applied at the time of ploughing and rest of the nitrogenous fertilizers were applied through top dressing at the time of flowering. The meteorological data prevailed during the infestation of aphids, *Rabi* 2018-19 and *Rabi* 2019-20 was procured from the meteorological observatory located at Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu & Kashmir.

Observation on aphid population was recorded soon after the appearance of the aphids on mustard and continued till the maturity of the crop. The population of the aphids was recorded on twenty randomly tagged plants at weekly interval. Initially at pre-bloom stage, the population of aphid was recorded on whole plant as a one single unit. At flowering/bloom stage, the aphids were counted from the upper 10 cm twig. At the post-bloom stage the aphids were recorded on the upper, middle and lower pods of plants on five randomly selected plants. The population of coccinellids was also recorded at pre-bloom, bloom, and post-bloom stages on whole plant at weekly interval. The data generated on the population of aphids was correlated with the weather parameters like maximum and minimum temperature, relative humidity and rainfall and with the population of coccinellids. Regression coefficient (R^2) and regression equation (Y = a+ bx) were computed by standard statistical methods.

RESULTS AND DISCUSSION

The commencement of mustard aphid population was from 12th standard week with average number 5.42 aphids/plant in 2018-19 and 3.67 aphids/plant in 2019-20 (Table 1 and 2). The pest reached to its peak population *viz*., 110.27 aphids/plant (2018-19) and 144.45 aphids/plant (2019-20) in the 16th standard week from where started declining and reached the population, 6.23and 10.85aphids/plant in 22nd standard week for 2018-19 and 2019-20 respectively. In *Rabi* 2018-19the population per plant ranged from 0.0 to 12.0, 78.0 to 124 and 5.0 to 20.0 aphids/plant in 12th, 16th and 22nd standard week, respectively. In *Rabi* 2019-20 the population per plant ranged from 0.0 to16.0, 95.0 to 165.0 and 8.0 to 23.0 in 12th, 16th and 22nd standard week respectively. The maximum and minimum temperature does not favour the aphid population however; rainfall, morning and evening relative humidity favoured the aphid population (Table 3). Thus negative correlation was observed between aphid population and maximum temperature and minimum temperature. Positive correlation was found between aphid population and rainfall. Significantly positive correlation was observed with morning relative humidity and evening relative humidity. Mishra and Kanwat (2018) also reported that aphid population is negatively correlated with maximum temperature and positively correlated with relative humidity. Dharavat et al (2016) observed negative correlation of aphids with maximum and minimum temperature and significantly positive correlation with humidity. Sahu et al (2017) reported that pest population drastically decreased after 3rd week of March due to gradual increase in high temperature. Kumar and Paul (2017) observed that the maximum temperature exhibited a negative effect RH with a significant positive effect. Earlier researchers also observed that aphid population exhibit negative correlation with maximum temperature and positive correlation with rainfall, morning and evening relative humidity (Pawar et al 2010, Hassan and

Table 1. Incidence of mustard aphid, *Lipaphis erysimi* and subsequent appearance of its predators during *Rabi* 2018-2019

SMW	No. of aphids/plant	*No. of predators/plant		Max. temp (°C)	Min. temp (°C)	Rainfall (mm)	Morning relative humidity (%)	Evening relative humidity (%)
		Coccinella septumpunctata	*Hippodamia variegata*					
12	5.42	0.03	0.00	13.57	1.76	30.60	82.42	57.14
13	19.32	0.37	0.02	19.36	4.36	2.20	69.57	48.43
14	25.54	0.63	0.25	23.07	4.79	1.40	64.71	36.14
15	50.34	1.15	0.56	21.93	7.57	5.40	77.14	51.14
16	110.27	3.21	1.73	19.5	7.57	13.40	84.71	62.29
17	75.54	2.43	1.16	22.36	8.19	30.20	77.72	59.14
18	70.23	1.79	0.73	20.29	7.33	10.80	80.57	57.29
19	21.59	1.52	0.54	23.57	6.51	22.80	65.42	43.71
20	17.52	1.16	0.37	22.14	8.51	15.60	76.00	59.00
21	8.67	0.43	0.13	22.50	9.57	34.80	80.14	67.29
22	6.23	0.00	0.00	28.14	9.00	6.20	67.71	45.86

SMW = Standard meteorological week
* Mean of population on 20 plants

Table 2. Incidence of mustard aphid, *Lipaphis erysimi* and subsequent appearance of its predators during *Rabi* 2019-20

SMW	No. of aphids/plant	*No. of predators/plant		Max. temp (°C)	Min. temp (°C)	Rainfall (mm)	Morning relative humidity (%)	Evening relative humidity (%)
		Coccinella septumpunctata	*Hippodamia variegata*					
12	7.30	0.07	0.00	16.71	4.64	21.30	74.29	56.57
13	23.73	0.59	0.28	13.57	4.27	68.39	85.71	75.71
14	31.56	0.87	0.64	17.79	3.24	53.20	76.85	60.71
15	64.32	1.48	0.99	21.29	6.34	18.20	74.00	58.29
16	144.45	4.80	2.96	16.71	6.71	29.19	86.28	74.14
17	91.90	3.74	2.01	25.14	8.42	2.03	71.43	65.00
18	83.27	2.85	1.75	23.07	9.50	64.61	73.29	71.00
19	29.07	2.01	1.36	25.29	8.73	6.58	75.29	75.00
20	27.40	1.59	0.80	23.36	8.66	15.61	73.14	65.86
21	12.89	0.67	0.28	28.86	9.01	0.00	70.71	44.57
22	10.58	0.20	0.06	23.21	11.05	42.98	85.57	76.14
23	0	0	0	27.64	12.06	15.80	74.57	68.14

SMW = Standard meteorological week
* Mean of population on 20 plants

Singh 2010, Nayak 2010, Varmora et al 2009). Ahlawat et al (2021) also observed the positive correlation of aphid population with relative humidity and rainfall. The variation in the month of incidence of aphids may be due to different climatic conditions of the Kashmir valley.

The predator population *viz*; *Coccinella septumpunctata* and *Hippodamia variegata* on the mustard aphid appeared simultaneously with the aphid population. *C. septumpunctata* appeared during the 12th standard week as0.03 beetles per plant (2018-19) and 0.07 beetles per plant (2019-20), and *H. variegate* occurrence was observed during the 13th standard week as 0.02 per plant (2018-19) and 0.28 beetles per plant (2019-20). Both the predator populations reached its peak during 16th standard week being 3.21 and 1.73 (2018-19) and 4.80 and 2.96 beetles per plant during 2018-19 and 2019-20 coinciding the peak population of aphids and then again decreased with the decline of aphid population to 0.43 and 0.13 beetles per plant in 2018-19 and 0.20 and 0.06 beetles per plant in 2019-20, respectively (Table 1 and 2). *Brevicoryne brassicae* exhibited positive correlation with coccinellid predators *viz*; *C. septumpunctata* and *H. variegate* (Table 3). Ali et al (2012) also reported that population of coccinellids increased along with the increased population of aphids and thus revealed positive correlation between *B. brassicae* population and coccinellid predators.Mishra & Kanwat (2018) observed that the population of *C. septumpunctata* was influenced by the host insect and both were at peak the same time(17 beetles/404.25 aphids). Similarly Pal et al(2018) reported that the population of predator fluctuated according to its prey

Table 3. Correlation and regression analysis between abiotic as well as biotic factors and *Lipaphis erysimi* population on *Brassica juncea* (Pooled 2018-19 and 2019-20)

Parameters	Regression equation	Correlation coefficient (r)
Abiotic factors	Aphid population/plant	
Maximum temperature	y = -0.025x+22.92 R^2 = 0.066	-0.26
Minimum temperature	y = -0.002x+7.570 R^2 = 0.001	-0.05
Rainfall	y = 0.012x+21.36 R^2 = 0.003	0.06
Morning RH	y = 0.067x+72.81 R^2 = 0.360	0.60*
Evening RH	y = 0.077x+56.16 R^2 = 0.334	0.58*
Biotic factors		
C. septumpunctata	y = 0.031x+0.105 R^2 = 0.894	0.95**
H. variegata	y = 0.018x-0.011 R^2 = 0.922	0.96**

population in the season and population of predator was positively correlated with prey population. Bilashini and Singh (2011) reported that numerical density of the predator was observed to increase with increase in density of aphid prey in the field and correlation analysis showed highly positive significant correlation between predator and aphid species.

CONCLUSION

The incidence of mustard aphid, *Brevicoryne brassicae*on mustard was observed from last week of

March i.e. 12th and later reached to peak at 16th standard week. So by manipulating the calendar of sowing of mustard, can protect crop from the peak aphid population infestation. Similarly the population of coccinellid predators also reached peak at 16th standard week, thus coinciding with the peak population of aphids. Aphids exhibit negative correlation with maximum temperature and positive correlation with minimum temperature, rainfall, morning relative humidity, evening relative humidity and positive correlation was between mustard aphid and its predators: *Coccinella septumpunctata* and *Hippodamia variegata*.

REFERENCES

Ahlawat DS, Kumar D and Punia R 2021. Population dynamics of mustard aphid, *Lipaphis erysimi* on Brassica crop in relation to abiotic factors and sowing date. *Journal of Applied Entomologist* **1**(2): 15-18.

Ali A and Rizvi PV. 2012. Influence of abiotic and biotic factors on the population dynamics of mustard aphid, *Lipaphis erysimi* (Kalt.) on Indian mustard, *Brassica juncea* with respect to sowing dates. *Academic Journal of Plant Sciences* **5**(4): 123-127

Bilashini Y and Singh TK 2011. Relative abundance of aphid Lipaphis erysimi (Kaltenbach) and predator *Coccinella septempunctata* Linnaeus on *Brassica oleracea* var. botrytis in relation with abiotic factors. *Environment and Ecology (Kalyani);* **29**(3A): 1372-1375.

Biswas GC, and Das GP 2000. Population dynamics of the mustard aphid, *Lipaphis erysimi* (Kalt.) (Hemiptera: Aphididae) in relation to weather parameters. *Bangladesh Journal of Entomology* **19**(1&2): 15-22.

Dharavat N, Mehera B, Nath S, Patra S and Rout S 2016. Effect of sowing dates on population dynamics of mustard aphid (*Lipaphis erysimi*) in mustard (*Brassica juncea*) under Allahabad climatic condition. *Advances in Life Sciences* **5**(20): 9109-9113.

Hasan W and Singh CP 2010. Relationship between the population of mustard aphid, *Lipaphis erysimi* (Kaltenbach) and weather parameters on different cultivars of Indian mustard (*Brassicajuncea* L.). *The Journal of Plant Protection Sciences* **2**(1): 71-76.

Liu T and Yue B 2001. Comparison of some life history parameters between alate and apterous forms of turnip aphid (Homoptera: Aphididae) on cabbage under constant temperatures. Florida Entomologist **84**: 239-242.

Mishra SK and Kanwat PM 2018. Seasonal incidence of mustard aphid, *Lipaphis erysimi* (Kalt) and its major predator on mustard and their correlation with abiotic factors. *Journal of Entomology and Zoology Studies* **6**(3): 831-836.

Nayak MK 2010. Population dynamics of major insect species of mustard (*Brassica Compstris sariah*) towards weather parameters. *Journal of Rural and Agricultural Research* **10**(1): 19-21.

Pal S, Singh DK and Umrao RS 2018. Population dynamics of insect pests in mustard and ecofriendly management of *Lipaphis erysimi* (Kaltenbach) in Uttrakhand. *International Journal of Current Microbiology Applied Sciences* **7**(7): 324-331

Pawar VR, Bapodra JG, Joshi MD and Ghadge SM 2010. Population dynamics of aphid, *Lipaphis erysimi* (Kaltenbach) on mustard. *Agricultural Science Digest* **30**(3): 221-223

Sahu V, Yadav R, Singh RP and Bareliya PK 2017. Seasonal incidence of mustard aphid, *Lipaphis erysimi* in Jhansi during Rabi crop season. *Plant Archives* **17**(2): 1505-1507

Singh B 1986. *Morphological/biochemical traits of Brassica genotypes vis-a vis mustard aphid, Lipaphis erysimi (Kalt.) resistance*. M.Sc. (Ag.) Thesis, Haryana Agricultural University, Hisar, India.

Singh R, Singh MP, Singh KP, Devi TB and Singh NG 2007. Comparative efficacy of certain Neem products and conventional and insecticides against mustard aphid, *Brevicoryne brassicae* (Kalt.) and their safety to its natural enemies. *Indian Journal of Entomology* **69**(3): 259-264.

Singh YP and Sharma KC 2012. Integrated approach to manage the mustard aphid, *Lipaphis erysimi* (Kalt) (Homoptera; Aphididae) in oilseed Brassica crops: A review. *Journal of Aphidology* **16**: 77-88.

Varmora JM, Raghvani KL, Joshi MD, Makadia RR, Dalwadi NG. and Boricha HV 2009. Population dynamics of aphid, *Lipaphis erysimi* (Kalt.) and predators on cabbage. *Asian Sciences* **4**(1,2): 56-58.

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Quantification of Spray Drift of Wheel Operated Boom Sprayer for Assessing Environmental Risk

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Abstract: In the present study a wheel operated boom sprayer was evaluated on the basis of spray drift. The study involved the use of water sensitive paper (WSP) to capture the off-target spray laid on ground at a distance of 50 cm from the edge of the boom carrying nozzle. The results indicated that the spray drift was maximum for a hollow cone nozzle at 9.1% and minimum for flood jet nozzle at 0.2%. The spray drift increased with an increase in the height of spraying because of more time span for water droplets to remain suspended in air. The spray drift also decreased with an increase in the number of nozzles carried on the boom of the sprayer. The decrease in the spray drift with an increase in number of nozzles was due to the decrease in the atomization of liquid thus producing large droplets which are comparably less prone to the drift as compared to the smaller droplets.

Keywords: Wheel sprayer, WSP, Dropleaf, Spray drift

Pesticides are the chemicals or mixture of substances used in various agricultural practices to control or eradicate pests, weeds and diseases in plants. The pesticides include herbicides, insecticides, fungicides, rodenticides, nematicides and other chemicals based on their intended target organism. On the basis of their use, they are classified as defoliants, desiccants, fumigants and plant growth regulators. Pesticides have substantially aided in the development of agricultural yields by controlling pests and diseases, as well as in the control of the insect-borne diseases (malaria, dengue fever, encephalitis, filariasis, and other parasitic disorders) in the human health sector (Abhilash and Singh 2009). The use of a various pesticides on crop plants is essential to reduce losess. However, the excess use results in significant consequences not only to public health but also results in an impact load on the environment. The conventional agricultural practices demand pesticides use either in bulk or its pure form without any adjuvant. The major drawback of the conventional pesticides applications is the loss depending on the mode of application i.e., spray drift from the sprayers at the time of application and weather conditions. (Singh et al 2020). Spray drift is a portion of spray which unintentionally reaches outside the target area, either in the form of droplets, dry particles or vapour during or after the spraying application on the target area (Carlsen et al 2006). According to the Environmental Protection Agency (EPA 2019) and the American Society of Agricultural Engineers (ASAE Standards 2009) spray drift is the pesticide carried by the air action during the application process or immediately after spray application. The drift of the spray from pesticide applications can expose people, plants, animals and the environment to the pesticide residues that can cause health and environmental effects and property damage. The spray drift can lead to the litigation, financially damaging court costs, and appeals to restrict or ban the use of crop protection materials. Arvidsson et al (2011) observed that with the increase in the height from the drift increased to the tone of 0.94% for each height of 0.1m. It was also observed that the fraction of droplets having sizes less than 102 microns are more prone to the drift. In order determine the effect of wind speed on spray drift, wind tunnel was used to provide cross winds of 1, 2 and 3 m/s and reported that by the increment of height of 10 cm the spray drift increased to the tune of 33.5%. Thus, it was concluded closer the nozzle to the target lesser is the spray drift.

MATERIAL AND METHODS

The study to assess the spray drift characteristics of a wheel operated boom sprayer (Zaffar 2020) was conducted at the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K India with three types of booms (boom carrying two, three and four nozzles) and three different types of nozzles i.e., fan type, hollow cone and flood jet nozzle at three different heights of 40, 50 and 60 cm.

Description of a Wheel operated sprayer: The wheel operated sprayer consists of a bicycle wheel of 640 mm diameter attached at the front end of the main frame. On the rear end of the main frame a sprayer pump is mounted the sprayer consists of eccentric mechanism by which the rotational motion of the front wheel was converted into the reciprocating motion of the pump. The pump is attached with the hose pipe which in turn is connected with the boom carrying nozzles for the spraying operation. The main components of the wheel operated sprayer are main frame, sprayer tank cum pump, boom stand, boom and nozzles (Fig. 1).

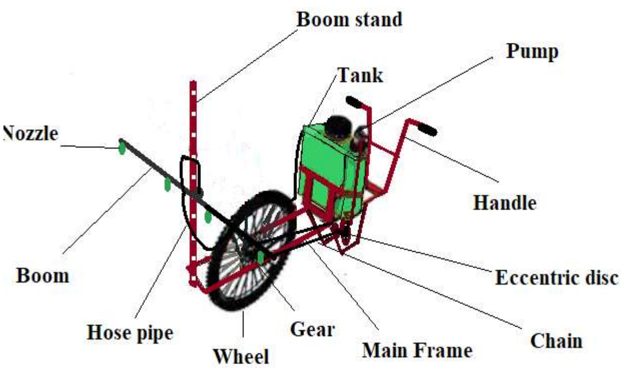

Fig. 1. Labelled figure of a wheel operated boom sprayer

Study area: The study was conducted at SKUAST Jammu on the knoll khol crop and spraying operation was done perpendicular to the wind direction. The size of the plot was 20 × 20 m^2 located at center of the university (32°65`29`` N, 74°80`71`` E) and represents a typical knol khol field at a mature crop stages 68-74% of leaf ground coverage and 0.25 m plant height.

Sampling setup: A total of 81 trials were performed to measure the spray drift deposition on the downwind side soil outside of the treated area (NW orientation) at 50 cm distance from the edge of the last nozzle.

Spraying technique: The spraying was done using a wheel operated boom sprayer in the field of the knol khol crop where the water sensitive papers were laid on about 50 cm from the extreme end of the nozzle. The spray drift was assessed on three types of the nozzles namely flat fan, hollow cone and flood jet nozzle at the three heights of the boom from the ground i.e. 40, 50 and 60 cm. The drift deposition was measured by analyzing the water sensitive paper after spraying of water over the mobile based software namely Dropleaf. The software provided the overall deposition of the liquid on the water sensitive papers which in turn determines the overall drift of the liquid from the specific nozzle at the specific height.

Meteorological conditions: The meteorological variables considered during the study were wind speed, temperature and relative humidity. The area has an average wind speed of 1.2 ± 1 ms^{-1}, maximum and minimum temperature of 31.2 and 18.5° respectively and also relative humidity of 84 and 44 at morning and night. (SKUAST- J 2020)

Design of experiments: To study the combined effect of different operational parameters namely type of nozzle, number of nozzles and height of the spraying on spray drift a factorial randomized block design of experiments was used with the three levels of variables for each.

Types of nozzle: The spray drift was assessed on three types of the nozzles i.e. flat fan nozzles, hollow cone nozzle and flood jet nozzle as these types of nozzles are readily used in agricultural spraying.

Flat fan nozzle: The flat fan nozzle is used for most of the broadcast spraying of herbicides and for certain insecticides when foliar penetration and coverage are not required. In order to maintain the uniformity overlapping of flat-fan nozzles is done. The overlap of approximately 30% of each edge is desirable in flat fan type of nozzles (Mulatu 2018) and same was kept during the experiments. There are two common designs of flat fan nozzle; elliptical orifice type and the deflection type. The one which we have adopted and is common in agricultural spraying is the elliptical orifice type. The spray pattern in this type of nozzle is formed by the exit of the fluid through a shaped orifice (Fig. 3). The slightly tapered

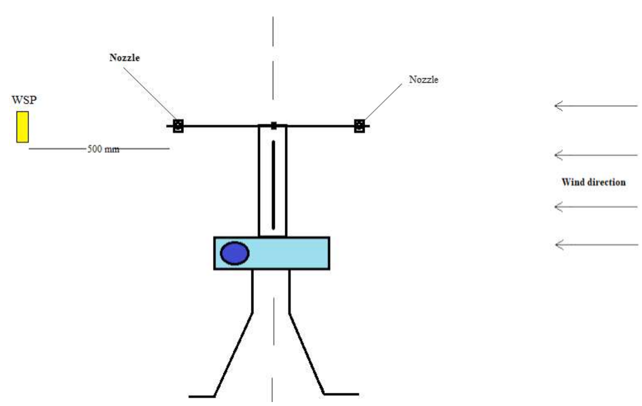

Fig. 2. Schematic diagram of spraying technique for the measurement of spray drift

nature of the flat spray patterns results in the spray distribution of not being entirely even. The components of the nozzles are; body, filter, washers, nozzle tip and nozzle head as shown in Figure 4.

Hollow cone nozzle: The hollow cone nozzles are primarily used when plant foliage penetration is essential for effective insect or disease control and when drift is not a major concern. The hollow cone contains a whirl chamber inside it which sets the whirl motion to the fluid (Fig. 5). The resulting turbulence breaks up the fluid into the droplets which are then shaped into a hollow cone as they exit the orifice. The components of the hollow cone nozzles are; body, whirl chambers, washers and nozzle head as shown in Figure 6.

Flood jet nozzle: The flood jet nozzles also called solid stream nozzles (Fig. 7) are ideal for high application rates and speeds, because they produce a wide-angle, flat fan pattern. Generally, the spray generated by the flood jet is not as uniform as the flat-fan type (TNAU 2015). The flood jet is the simplest of all nozzles, being little more than a circular orifice at the end of a funnel. The flood jet nozzles give the highest impact of any spray pattern as the full momentum of liquid is concentrated into a small area. The droplet size is irreverent in flood jet nozzles unlike other nozzles as the liquid is not atomized. The components are body, head, washer and nozzle tip (Fig. 8).

Height of the spraying: In the present study the spray drift potential of a wheel operated sprayer was analysed on the basis of three heights from the targeted surface keeping the coverage and recommended overlap in consideration. The height of the boom carrying the nozzles was kept 40, 50 and 60 cm above the targeted surface.

Number of nozzles: In order to assess the combined effect of the spray from more than one nozzle at a time over a spray drift three types of booms were used viz. boom carrying two nozzles, three nozzles and four nozzles at a nozzle to nozzle spacing of 50 cm maintaining proper spray coverage over the targeted area.

Spray Drift: Zande et al (2008) placed the collectors at the distance of 0-50 cm from the end of the last nozzle to measure the drift deposit horizontally. In the study the water sensitive papers were laid on the surface perpendicular to the direction of operation at about 500 mm away from the end of nozzle for all types of booms under the study. The water sensitive papers were than analyzed for spray coverage percentage or drift percentage using a dropleaf tool.

Dropleaf: Dropleaf is a smart phone application used to measure the quality of pest control spraying machine via image analysis. Dropleaf measures the effectiveness of spraying methods and nozzles using images of water sensitive papers (spray cards) either captured from a

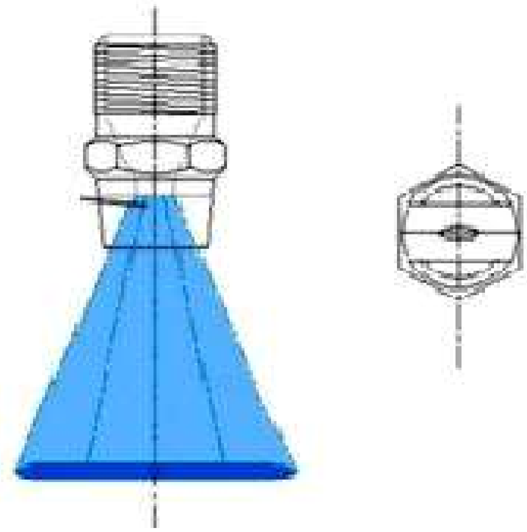

Fig. 3. Spray pattern of flat fan nozzle

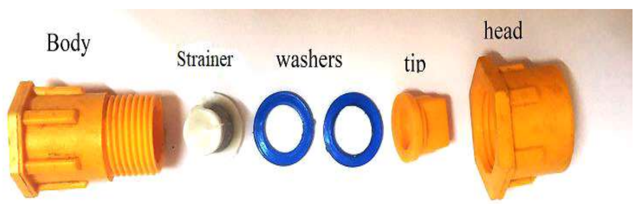

Fig. 4. Components of flat fan nozzle

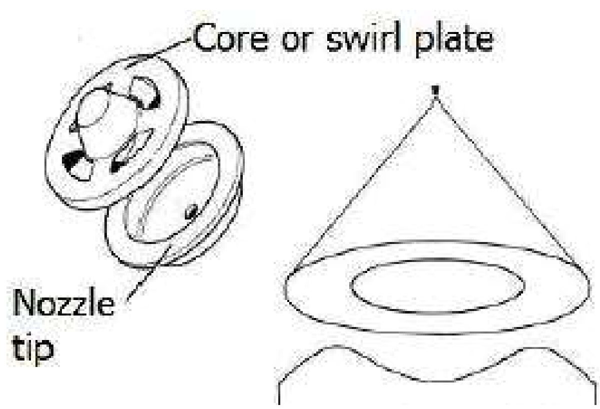

Fig. 5. Spray pattern of hollow cone nozzle

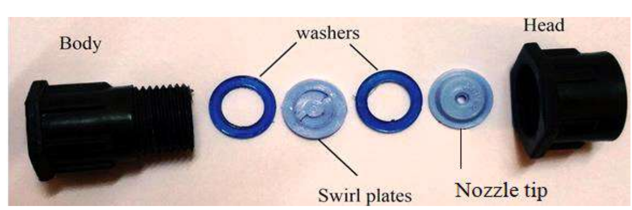

Fig. 6. Components of hollow cone nozzle

smartphone or loaded from the photo gallery. In the present study the dropleaf was used to measure the Spray drift coverage (%) to determine spray drift potential from the different types of nozzles mounted on a wheel operated boom sprayer.

RESULT AND DISCUSSION

Spray drift: The spraying operation was done perpendicular to the wind direction and spray drift was affected by nozzle type (N), type of boom (B) and height of boom (H) (Table 2).

Effect of nozzle type on the spray drift : The maximum drift of 8.9 % for a flat fan nozzle at a height of spraying of 600 mm having two nozzles (B_1) whereas minimum of 1.8 % for flat fan nozzle type was attained at a height of 500 mm having four nozzles (B_3). For hollow cone nozzle the maximum and minimum spray drifts of 9.1 and 1.3 % were attained at a height of spraying of 600 mm having two nozzles on the boom (B_1) and height of 500 mm having three nozzles on the boom (B_3). In case of flood jet nozzle N_3, the maximum and minimum spray drift of 6.4 and 0.4 % were achieved at a height of 600 mm and having two nozzles on the boom (B_1). The spray drift was maximum for a hollow cone and minimum for flood jet nozzles. The minimum spray drift for the flood jet nozzle may be due the design features which produced large sized droplets as compared to the flat fan and hollow cone nozzles. In case of flat fan nozzle and hollow cone nozzles, finer droplets are produced which are more prone to the drift. The main effect of nozzle type on spray drift was not statistically significant at 5% level of significance. The first level interaction N×B were statistically significant at 5% level of significance. The first order interaction N×H as well as second order interaction N×B×H were significant at 5% level of significance.

Effect of the number of nozzles: The maximum spray drift of 9.1 % for two nozzle boom was attained at 600 mm height of spraying having flood jet nozzles whereas minimum spray drift of 0.4 % for two nozzle boom (B_1) was attained at the height of spraying of 400 mm having hollow cone nozzles. The maximum and the minimum spray drift of 8.9 and 0.3% for the three nozzle boom B_2 was attained at a height of 600 mm having flood jet nozzle and at a height of 400 mm having hollow cone nozzle respectively. In boom having four number of the nozzles, the maximum spray drift of 3.7 % was attained at two-treatment combination i.e. spraying height of 600 mm for flat fan nozzle and 600 mm for flood jet nozzle while as minimum spray drift of 0.3 % was at 400 mm height of spraying for hollow cone nozzle respectively. The spray drift

Fig. 7. Flood jet nozzle

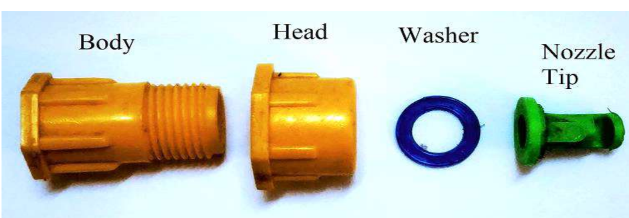

Fig. 8. Components of flood jet nozzle

Table 1. Treatment details for the assessment of spray drift from the sprayer

Independent variables	Levels	Dependent variables
Type of nozzles	Flat fan nozzles (N_1)	Spray drift
	Hollow cone nozzles (N_2)	
	Flood jet nozzles (N_3)	
Number of nozzle	Boom carrying two nozzles (B_1)	
	Boom carrying three nozzles (B_2)	
	Boom carrying four nozzles (B_3)	
Height of spraying	40 cm (H_1)	
	50 cm (H_2)	
	60 cm (H_3)	

Table 2. Effect of the nozzle type, number of nozzles and height of the spraying (mm) on spray drift

Nozzle type	No. of nozzles	Spray drift (%)		
		H_1	H_2	H_3
N_1	B1	4.4	5.3	8.7
	B2	4.1	5.0	8.9
	B3	2.8	2.8	2.9
N_2	B1	4.9	5.5	9.1
	B2	4.0	4.3	6.6
	B3	3.1	3.1	3.7
N_3	B1	0.4	4.2	6.4
	B2	0.2	0.4	2.2
	B3	0.3	0.7	1.9
CD (p=0.05)	(N)	=	0.04,	
	(B)	=	0.04	
	(H)	=	0.04	
	N × B	=	0.08	
	N × H	=	0.08	
	B × H	=	0.08	
	N × B × H	=	0.13	

decreased with the increase in the number of the nozzles on boom. The decrease of 33.3, 66.0 and 67.8% in spray drift was observed when the numbers of flat fan nozzles were increased from two to four at the height of 40, 50 and 60 cm respectively. In hollow cone nozzle, the decrease of 36.7, 76 and 59 % in spray drift was observed with the increase in number of nozzles from two to four. Similarly, for flood jet nozzle the decrease of 25, 83 and 70.0% in spray drift was observed with the increase in the number of nozzles from two to four. The decrease in the spray drift with an increase in number of nozzles is simply due to the decrease in atomization of the liquid thus producing large droplets which are comparably less prone to the drift as compared to the smaller droplets.

Effect of height of the spraying on spray drift: The maximum spray drift of 4.9 % for the height of spraying of 400 mm with two hollow cone nozzles whereas minimum spray drift of 0.2 % at the height of spraying of 400 mm with three nozzle boom for flood jet nozzle. The maximum and minimum spray drift of 5.5 and 0.4 % for the height of spraying of 500 mm was attained for two hollow cone nozzle boom and three flood nozzle boom. For the height of spraying of 600 mm the maximum and minimum spray drift of 9.1 and 1.9 % were attained for two hollow cone nozzle boom and four flood jet nozzle boom. The spray drift increased with an increase in the height of spraying. The increase of 49.4, 53.9 and 3.4% in spray drift was observed when the height of flat fan nozzles was increased from 40 to 60 cm for two, three and four nozzle booms respectively. In hollow cone nozzle, the increase of 46.1, 39.3 and 16.2% in spray drift was observed with the increase in the height from 40 to 60 cm. For the flood jet nozzle, the increase of 93.7, 90.9 and 84.2% was observed by increasing the height from 60 to 80 cm for two, three and four nozzle booms respectively. The increase in the spray drift with an increase in the height of boom may be due to more time span for water droplets to remain suspended in air which results in more drift due to the flow of wind. Nordby and Skuterud (2006) reported the same relationship between drift and height of the boom.

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CONCLUSIONS

The present study concluded that the spray drift is directly linked with the type of the nozzle, height at which spraying is performed and number of the nozzles. It was observed that the height has a positive relation with spray drift i.e., the drift increases with an increase in the height of spraying and its magnitude depend on the type of nozzle. The hollow cone nozzle recorded maximum spray drift which may be due to its design features while the flood jet nozzles have the least spray drift. Thus, using proper nozzle at proper height of spraying the spray drift from an agriculture sprayer can be minimized.

REFERENCES

Abhilash PC and Singh N 2009. Pesticide use and application: An Indian scenario. *Journal of Hazardous Materials* **165**(1-3): 1-12.

Arvidsson T, Bergsrrom L and Kreuger J 2011. Spray drift as influenced by meteorological and technical factors. *Pest Management Science* **67**(5): 586-598.

ASAE 2009. *Spray nozzle classification by droplet spectra*. American Society of Agricultural Engineers.

Carlsen SCK, Spliid NH and Svensmark B 2006. Drift from ten herbicides after tractor spray application. *Chemosphere* **64**(5): 778-786.

EPA 2019. *Environmental Protection Agency. Introduction to pesticide drift*. Available online at https://www.epa.gov.

Hassen NS, Sidik NAC and Sheriff JM 2014. Effect of nozzle type on spray drift in banding application. *Applied Mechanics and Materials* **465**(466): 520-525.

Mulatu Y 2018. Fabrication and performance evaluation of ground wheel operated boom sprayer. *International Journal of Engineering Research* **6**(8): 16-23.

Singh A, Dhiman N, Kar AK, Singh D, Purohit MP, Ghosh D and Patnaik S 2020. Advances in controlled release pesticide formulations: Prospects to safer integrated pest management and sustainable agriculture. *Journal of hazardous materials*, 385:1-76.

TNAU 2015. Tamil Nadu Agriculture University. TNAU Agritech portal. http://agritech.tnau.ac.in/crop_protection.

Zaffar O 2020. *Development and Evaluation of a Wheel Operated Boom Sprayer for Small Holding Farmers*. M.Tech Dissertation, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu, India.

Zande JCV, Huijsmans JFM, Porskamp HAJ, Michielsen JMGP, Stallinga H, Holterman HJ and Jon DA 2008. Spray techniques: How to optimise spray deposition and minimise spray drift. *Environmentalist* **28**(1): 9-17.

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Evaluation of Different IPM Modules for Management of Fruit Fly *Bactrocera cucurbitae* (Coquillett) in Summer Squash (*Cucurbita pepo* L.)

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Abstract: Six integrated pest management (IPM) modules were evaluated with cost benefit ratio was calculated. M-I and M-II were tested with integration of pest management strategies i.e., use of methyl eugenol trap, weekly clipping of infested fruits, maize as a trap crop and use of chemical insecticides i.e., spinosad in M-I and imidacloprid in M-II. Malathion with sugar was tested in M-III. In M-IV, recommended package of practices were followed and in M-V, farmers practice was tested while as M-VI was control. All IPM modules were significantly superior over control in reducing fruit fly damage. However, module-I showed least percent damage in summer squash fruit on number basis (16.15%) and on weight basis (11.69%). The maximum adult fruit fly mortality (87.00%) was with spot application of spinosad and maximum fruit yield (35 t/ha) were obtained in M-I with highest cost -benefit ratio (1: 3.96) for the whole cropping period.

Keywords: Summer squash, *Bactrocera cucurbitae*, Methyl eugenol, Spinosad, IPM

Cultivation of summer squash (*Cucurbita pepo* L.) is now gaining momentum and popularization among farming community due to higher nutritional value, short duration nature, accompanied with higher economic returns in shorter span of time. In India, summer squash along with other gourd crops cultivated on 4.77 m ha with annual production of 5.10 million tonnes which brings up the average productivity of 9.72 tonnes/ha (FAO 2017). In Jammu region, the cucurbits cover an area of 2486 ha with annual production of 51707.11 MT (Anonymous 2017). The major limiting factors responsible for considerable crop damage at different stages from nursery raising to the harvest are insect pests. Among them, tephritid fruit fly, *Bactrocera cucurbitae* is the most destructive insect pests of cucurbits and squash (Sapkota et al 2010). The extent of losses inflicted by dipteran flies vary from 30 to 100 per cent depending upon cucurbit species and environmental conditions (Dhillon et al 2005, Jayraj 2013, Shooker et al 2006,). Their attack not only results in reduced crop yield but also causes indirect loss such as reduction in trade and export prospect (Sharma et al 2015) thereby affecting local and export markets and thus making farming unprofitable. The management of fruit fly in cucurbitaceous is reasonably difficult because the maggot of *B.cucurbitae* is an internal feeder due to which the farmers rely largely on different kinds of broad spectrum chemical insecticides. However, the increasing use of chemical insecticides has led to number of problems such as development of resistance in insect pests against insecticides, resurgence of pests, secondary pest outbreaks, ecological imbalance, risk to human health and environment. Also, before the non-judicious use of chemical insecticides has aggregated the problem of pesticidal residue in crops which is a matter of serious concern. Thus emphasis is on integrated pest management strategies as an alternative tool that can be explore for developing an effective, cheap and eco-friendly pest control devise. Keeping these facts in view, the present experiment was carried out to evaluate different IPM modules for management of fruit fly in Jammu region.

MATERIAL AND METHODS

The experiment comprised of 6 treatments (Table 1) and was conducted in randomized block design with four replications in plot size of 5×4 m^2 at Sher-e-Kashmir University of Agricultural Sciences and Technology Chatha, Jammu (Skuast-Jammu). The summer squash variety "DON 17" was sown in polybags in February 2018, and transplanted in main field in March, 2018. All cultural practices recommended as per the package of practices of Skuast-Jammu were followed. Observations on percent fruit damage (number basis and weight basis), adult fruit fly mortality and yield in each module were recorded to calculate benefit cost ratio on the basis of increased yield over control. Data were statistically analysed by SPSS-16.0 software and means were compared with Tukey's HSD test at P≤0.05.

RESULTS AND DISCUSSION

All the IPM modules were significantly superior over control wherein, M-I out yielded all other treatments and recorded highest cost: benefit ratio (1:3.96), least per cent damage on number basis (16.15%) and on weight basis (11.69%) along with maximum fruit fly mortality (87.00%) with spot application of spinosad for whole cropping period. The descending order of performance of different modules was Module I> Module II > Module III > Module IV > Module V> Module VI. Birah et al (2015) also observed that IPM module comprising of installation of cue-lure baited traps was most effective for managing fruit fly (*B. cucurbitae*) in cultivated cucurbits.

Damage of summer squash fruit (Number basis): Among different IPM modules, module I was found to be superior and showed least percent damage (16.15%) followed by module II with 17.15% damage. The module III recorded 23.40% fruit damage followed by module IV and module V with 28.35% and 40.19% fruit damage respectively. The descending order of performance of modules was as follows: Module I > Module II > Module III > Module IV > Module V>Module VI (Table 2). Shinde et al (2007) also reported that spinosad 75 SC @75 a.i per ha resulted in minimum fruit infestation as in module I in which application of spinosad with gur as spot application along with maintaining field sanitation by weekly clipping of infested fruits, using maize as a trap crop and use of low cost innovative traps showed least fruit infestation.

Damage of summer squash fruit (Weight basis) : IPM modules showed significant difference over each other for percent damage of fruits on weight basis. Module I was superior with lowest per cent damage of summer squash fruit (11.69%) followed by module II, III, IV and V. Module VI (control) recorded maximum per cent damage of fruit on weight basis (52.39%). Raghuvanshi et al (2008) and Vargas et al (2005) reported that male annihilation techniques play an important role in suppression of fruit flies that results in minimum percent damage. In present study use of low cost methyl eugenol trap played key role beside spot application of spinosad resulted in minimum damage on weight basis.

Adult fruit fly mortality in summer squash on spot application of insecticides: Module I was superior and recorded highest adult fruit fly mortality (87%)for the whole cropping period followed by module II , III , IV (Table 2). Module V recorded lowest fruit fly mortality (40.32%). In module VI (control) no adult fruit fly mortality was recorded. Yee et al (2006) who also reported that application of spinosad and traps baited with spinosad cause maximum adult mortality in fruit fly and also observed that spinosad was more effective.

Economics of different IPM modules for management of fruit fly in summer squash: During 2018 all modules were cost effective (Table 3). The highest yield was in module I with 35 t/ha followed by module II, module III, module IV and module V with 32t/ha, 26t/ha, 22t/ha and 16t/ha respectively. The least yield was in module control (8 t/ha). The increase in yield of cucurbits using bait technique has also been reported by

Table 2. Performance of different IPM modules

Modules	Fruit damage (%) (Number basis)	Fruit damage (%) (Eight basis)	Adult fruit fly mortality (%)
M I	16.15[e]	11.69[e]	87.00[a]
M II	17.15[e]	12.51[e]	84.82[b]
M III	23.40[d]	17.98[d]	73.92[c]
M IV	28.35[c]	22.03[c]	60.64[d]
M V	40.19[b]	32.81[b]	40.32[e]
M VI (Control)	60.19[a]	52.39[a]	0.00[f]
F-value (P-value)	5394.00** (<0.01)	3584.00** (<0.01)	1540.00** (<0.01)

In a column means followed by different alphabets are significantly different by Tukey's HSD (0.05)

Table 1. The treatment details of experiment

Modules	Treatments
Module-I	• Weekly clipping of infested fruits • Low-cost methyl eugenol trap with spinosad • Maize as a trap crop • Spraying as spot application with spinosad+gur
Module-II	• Weekly clipping of infested fruits • Low-cost methyl eugenol trap with spinosad • Maize as a trap crop • Spraying as spot application with imidacloprid+gur
Module-III	• Bait spray 0.1 % malathion and sugar i.e. 40 ml of malathion and 200g of sugar in 20 lit of water per ha.
Module-IV	• Package of Practice:Spraying as spot application with deltamethrin+gur
Module-V	• Farmer's Practice: Spraying of profenophos @ 1000 ml/ha
Module-VI	• Control: Sole crop (water spray)

Table 3. Economics of different IPM modules for management of fruity fly in summer squash during 2018-19

Treatment	Average yield (t/ha)	Increase over control (t)	Value of additional yield (Rs./ha)	Cost of treatment (Rs./ha)	Net profit (Rs.)	Benefit cost ratio
Module I	35.00[a]	27.00	270000.00	54450.00	215550.00	1 : 3.96
Module II	32.00[b]	24.00	240000.00	50732.00	189268.00	1 : 3.73
Module III	26.00[c]	18.00	180000.00	42500.00	154345.00	1 : 3.63
Module IV(PoP)	22.00[d]	14.00	140000.00	40000.00	100000.00	1 : 2.5
Module V (Farmers practice)	16.00[e]	8.00	80000.00	36000.00	44000.00	1 : 1.22
Module VI (Control)	8.00[f]	_	_	_	_	_
CD at 5 %	1.504	_	_	_	_	_

In a column means followed by different alphabets are significantly different by Tukey's HSD (0.05)
Cost of summer squash during 2018 was Rs. 10000/tonnes
Labour charges @ Rs. 300/labour/day

Stonehouse et al (2002). The present study thus indicates the superiority of using innovative lure baited traps in combination with chemical insecticides as evidenced by minimum fruit infestation and more fruit yield in this experimentation. Module I provided highest benefit of Rs. 215550 followed by module II (Rs. 189268). The highest cost benefit ratio was obtained in case of module I with 1:3.96 followed by module II, module III and module IV with 1:3.73, 1:3.63 and 1:2.5 respectively. The least cost benefit ratio was recorded in module V with 1:1.22. Similar Satpathy and Rai (2002) and Birah et al (2015) during the studies on management of fruit fly in cucurbit crops observed that IPM strategies could provide higher yields and returns beside judicious use of pesticides which is an important component of IPM .

CONCLUSION

Module-I was significantly superior over all other treatments wherein clipping of infested fruits, installation of low-cost mineral bottle methyl-eugenol traps with spinosad, along with maize grown as trap crop and need based spot application of spinosad with gur effectively managed the fruit fly population in summer squash. The same module M-I revealed highest benefit of Rs. 2, 15,550 with highest cost benefit ratio (1:3.96).

REFERENCES

Anonymous 2017. Report of Vegetable Improvement Scheme. Directorate of Agriculture, Krishi Bhawan Talab Tillo, Jammu

Birah A, Singh S, Singh PK and Roy SD 2015. Evaluation and efficacy of pest management modules for cucurbits against Fruit fly, *Bactrocera cucurbitae*(Coquillett) in Andaman. *Vegestos Journal* **28**(4): 62-66.

Received 06 August, 2022; Accepted 15 September, 2022

Dhillon MK, Singh R, Naresh JS and Sharma HC 2005. The melon fruit fly, *Bactrocera cucurbitae*: A review of its biology and management. *Journal of Insect Science* **5**(1): 40.

FAO (Food and Agriculture organization, Rome) 2017. http//:faostat.fao.org. (Accessed June15,2018).

Jayraj J. 2013. Controlling fruit fly menace in bitter gourd. *The Hindu dated : 18 Dec 2013*.

Raghuvanshi AK, Satpathy SA and Mishra DS 2008.Attract-annihilation and mass trapping method for management of fruit fly, *Bactrocera cucrbitae*(Coquillett) in bitter Gourd. *Indian Journal of Entomology* **70**(1): 71-84.

Sapkota R, Dahal KC and Thapa RB 2010. Damage assessment and management of cucurbit fruit flies in spring-summer squash. *Journal of Entomology and Nematology* **2**: 07-12.

Satpathy S and Rai S 2002. Luring ability of indigenous food baits for fruit fly *Bactrocera cucurbitae* (Coquillett). *Journal of Entomological Research* **26**: 249-252.

Sharma DR, Adhika D and Tiwari DB 2015. Fruit fly surveillance in Nepal. *Journal of Agricultural and Biological Science* **1**: 121-125.

Shinde BD, Sarkate MB, Nemade PW and Sable YR 2007. Bio efficacy of botanical, microbial and synthetic insecticides against okra fruit borer. *Pestology* **31**: 19-22.

Shooker P, Khayrattee F and Permalloo S 2006. Use of maize as a trap crop for the control of melon fly, *Bactrocera cucurbitae* (Diptera: Tephritidae) with GF-120. *Bio control and other control methods (online),Available on: http\\www.fela.edu/fla Ent/fe87p3s4. Pdf.*

Stonehouse JM, Mahmood R, Poswal A, Mumford JD, Baloch KN, Chaudhary ZM, Mukhdum GM and Huggett J 2002. Field assessment of fruit flies (Diptera: Tephritidae) in Pakistan: distribution, damage and control. *Project Document, India-UK Fruit fly project, 61p*.

Vargas RL, Stark JD, Mackey B and Bull R 2005. Weathering trials of amulet cue- lure and amulet Methyl eugenol "Attract-and-kill" stations with male melon flies and oriental fruit flies (Diptera: Tephritidae) in Hawaii. *Journal of Economic Entomology* **98** (5): 1551-1559.

Yee WL and Alston DG 2006. Effects of spinosad, spinosad bait, and chloronicotinyl insecticides on mortality and control of adult and larval western cherry fruit fly (Diptera: Tephritidae). *Journal of Economic Entomology* **99**(5): 1722-1732.

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Evaluation of Different Cucumber Germplasm against Cucumber Mosaic Virus in Jammu, India

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Abstract: Cucumber (*Cucumis sativus* L.) is one of the most important vegetable crops of the family Cucurbitaceae, grown extensively in tropical and sub-tropical parts of the country. Cucumber production is under constant threat due to various fungal, bacterial and viral diseases. Among these, mosaic disease caused by cucumber mosaic virus (CMV) is the most predominant. Thus, the present study on screening of different cucumber germplasm against cucumber mosaic disease revealed that out of forty germplasm, two germplasm *viz*., Dasher II and Poinsett were resistant whereas CS-13, CS-16, CS-51, CS-54, Fumiko-10 and Don-1 were found moderately resistant during both the cropping season (2019 and 2020). The presence of CMV in infected plants were then confirmed serologically using DAS-ELISA. The resistant and moderately resistant cucumber lines from our study could be further used by farmers in cultivation under integrated production systems and by breeders in developing new varieties resistant to CMV.

Keywords: Cucumber Mosaic Virus, Screening, Detection, DAS- ELISA, Management

Cucumber production is adversely affected by many biotic and abiotic factors. Among various biotic factors, mosaic disease caused by cucumber mosaic virus (CMV) belonging to family *Bromoviridae* and genus *Cucumovirus*, is one of the most devastating and economically important disease of cucumber. Cucumber mosaic virus was first reported in 1916 by Doolittle and since then reported to cause disease in a variety of economically important agricultural, horticultural and ornamental crops under favorable environmental conditions. It has widest host range infecting over 1,200 species from 100 plant families. CMV is a positive sense tripartite virus having single stranded RNA, which is en-capsidated in a 28 nm icosahedral particle (Nault 1997). Cucumber plants may become infected with mosaic disease at any stage of growth, from emergence of the seedling to crop maturity and estimated to cause severe yield losses up to 40-60 per cent (Bananej and Vahdat 2008). CMV is transmitted by mechanical inoculation of plant sap and naturally transmitted by more than 80 species of aphids in non-persistent manner (Palukaitis and Garcia-Arenal 2003). *Myzus persicae* and *Aphis gossypii* are among the more efficient vectors for this virus (Tejashwani et al 2019). There are number of cultural control measures that can be used to prevent or reduce the spread of non-persistently transmitted viruses. Use of disease resistant crop varieties is regarded as an economical and durable method for controlling plant diseases, especially those caused by viruses. It is easy to adopt, cheap, and also environment friendly. There are no adequate data regarding the evaluation of local germplasm for resistance against cucumber mosaic virus in Jammu region. Favorable environment for both vector and virus, lack of awareness about viral diseases among farmers and its wide host range results in severe epidemics of many of these plant viral diseases. Therefore, the present study was conducted to screen out different cucumber germplasm against CMV under field conditions.

MATERIAL AND METHODS

The study was carried out at an experimental farm of Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu (SKUAST- J) during the cropping season of 2019 and 2020.

Screening of cucumber germplasm: A total of forty cucumber germplasm collected from various sources (Table 1) were evaluated against cucumber mosaic virus in natural epiphytotic conditions in randomized block design with three replications. Recommended cultural practices were followed except for insecticidal sprays to encourage the vector population for the natural spread of the disease (Anonymous 2020). The data was recorded at 15 days interval on percent disease incidence starting from 30 days after transplanting and germplasm lines were divided into different categories (susceptible, moderately susceptible, moderately resistant and resistant) according to the disease rating scale by Shah et al 2011 (Table 2). The percent disease incidence was recorded by using the following formula:

$$\text{Percent disease incidence (PDI)} = \frac{\text{No. of infected plants}}{\text{Total no. plants observed}} \times 100$$

Detection of virus through serological methods (DAS-ELISA): Leaf samples of cucumber plant showing characteristics symptoms of CMV were collected from the experimental field. These infected leaf samples were chopped into small pieces and grounded in pestle and mortar in phosphate buffer. Sap was filtered through double layered muslin cloth. Serological detection of these samples through DAS- ELISA (Double Antibody Sandwich- Enzyme Linked Immuno-sorbant Assay) described by Clark and Adams (1977) was then carried out under laboratory conditions at Division of Plant Pathology, SKUAST J.

RESULTS AND DISCUSSION

The forty germplasm lines were screened under natural epiphytotic conditions during the cropping seasons of 2019 and 2020 and were classified into four reaction groups based on the percent infected plants. The symptoms observed on CMV infected cucumber plants during the study were uneven yellow and green specks and patches on the leaves. Infected cucumber leaves also showed mottling and mosaic symptoms. In severely infected plants distortion of leaves was also observed. Out of forty germplasm, except for two, all other germplasm were susceptible to cucumber mosaic virus during both the cropping seasons of 2019 and 2020 (Table 3). Two germplasm viz., Dasher II and Poinsett were resistant whereas six germplasm *viz*., CS-13, CS-16, CS-51, CS-54, Fumiko-10 and Don-1 were moderately resistant. Twenty one germplasm were moderately susceptible while eleven germplasm were susceptible during 2019 and 2020. Many germplasm accessions showing resistance to CMV have been reported in cucumber by many other researchers. Munshi et al (2008) screened 31 accessions of *C. sativus* var. Hardwickii for CMV resistance and observed lowest mean percent disease intensity (PDI) in IC-277048 while the highest PDI in IC-331631. Akbar et al (2015) screened seventeen germplasm in Pakistan and observed summer green, Local green, Khyber, Diamond, VEGAF1 and Yousuf as susceptible to mosaic disease of cucumber. Similarly, Shafiquique (2009) screened 12 varieties of cucumber against CMV in Faisalabad, Pakistan and found Beit alpha as moderately resistant with disease incidence of 16.26 per cent whereas Nandini-732 as highly susceptible.

All the germplasm screened during the cropping season of 2019 and 2020 were also tested serologically via DAS-ELISA for the confirmation of presence of cucumber mosaic virus (CMV). The advantage of this assay is that only virus particles are concentrated from infected plant extracts by the specific antibody coated in wells and other components are removed (Khan et al 2003). CMV specific antibody (Agdia, USA) was used to test the presence or absence of respective causal virus. Infected samples collected during screening were loaded into different wells of the ELISA plate coated with specific antibody. The data recorded on optimal density (OD value) i.e. absorbance value at 405 nm wavelength in both the year are presented in Table 4 and the overall results thus revealed that expect for the samples from Dasher II and Poinsett all other screened lines were found infected with cucumber mosaic virus and showed positive reaction (presence of yellow color) with CMV specific antibody as the O.D values were more than twice the value of negative control reaction. Shetti et al (2012), Suresh et al (2013) and Hasan and Shams-bakhsh (2017) also detected cucumber mosaic virus (CMV) in cucumber (*Cucumis sativus*) and other cucurbits through direct plate and Dot-Enzyme Linked Immunosorbent Assay (ELISA).

Table 2. Disease rating scale for grading of varietal response to cucumber mosaic virus in cucumber germplasm

Disease incidence	Grade	Reaction group
0-10 %	R	Resistant
>10-30 %	MR	Moderately resistant
>30-50 %	MS	Moderately susceptible
>50 %	S	Susceptible

Table 1. Source of cucumber germplasm/lines

Source	Germplasm/lines	No. of entries
School of Biotechnology, SKUAST Jammu	CS-1, CS-13, CS-15, CS-16, CS-20, CS-22, CS-33, CS-34, CS-48, CS-51, CS-52, CS-54, CS-61, CS-67, CS-70, CS-73, CS-88, CS-103, CS-115, CS-149	20
Division of Vegetable Science, SKUAST Jammu	Cucumber Summer Green, Malini	02
Department of Agriculture, Talab Tillo, Jammu	Pusa Sanyog	01
Local Market Jammu	Fumiko-10, RK-180, R K 40, Poinsett, Khira Hybrid-1(KH-1), Khira 75, Dasher II, Nandini-732, Cucumber-DASH, Mahy Sylvia, Kirloskar, Prabhat, Don-1, Vardan, Garima Super, Cucumber Green Long, Local	17

Table 3. Screening of different germplasm of cucumber against cucumber mosaic disease under field conditions (2019 and 2020)

Germplasm	Per cent disease incidence						Mean (%)		Grade
	30 DAT		45 DAT		60 DAT		2019	2020	
	2019	2020	2019	2020	2019	2020			
CS-1	37.50	33.33	45.83	45.83	54.16	54.16	45.83	44.44	MS
CS-13	16.66	20.83	25.00	29.16	29.16	33.33	23.60	27.77	MR
CS-15	25.00	29.16	41.66	37.50	54.16	50.00	40.27	38.88	MS
CS-16	16.66	20.83	29.16	25.00	37.50	33.33	27.77	26.38	MR
CS-20	33.33	29.16	41.66	37.50	50.00	54.16	41.66	40.27	MS
CS-22	33.33	25.00	45.83	41.66	54.16	45.83	44.44	37.49	MS
CS-33	37.50	33.33	41.66	41.66	45.83	50.00	41.66	41.66	MS
CS-34	45.83	45.83	54.16	50.00	58.33	58.33	52.77	51.38	S
CS-48	29.16	20.83	37.50	33.33	41.66	37.50	36.10	30.55	MS
CS-51	20.83	16.66	29.16	25.00	33.33	37.50	27.77	26.38	MR
CS-52	25.00	29.16	33.33	33.33	37.50	37.50	31.94	33.33	MS
CS-54	25.00	12.50	25.00	20.83	29.16	25.00	26.38	19.44	MR
CS-61	29.16	25.00	41.66	37.50	50.00	45.83	39.58	36.11	MS
CS-67	45.83	37.50	58.33	54.16	58.33	62.50	54.16	51.38	S
CS-70	41.66	45.83	54.16	54.16	62.50	58.33	52.77	52.77	S
CS-73	20.83	29.16	33.33	29.16	37.50	33.33	30.55	30.55	MS
CS-88	25.00	37.50	41.66	50.00	54.16	54.16	40.27	47.22	MS
CS-103	29.16	33.33	45.83	45.83	50.00	54.16	41.66	44.44	MS
CS-115	16.66	25.00	33.33	33.33	45.83	41.66	31.94	33.33	MS
CS-149	37.50	25.00	45.83	37.50	54.16	50.00	45.83	37.50	MS
Cucumber summer green	41.66	41.66	50.00	54.16	62.50	62.50	51.38	52.77	S
Fumiko-10	20.83	16.66	25.00	25.00	25.00	29.16	23.61	23.60	MR
RK-180	37.50	37.50	41.66	50.00	50.00	54.16	43.05	47.22	MS
R K 40	41.66	45.83	54.16	50.00	62.50	58.33	52.77	51.39	S
Poinsett	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	R
Pusa Sanyog	25.00	29.16	33.33	33.33	37.50	37.50	31.94	33.33	MS
Khira Hybrid-1(KH-1)	25.00	25.00	41.66	37.50	45.83	41.66	37.49	34.72	MS
Khira 75	37.50	41.66	37.50	50.00	54.16	50.00	43.05	47.22	MS
Dasher II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	R
Nandini-732	41.66	41.66	54.16	54.16	58.33	58.33	51.38	51.38	S
Cucumber-DASH	29.16	29.16	37.50	29.16	41.66	41.66	36.10	33.32	MS
Malini	45.83	45.83	54.16	58.33	66.66	62.50	55.55	55.55	S
Mahy Sylvia	37.50	37.50	45.83	50.00	50.00	54.16	44.44	47.22	MS
Kirloskar	29.16	25.00	41.66	33.33	54.16	50.00	41.66	36.11	MS
Prabhat	25.00	29.16	41.66	45.83	50.00	50.00	38.88	41.66	MS
Don-1	20.83	20.83	29.16	25.00	37.50	33.33	29.16	26.38	MR
Vardan	45.83	41.66	58.33	54.16	62.50	62.50	55.55	52.77	S
Garima Super	41.66	45.83	54.16	54.16	58.33	58.33	51.38	52.77	S
Cucumber Green Long	50.00	50.00	54.16	58.33	66.66	66.66	56.94	58.33	S
Local	50.00	54.16	62.50	66.66	70.83	70.83	61.11	63.88	S

Table 4. Serological detection of cucumber mosaic virus in different germplasm/lines (2019 and 2020)

Germplasm	No. of wells charged	OD value of CMV at 405 nm		Presence (+) or Absence (-) of virus
		2019	2020	
CS-1	2	0.1266- 0.1357	0.1830-0.2103	+
CS-13	2	0.1601-0.1797	0.2143-0.3970	+
CS-15	2	0.1422-0.1675	0.2503-0.2675	+
CS-16	2	0.2603-0.2887	0.1220-0.1387	+
CS-20	2	0.2160-0.2613	0.8830-1.1160	+
CS-22	2	0.1327-0.1520	0.4362-1.1270	+
CS-33	2	0.1877-0.2025	0.2650-0.2880	+
CS-34	2	0.1056-0.1215	0.1150-0.1376	+
CS-48	2	0.2033-0.2378	0.1560-0.1670	+
CS-51	2	0.2433-0.2680	0.2680-0.2980	+
CS-52	2	0.1520-0.1550	0.2440-0.2635	+
CS-54	2	0.1251-0.1775	0.1533-0.1775	+
CS-61	2	0.1620-0.1691	1.5310-1.691	+
CS-67	2	0.2903-0.3096	0.3565-0.3676	+
CS-70	2	0.2201-0.2894	0.1660-0.1894	+
CS-73	2	0.1590-0.1696	0.1866-0.2696	+
CS-88	2	0.1894-0.2011	0.1370-0.1894	+
CS-103	2	0.1686-0.2423	0.1330-0.1686	+
CS-115	2	0.2430-0.2968	0.1465-0.19021	+
CS-149	2	0.1591-0.1719	0.1560-0.16600	+
Cucumber Summer Green	2	0.1022-0.1436	0.2406-0.2641	+
Fumiko-10	2	0.9220-1.0270	1.0230-1.0274	+
RK-180	2	0.3210-0.3310	0.2630-1.033	+
R K 40	2	0.9622-1.0610	0.1822-1.061	+
Poinsett	2	0.0301-0.0462	0.0266-0.0288	-
Pusa Sanyog	2	0.1973-0.2050	0.2440-0.2907	+
Khira Hybrid-1(KH-1)	2	0.3801-0.3770	0.3662-1.0041	+
Khira 75	2	0.2160- 0.2811	0.2210- 0.2720	+
Dasher II	2	0.0182-0.0221	0.0161-0.0250	-
Nandini-732	2	0.2104-0.2690	0.1104-0.1420	+
Cucumber-DASH	2	0.2210- 0.2516	0.2310- 0.2396	+
Malini	2	0.1803-0.2350	0.2105-0.2450	+
Mahy Sylvia	2	0.2210- 0.2516	0.2370- 0.2530	+
Kirloskar	2	0.1860-0.2130	0.1800-0.2101	+
Prabhat	2	0.1706-0.1801	0.1702-0.1851	+
Don-1	2	0.1350-0.1720	0.1421-0.1520	+
Vardan	2	0.3213-0.3611	0.2213-0.3101	+
Garima Super	2	0.2658-0.2800	0.2654-0.2731	+
Cucumber Green Long	2	0.1866-0.1983	0.4066-0.7123	+
Local	2	0.2541-0.2960	0.5251-0.5901	+
Healthy tissue	2	0.0243-0.0409	0.0301-0.0470	-
Buffer	2	0.0227-0.0230	0.0220-0.0261	-

Table 5. Disease reaction of cucumber germplasm against cucumber mosaic disease under field conditions (2019 and 2020)

Reaction group	Percent disease incidence	No. of entries	Germplasm
Resistant	0-10 %	2	Dasher II, Poinsett
Moderately resistant	> 10-30 %	6	CS-13, CS-16, CS-51, CS-54, Fumiko-10, Don-1
Moderately susceptible	> 30-50 %	21	CS-1, CS-15, CS-20, CS-33, CS-22, CS-48, CS-52, CS-61, CS-73, CS-103, CS-115, CS-149, CS-88, RK-180, Pusa Sanyog, Khira Hybrid-1 (KH-1), Khira-75, Cucumber-Dash, Mahy Sylvia, Prabhat, Kirloskar
Susceptible	> 50 %	11	CS-67, CS-70, CS-34, Cucumber Green Long, Vardan, Garima Super, Malini, Nandini-732, Cucumber Summer Green, RK-40, Local

CONCLUSION

Out of forty germplasm/lines of cucumber screened against cucumber mosaic disease during 2019 and 2020 only two germplasm *viz*., Dasher II and Poinsett were found resistant whereas CS-13, CS-16, CS-51, CS-54, Fumiko-10 and Don-1 were moderately resistant. Thus, these resistant lines from our study can be further utilized in programs to explore resistant genes to develop CMV resistant cucumber cultivars and are suggested to be used as one of the management strategies to control the disease.

REFERENCES

Akbar A, Ahmad Z, Begum F, Ubairah and Raees N 2015. Varietal reaction of cucumber against cucumber mosaic virus. *American Journal of Plant Sciences* **6**: 833-838.

Anonymous 2020. *Package of Practices for Vegetable Crops*. Directorate of Extension, SKUAST-Jammu p 32.

Bananej K and Vahdat A 2008. Identification, distribution and incidence of viruses in field grown cucurbit crops of Iran. *Phytopathologia Mediterranea* **47**(3): 247-257.

Clark MF and Adams NA 1977. Characteristics of the microplate method of enzyme- linked immunosorbent assay for the detection of plant viruses. *Journal of General Virology* **34**: 475-83.

Doolittle SP 1916. A new infectious mosaic disease of cucumber. *Phytopathology* **6**: 145-147.

Hasan and V and Shams-bakhsh M 2017. Identification of viruses infecting cucurbits and determination of genetic diversity of cucumber mosaic virus in Lorestan province, Iran. *Journal of Plant Protection Research* **57**(2): 91-100.

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Khan MS, Hoque MI, Sarker RH and Muehlbach HP 2003. Detection of important plant viruses in in vitro regenerated potato plants by double antibody sandwich method of ELISA. *Plant Tissue Culture* **13**: 21-29.

Munshi AD, Panda B, Mandal B, Bisht IS, Rao ES and Kumar R 2008. Genetics of resistance to cucumber mosaic virus in *Cucumis sativus* var. Hardwickii R. Alef. *Euphytica* **164**: 501-507.

Nault LR 1997. Arthropod transmission of plant viruses: A new synthesis. *Annals of Entomological Society of America* **90**: 521-541.

Palukaitis P and Garcia-Arenal F 2003. Biophysical characterization, host range and transmission studies of cucumber mosaic virus. *The Bioscan* **8**(2): 437-44.

Shafiquique 2009. *Screening of Cucumber Varieties/Lines against CMV its Epidemiology and Management.* M.Sc. Thesis, Department of Plant Pathology, University of Agriculture Faisalabad, Pakistan.

Shah H, Yasmin T, Fahim M, Hmeed S, Haque IU, Munir M and Khanzada KA 2011. Reaction of exoctic and indigenous capsicum genotypes against Pakistan isolates of chilli veinal mottle virus. *Pakistan Journal of Botany* **43**: 1707-1711.

Shetti P, Peter A and Jingade P 2012. Serological and molecular detection of an isolate of cucumber mosaic virus (CMV) infecting cucumber (*Cucumis sativus* L.) and cloning of its coat protein gene. *Journal of Biochemical Technology* **3**(5): S198-S202.

Suresh LM, Malathib VG and Shivannac MB 2013. Serological diagnosis and host range studies of important viral diseases of a few cucurbitaceous crops in Maharashtra, India. *Archieves of Phytopathological Plant Protection* **46**: 1919-1930.

Tejashwani NK, Ambika DS, Basavarajappa MP, Venkateshalu, Rudresh DL and Shashikanth E 2019. Occurrence of cucumber mosaic virus (CMV) in cucumber (*Cucumis sativus L.*) growing areas of bagalkot district of Karnataka. *Research Journal of Plant Pathology* **2**(1): 10.

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Standardization and Evaluation of Coloured Sticky Traps and their Height against Onion Thrips (*Thrips tabaci* L.)

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Abstract: Onion (*Allium cepa* L.), a highly commercial vegetable crop, witnesses significant yield loss by onion thrips (*Thrips tabaci* L.) in the context. The field experiment was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) in rabi 2019-20 to evaluate the efficacy of colour and height of sticky traps in mitigating the population of *T. tabaci* on onion under open field conditions. Four different coloured sticky traps (yellow, blue, green and white) were installed at four different heights (25, 50, 75 and 100 cm) in 15th standard week. Yellow sticky traps had highest efficacy in attracting the population of onion thrips followed by blue, green and white traps, respectively. The traps installed at 75cm above ground had highest efficacy in attracting the maximum population of onion thrips followed by traps installed at 100, 50 and 25cm, respectively.

Keywords: Onion, *Allium cepa*, *Thrips tabaci*, Coloured sticky traps, Standardization

Onion (*Allium cepa* L.), belonging to family Amaryllidaceae, is a highly prized vegetable crop consumed in almost every household throughout the globe (Gopal 2015, Hafeez et al 2016). However, a large magnitude of insect pest is the major impediment in causing economic damage in terms of qualitative and quantitative loss from seedling up to harvesting stage in the successful cultivation of onion. Among various insect pests, thrips, *Thrips tabaci* L. (Thysanoptera: Thripidae) is a major pest of onion that damages the crop in almost all the growth stages. *T. tabaci* is a polyphagous pest and is known to damage other important agricultural and horticultural crops (Daine and Daniel 2008, Mohan et al 2016). In last two decades, this pest has become a serious concern in onion in almost all agro-climatic zones of the world (Diaz-Montano et al 2011, Al-Karboli and Al-Anbaki 2014). The damage is inflicted by both nymphs and adults of *T. tabaci* which reduce the crop production and productivity by sucking the plant sap and thus develop silvery areas on the affected plant parts. They cause significant yield loss ranging from 34 to 59 per cent (Waiganjo et al 2008, Nault and Shelton 2008, Diaz-Montano et al 2011). Malik et al (2004) recorded decline in onion yield from 11500 to 4406 kg/ha when mean number of thrips increased from 5.41 to 11.77 thrips per plant, respectively. Besides, thrips also cause indirect damage to crop by transmitting lethal plant virus belonging to different genera like sobemovirus, tospovirus, ilavirus, carmovirus and machlomovirus (Kritzman et al 2001, Hsu et al 2010). To manage *T. tabaci* on onion, farmers make repeated application of insecticides, more often from the same class, that remains persistent in the environment for a long period of time. However, this practice leads to several concerning issues like pest resistance, secondary pest outbreak, environmental contamination, biomagnification of pesticide residues and disturbance in normal ecosystem functioning. Therefore, the non-chemical management of insect pests should be adopted to avoid the emerging pesticide problems and this could be done by reliance of farmers on management practices that are non-toxic to non-target organisms and are ecofriendly at the same time. Therefore, keeping in view the importance of onion crop and the adverse effect of pesticide application to control onion thrips, the present research was carried out to evaluate the effect of sticky traps in managing the population of *T. tabaci* on onion.

MATERIAL AND METHODS

A field experiment was conducted at SKUAST-K in rabi season, 2019-20. The seeds of onion variety “Yellow Globe” were sown in mid-October in the nursery bed of 1x3 m under greenhouse conditions. The onion seedlings were transplanted in the field during November, 2019 as per the package of practices recommended by SKUAST-K. The plot size was 3x3 m^2 with five replications. The distance from row to row and plant to plant was maintained at 15cm x 30 cm, respectively. In first experiment, four sticky cards *viz*., yellow, green, blue and white (Pheromone chemicals Hyderabad, Telangana, India) of size 12x10 cm were placed at a height of 70 cm from the ground level in onion field in 15th standard week to evaluate the attractiveness of thrips to different trap colors. In another experiment, four different coloured sticky traps (yellow, blue, green and white) were installed at four different heights (25cm, 50cm, 75cm and 100 cm) above the ground to evaluate the appropriate height for sticky trap installation for checking *T. tabaci* population. The data was collected at weekly intervals from commencement of thrips in the onion field till harvest of the crop. The number of thrips/card/week were recorded as total catch per card. The thrips stuck on the traps were counted using 10 x lens at weekly intervals. Ten such counts were made during the entire cropping period and average number of thrips captured was analyzed statistically.

Statistical analysis: The weekly data on thrips in different types of sticky traps were counted in all the replications separately throughout the cropping season. Further, the data was subjected to Tukey HSD test by using SPSS 20.0 IBM pack to draw valuable inferences.

RESULTS AND DISCUSSION

Colour of traps: The maximum population of *T. tabaci* was attracted to yellow coloured sticky traps (32.38 thrips/trap) after 70th day of installation of traps in the field. It was followed by blue (21.64 thrips/trap) and green coloured sticky traps (15.02 thrips/trap). However, white coloured sticky traps were least effective in attracting the population of *T. tabaci,* (8.66 thrips/trap after 70 days of installation of traps) (Table 1). The results are in agreement with Gharekhani et al (2014) where maximum population of *T. tabaci* was attracted to yellow sticky traps followed by blue and white coloured traps, respectively. Similarly, Demirel and Cranshaw (2005) reported that neon yellow coloured sticky traps had highest efficacy in attracting *T. tabaci* and *Frankliniella occidentalis* while as blue and white coloured traps failed to attract any of the *Thrips* species on *Brassica* sp. The highest efficacy of yellow sticky traps against *T. tabaci* has also been reported by Demirel and Yildirim (2008) on cotton and Jenser et al (2001) on tobacco. Other species of thrips have also revealed their strong affinity towards yellow traps such as *Scirtothrips perseae* on avocado (Hoddle et al 2002) and *Thrips calcaratus, Taeniothrips in-cortsequem, Neohydatothrips tiliae* on deciduous forests (Rieske and Raffa 2003).

Height of traps: The efficiency of height of yellow, blue, green and white sticky traps against *T. tabaci* was evaluated in rabi 2019-20 (Fig. 1). The perusal of the collected data revealed that yellow sticky traps installed at 75cm from the ground had maximum effectiveness in attracting the population of *T. tabaci* (32.48 thrips/trap) after 70 days of installation of traps. It was followed by 100, 50 and 25cm after 70th day of installation of yellow sticky traps. Similarly, blue sticky traps installed at 75 cm above ground recorded the maximum population of thrips followed by those installed at 100, 50 and 25 cm, respectively. The similar trend was observed in green and white sticky traps where the traps installed at 75cm from the ground attracted a greater number of thrips than the traps installed at 100, 50 and 25cm, respectively. The present results corroborate with Gharekhani et al (2014) where sticky traps installed at 70cm above ground surface attracted maximum population of immature and adult thrips as compared to the traps installed

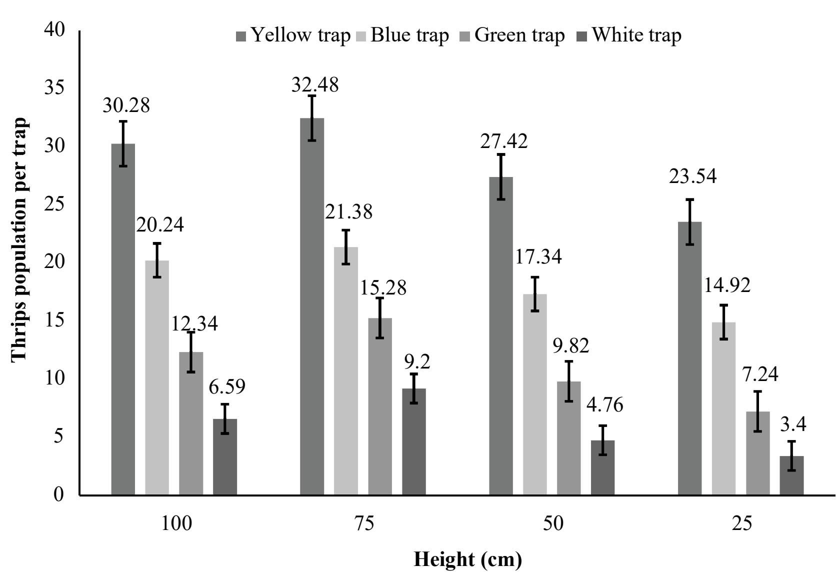

Fig. 1. Efficacy of height of different sticky traps against *T. tabaci* on onion (Mean ±standard error)

Table 1. Efficacy of different coloured sticky traps against *T. tabaci* in *rabi* 2019-20

Sticky trap	Thrips population/trap (days after installation of traps)									
	7	14	21	28	35	42	49l	56	63	70
White	0.40	1.80	3.20	4.80	9.60	12.80	17.80	14.80	12.00	9.40
Green	2.20	4.60	8.40	11.20	15.80	19.20	27.40	23.80	19.80	17.80
Yellow	4.60	12.60	17.80	26.00	37.40	42.60	52.40	47.00	43.20	40.20
Blue	2.40	3.80	9.60	16.60	23.00	28.60	40.60	35.40	29.40	27.00
CD (p=0.05)	1.10	2.99	1.73	2.01	2.65	2.92	1.99	2.47	2.31	2.71

at 100, 50 and 30cm above the ground. The sticky traps installed between 0.70 and 0.95m above the ground surface had highest efficacy in attracting *T. tabaci* population (Macintyre-Allen et al 2005). Mo et al (2008), after examining the congregation of thrips at various parts of the plant, reported that adults of onion thrips always congregate at upper parts rather than the lower parts of plant. The similar trend was observed in present findings where maximum population of adult thrips assembled on the sticky traps installed at 75-100cm above ground as compared to others.

CONCLUSION

The yellow sticky traps installed at 75cm above ground had highest efficacy in attracting the population of onion thrips. The traps should be installed right after transplanting the onion seedlings so that a continuous check is kept over the incidence of thrips in the field. However, sole reliance on yellow sticky traps to limit the population buildup of thrips on onion should not be advocated. Rather, integration of sticky traps with other components of location specific Integrated Pest Management should be followed wherein chemical application should only be done after proper surveillance programmes.

REFERENCES

Al-Karboli H and Al-Anbaki HA 2014. Efficacy of two sampling methods for monitoring, control and estimating seasonal abundance of onion thrips, *Thrips tabaci* Lindeman (Thripidae: Thysanoptera) on onion in Iraq. *International Journal of Agriculture Technology* **10**(1): 243-251.

Daine GA and Daniel D 2008. *Onion thrips (Thrips tabaci) fact sheet ENT-117- 08PR*. Utah Pests, Utah State University Extension and Utah Plant Pest Diagnostic Laboratory.

Demirel N and Cranshaw W 2005. Attraction of colour traps to *Thrips* species (Thysanoptera: Thripidae): A global pest of increasing concern in onion. *Journal of Economic Entomology* **104**: 1-13.

Demirel N and Yildirim AE 2008. Attraction of various sticky colour traps to *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) and *Empoasca decipiens* Paoli (Homoptera: Cicadellidae) in cotton. *Journal of Entomology* **5**: 389-394.

Diaz-Montano J, Fuchs M, Nault BA, Fail J and Shelton AM 2011. Onion thrips (Thysanoptera: Thripidae): A global pest of increasing concern in onion. *Journal of Economic Entomology* **104**(1): 1-13.

Received 22 August, 2022; Accepted 15 September, 2022

Gharekhani GH, Ghorbansyahi S, Saber M and Bagheri M 2014. Influence of the colour and height of sticky traps in attraction of *Thrips tabaci* (Lindeman) (Thysanoptera, Thripidae) and predatory thrips of family Aeolothripidae on garlic, onion and tomato crops. *Archives of Phytopathology and Plant Protection* **47**(18): 2270-2275.

Gopal J 2015. Onion research in India: Status and challenges. *Progressive Horticulture* **47**(1): 1-19.

Hafeez OBA, Amjad M, Ziaf K and Ahmad A 2016. Evaluation of low-cost irrigation methods for enhanced onion productivity under semi-arid climate of Pakistan. *Pakistan Journal of Agricultural Science* **53**(4): 947-953.

Hoddle MS, Robinson L and Morgan D 2002. Attraction of thrips (Thysanoptera: Thripidae and Aeolothripidae) to coloured sticky cards in a California Avocado orchard. *Crop Protection* **21**: 383-388.

Hsu CL, Hoepting CA, Fuchs M, Shelton AM and Nault BA 2010. Temporal dynamics of *Iris yellow spot virus* and its vector, *Thrips tabaci* (Thysanoptera: Thripidae), in seeded and transplanted onion fields. *Environmental Entomology* **39**(2): 266-277.

Jenser G, Szénási Á and Zana J 2001. Investigation on the colour preference of *Thrips tabaci* Lindeman (Thysanoptera: Thripidae). *Acta Phytopathologica et Entomologica Hungarica* **36**: 207-211.

Kritzman A, Lampel M, Raccah B and Gera A 2001. Distribution and transmission of *Iris yellow spot virus*. *Plant Disease* **85**(8): 838-842.

Malik MF, Nawaz M and Hafeez Z 2004. Evaluation of promising onion (*Allium cepa*) varieties against thrips infestation in the Agro-ecosystem of Balochistan, Pakistan–II. *Journal of Entomology* **1**(1): 47-49.

Macintyre-Allen JK, Scott-Dupree CD, Tolman JH and Harris CR 2005. Evaluation of sampling methodology for determining the population dynamics of onion thrips (Thysanoptera: Thripidae) in Onatro onion fields. *Journal of Economic Entomology* **98**(6): 2272-2281.

Mo J, Munro S, Boulton A and Stevens M 2008. Within-plant distribution of onion thrips (Thysanoptera: Thripidae) in onions. *Journal of Economic Entomology* **101**: 1331-1336.

Mohan C, Muthuram T, Yoganathan G and Arivudainambi S 2016. Evaluation of different colour sticky trap on mass trapping of onion thrips *tabaci* (Lindeman). *International Journal of Research in Applied Natural and Social Science* **4**(11): 93-98.

Nault BA and Shelton AM 2010. Insecticide efficacy and timing of sprays for onion thrips control, pp.52-56. **In**: Proceedings of *Empire State Fruit and Vegetable Expo*, February 12-14, 2008, Syracuse, New York.

Rieske LK and Raffa KF 2003. Evaluation of visual and olfactory cues for sampling three thrips species (Thysanoptera: Thripidae) in deciduous forests of northern United States. *Journal of Economic Entomology* **96**: 777-782.

Waiganjo M, Mueke JM and Gitonga LM 2008. Susceptible onion growth stages for selective and economic protection from onion thrips infestation. *African Journal of Horticultural Science* **1**: 82-90.

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Promotion of Natural Resource Management Technologies Through Frontline Demonstrations in Rice-Wheat Rotation in Punjab

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Abstract: Findings of the frontline demonstrations revealed that happy seeder sown wheat gave a similar yield to the conventional sown wheat and had a lower cost of cultivation resulting in higher economic returns. In the case of direct seeded rice, it resulted in a lower yield than the transplanted rice and a further lower cost of cultivation, also. So direct seeded rice also resulted in higher economic returns as compared to the transplanted rice.

Keywords: Happy seeder, Direct seeded rice, Groundwater, Stubble, Burning

Punjab state experienced remarkable growth in agriculture due to the success of the green revolution. The early success of the Green Revolution in Punjab prompted the Government of India to target the state as a source of rice and wheat for the national food procurement and distribution system, at a guaranteed price. Subsequently, the state government of Punjab provided electricity for agricultural pumping at a flat rate, irrespective of the quantity of groundwater used. These two factors led to the establishment of a rice-wheat annual crop rotation. (Sharma et al 2012). The heavy reliance on inputs resulted in a slew of issues related to the sustainability of agriculture (Balkrishna et al 2022). With the advancement in mechanization, combine harvesters became popular among the farmers for the harvesting of rice and wheat, which causes the huge amount of rooted and uprooted remains of these crops in the field. Wheat stubble is used as animal fodder by farmers, but due to its high silica content, paddy stubble is not much popular for animal feed. On the other hand, the collection of loose paddy straw from the field is very costly and laborious that can delay the wheat sowing(Roy et al 2018). Thus, paddy straw management and sowing of wheat in this short time window is a challenging task for farmers resulting in the burning of paddy stubble in Punjab at the mass level and it causes the air pollution at a hazardous level during the early winters every year (Lohan et al 2018, Ravindra et al 2019, Keil et al 2020). The rice wheat rotation also demands a large amount of water which has been met by exploiting groundwater resources. The quantity and quality of underground water in the state are declining. Groundwater irrigation is a bigger source of irrigation today with a significant gain in its coverage area in the past four decades due to an increase in the number of tube wells (Balkrishna et al 2022). To meet the water demand in Punjab, 35.78 BCM of water is being withdrawn every year having an availability of only 21.58 BCM, leading to the 166 per cent extraction rate as a percentage of total percolation and at such withdrawal rate, groundwater resources of Punjab are likely to be used in 20-25 years (Anonymous 2018). Thus, the rice-wheat crop rotation has negative consequences on the natural resources of Punjab in terms of groundwater depletion, air pollution and loss of soil micro-organisms. To curb the problem of natural resource depletion, policymakers and researchers are trying to find suitable solutions. Among the various solutions, happy seeder for the sowing of wheat in standing stubble and direct seeded rice are the potential candidates. PAU adopted two villages in the Sangrur district of Punjab to evaluate the performance of these FLDs on happy seeder and direct seeded rice (DSR).

MATERIAL AND METHODS

Two villages Chatha Nanhera and Tranji Khera in district Sangrur were selected to evaluate and popularize the sustainable resource conservation technologies; with 1000 frontline demonstrations (FLDs) of happy seeder sown wheat for in-situ management of paddy stubble and 300 demonstrations of direct seeded rice were conducted from the year 2017-18 to 2021-22 (Fig. 1). The area under each demonstration was 0.4 hectare.

The necessary steps for selection of site, selection of farmers, the layout of demonstrations etc. were followed as suggested by Choudhary (1999) and Venkatasubramanian et al (2009). Farmers were provided with the trainings as per requirement and guidance through the field visits from time to time. The performance of FLDs was evaluated by comparing these with their counterfactuals i.e. happy seeder sown wheat with conventionally sown wheat and direct seeded rice with transplanted rice. Data regarding yield, cost of cultivation, and returns were collected for the FLDs and check plots. B:C ratio was calculated using the net returns and cost of cultivation.

RESULTS AND DISCUSSION

Performance of FLDs on happy seeder sown wheat: The happy seeder sown wheat gave a similar yield to conventional sown wheat (Fig. 2). In 2021-22, the wheat yield of wheat was reduced due to the heat wave, and the yield reduction in the happy seeder sown wheat was lesser than conventional sown wheat. The maximum yield was obtained in the year 2019-20, which was 56.85 q/ha. As happy seeder replaces the multiple operations (cultivating, planking, sowing) with a single operation i.e. direct sowing of wheat in standing stubbles, thus it was hypothesized to save the cost of cultivation in wheat. The findings revealed that the cost of cultivation can be reduced with the happy seeder. The saving in cost of cultivation ranged from Rs. 4346 per ha to Rs. 6785 per ha (Table 1). Further due to comparable or higher yield, happy seeder sown wheat also resulted in higher gross returns and ultimately higher net returns. The maximum increase in net returns was seen in the year 2021-22, which was Rs. 12507 per ha. As the result, happy seeder sown wheat has a higher benefit-to-cost ratio in all years.

Performance of FLDs on direct seeded rice: In order to sensitize the farmers regarding water saving, frontline demonstrations of direct seeded rice were also conducted in the project villages. There was no specific trend inthe yield of direct seeded rice and transplanted rice (Fig. 3). In the year 2017-18, 2018-19 and 2021-22, FLDs on direct seeded rice resulted in the lower yield than transplanted rice,

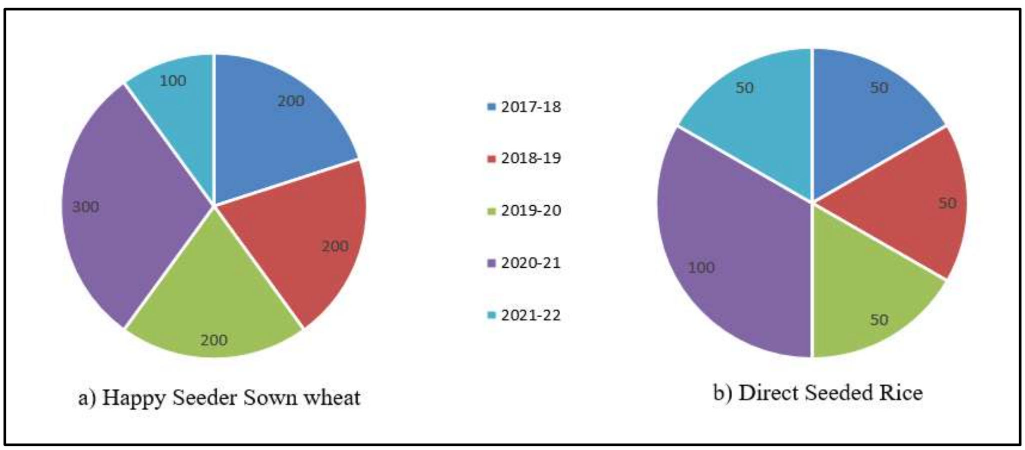

Fig. 1. Year-wise number of demonstrations of a) Happy seeder sown wheat b) Direct seeded rice

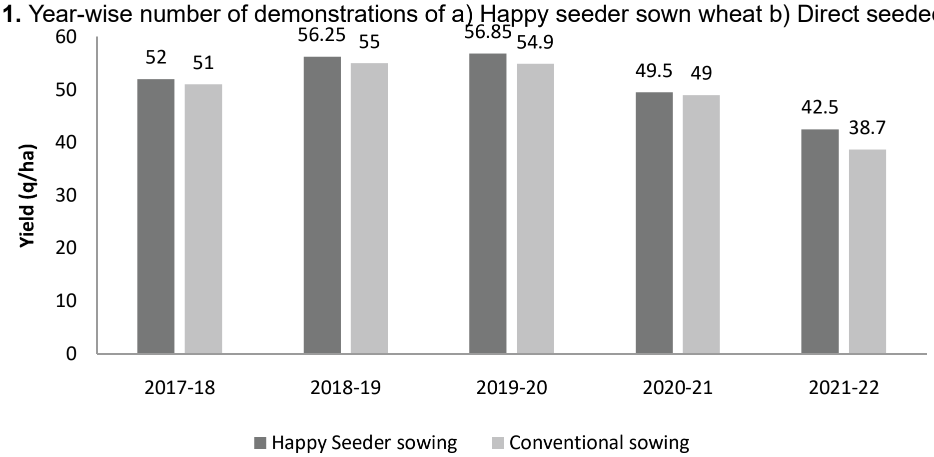

Fig. 2. Yield performance of happy seeder sown wheat vs conventionally sown wheat

whereas in the year 2019-20 and 2020-21, the yield obtained from the FLDs on direct seeded rice was higher than the transplanted rice. The maximum increase in yield of direct seeded rice over transplanted rice was observed in the year 2019-20, whereas maximum reduction was observed in the year 2021-22. The direct seeded rice saved

Table 1. Economic analysis of FLDs on happy seeder sown wheat

Particulars	Happy seeder sowing	Conventional sowing	Change
2017-18			
Cost of cultivation (Rs/ha)	21068	25414	-4346
Gross returns (Rs/ha)	90146	87971	+2174
Net returns (Rs/ha)	69078	62557	+6521
B.C ratio	3.28	2.46	+0.82
2018-19			
Cost of cultivation (Rs/ha)	22508	27325	-4818
Gross returns (Rs/ha)	103500	101200	+2300
Net returns (Rs/ha)	80993	73875	+7118
B.C ratio	3.60	2.70	+0.89
2019-20			
Cost of cultivation (Rs/ha)	22680	27845	-5165
Gross returns (Rs/ha)	104250	102230	+2020
Net returns (Rs/ha)	81570	74385	+7185
B.C ratio	3.60	2.67	+0.93
2020-21			
Cost of cultivation (Rs/ha)	23745	30530	-6785
Gross returns (Rs/ha)	97763	96775	+988
Net returns (Rs/ha)	74018	66245	+7773
B.C ratio	3.12	2.17	+0.95
2021-22			
Cost of cultivation (Rs/ha)	31400	36250	-4850
Gross returns (Rs/ha)	85638	77981	+7657
Net returns (Rs/ha)	54238	41731	+12507
B.C ratio	1.73	1.15	+0.58

Table 2. Economic analysis of FLDs on direct seeded rice

Particulars	Direct seeded rice	Transplanted rice	Change
2017-18			
Cost of cultivation (Rs/ha)	25380	32474	-7094
Gross returns (Rs/ha)	115217	116713	-1496
Net returns (Rs/ha)	89837	84239	+5598
B.C ratio	3.54	2.59	+0.95
2018-19			
Cost of cultivation (Rs/ha)	25420	32474	-7054
Gross returns (Rs/ha)	140280	140857.5	-577.5
Net returns (Rs/ha)	114860	108383.5	+6476.5
B.C ratio	4.52	3.33	+1.19
2019-20			
Cost of cultivation (Rs/ha)	26114	32326	-6212
Gross returns (Rs/ha)	141082	137984	+3098
Net returns (Rs/ha)	114968	105658	+9310
B.C ratio	4.40	3.27	+1.13
2020-21			
Cost of cultivation (Rs/ha)	29680	37514	-7834
Gross returns (Rs/ha)	144583	142902	+1681
Net returns (Rs/ha)	115903	107069	+8834
B.C ratio	4.81	3.81	+1.00
2021-22			
Cost of cultivation (Rs/ha)	37000	44450	-7450
Gross returns (Rs/ha)	153066	156364	-3298
Net returns (Rs/ha)	116066	111914	+4152
B.C ratio	3.14	2.52	+0.62

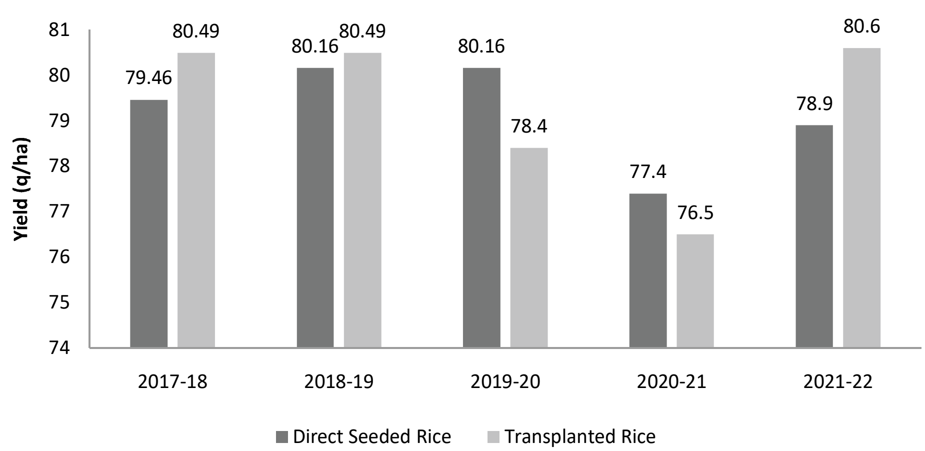

Fig. 3. Yield performance of direct seeded rice vs transplanted rice

the cost of cultivation in rice. The saving ranged from Rs. 6212 per ha in 2019-20 to Rs. 7450 per ha in the year 2021-22. The saving in the cost of cultivation in direct seeded rice was due to the labour cost for transplanting although expenses on the herbicides increase to some extent in DSR. The gross returns in DSR were also slightly lower than the transplanted rice in the year 2017-18, 2018-19 and 2021-22 due to lower yield, whereas higher in the remaining years. Due to large savings in the cost of cultivation, FLDs on DSR proved to fetch higher net returns in all years resulting in a higher benefit-to-cost ratio for DSR as compared to transplanted rice.

CONCLUSION

Happy seeder technology and direct seeded rice are the potential solutions to curb the problem of air pollution and groundwater depletion in Punjab, respectively. The happy seeder sown wheat had similar or higher yield and ultimately higher economic returns than the conventionally sown wheat. Direct seeded rice had a slightly lower yield, but due to the low cost of cultivation, it also resulted in higher economic returns. Thus, these technologies can also offer significant economic returns along with the conservation of natural resources.

REFERENCES

Anonymous 2018. *Groundwater resources of Punjab state*. Draft report. Water Resources & Environment Directorate, Water Resources Department, Punjab, Mohali and Central Ground Water Board North Western Region Chandigarh. Retrieved from https://dswcpunjab.gov.in/contents/docs/publications/Draft%20Report%20Punjab%20Groundwater%20Resources%202017.pdf on 25.07.2022

Balkrsihna A, Sharma G, Sharma N, Rawat N, Kumar A and Arya V 2022. Transition of agriculture from gloriuos past to challenging future: A serious concern. *Indian Journal of Ecology* **49:** 977-986.

Choudhary BN 1999. *Krishi Vigyan Kendra: A guide for KVK managers*. pp. 73-78. Division of Agricultural Extension, ICAR, New Delhi, India.

Keil A, Krishnapriya PP, Mitra A, Jat ML, Sidhu HS, Krishna VV and Shyamsundar P 2020. Changing agricultural stubble burning practices in the Indo-Gangetic plains: Is the Happy Seeder a profitable alternative? *International Journal Agricultural Sustainability* **19**: 128-151.

Lohan SK, Jat HS, Yadav AK, Sidhu HS, Jat ML, Choudhary M, Peter JK and Sharma PC 2018. Burning issues of paddy residue management in north-west states of India. *Renewable and Sustainable Energy Reviews* **81**: 693-706.

Ravindra K, Singh T and Mor S 2019. Emissions of air pollutants from primary crop residue burning in India and their mitigation strategies for cleaner emissions. *Journal of Cleaner Production* **208**: 261-273.

Roy P, Kaur M, Burman RR, Sharma JP and Roy TN 2018. Determinants of paddy straw management decision of farmers in Punjab. *Journal of Community Mobilization Sustainable Development* **13**: 203-210.

Sharma P, Krishnamurthy CK, Sidhu RS, Vatta K, Kaur B, Modi V, Fishman R, Polycarpou L and Lall U 2012.*Columbia water center white paper- Restoring groundwater in Punjab, India's bread basket:* Finding agricultural solution for water sustainability.

Venkatasubramanian V, Sajeev MV and Singha AK 2009. *Concepts, approaches and methodologies for technology application and transfer: A resource book for KVKs*. Pp 83-98. Zonal Project Directorate, Zone – III Indian Council of Agricultural Research, Umiam, Meghalaya.

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Impact of Integrated Nutrient Management on Seed Quality of Field Pea During Ambient Storage

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Abstract: The experiment was conducted at CCS, Haryana Agriculture University, Hisar, Haryana from 2016-18 and encompassed of nineteen treatment amalgamations of biofertilizers viz., Rhizobium & PSB @50 ml/10 kg, FYM & Vermicompost @ 20 t/ha and 5 t/ha respectively and inorganic fertilizer viz., 20kg N, 40 kg P_2O_5 per ha. The newly harvested field pea seeds of complete nineteen treatment plot combinations were kept in plastic containers under normal room environments up to a period of fifteen months and seed quality was evaluated at a regular interval of five months. The treatment combination of Rhizobium and PSB along with 75% recommended dose of nitrogen showed significantly higher germination(88.33%), seedling length (26.60 cm), dry weight (0.41 g), vigour index-I (2350) and vigour index-II (36) followed by Rhizobium with 100% RDN after fifteen months of storage at room temperature as compared to control. The electrical conductivity 531 was minimal even after treatment with Rhizobium and PSB along with 75% RDN followed by Rhizobium with 100% RDN after a storage at room temperature, with maximum in the control group. This conjoint application of Rhizobium + PSB at 75% recommended dose of nitrogen performed best in terms of seed quality parameters viz., germination%, dry weight, seedling length, vigour index-I and II and electrical conductivity.

Keywords: Field pea, PSB, Nitrogen, Rhizobium, Storage

Integrated nutrient management helps maintaining soil fertility to an ideal level which is imperative to attain maximum advantage for crop productivity. Use of excessive nutrients leads to declination of nutrient-use effectiveness making fertilizer consumption inefficient and it create adversative impact on atmosphere (Aulakh and Adhya 2005) as well as groundwater excellence (Aulakh et al 2009). The inorganic fertilizer singly is detrimental to soil health and soil productivity, usage of organic and bio-fertilizers augments crop production and helps to maintain soil health (Akbari et al 2011). INM is a vital step to fulfill the twin concerns of nutrient surfeit and nutrient exhaustion (Sangeeta et al 2014). Keeping in view the increasing demand of pulses, there is a critical need to increase productivity. Quality seed has a major role in the agricultural production. The use of quality seeds may increase productivity of crop by 15-20% (Chauhan et al 2015). In field pea, seed quality decline due to many reasons which results in poor germination. One such reason of deterioration could be probably imbalanced mother plant nutrition (Maruthi and Paramesh 2016). In recent years, realized that seed yield and quality were better under organic as compared to inorganic fertilizers application. So, in order to improve the seed quality, better nutritional management practices are to be adopted. Integrated nutrient management holds great assurance in meeting the growing nutrient demands of intensive agriculture. The advantage of integrated nutrient management increases water holding capacity, amount of nutrients, resistance to diseases and make the soil able to withstand drought and also plays a great role in seed quality and storability. Considering these facts, the purpose of this study was to study the effect of integrated nutrient management on seed storage.

MATERIAL AND METHODS

The experiment was performed during 2015-17 at CCS Haryana Agriculture University, Hisar, Haryana. The freshly harvested seeds of the field pea variety “HFP 529” were kept in plastic containers under normal room environments up to a period of fifteen months. The seeds of each treatment plot were sampled at an interval of five months and evaluated for seed quality parameters in a completely randomized design. The biofertilizers, rhizobium and phosphorous solubilizing bacteria were used as seed treatment @50 ml/10 kg of seed while farm yard manure (FYM) and vermicompost were used @ 20 t/ha and 5 t/ha respectively. The recommended dose of fertilizers (RDF- 20kg N + 40 kg P2O5 + 0 kg K2O per ha) was applied to the plots as per the treatment details. The samples were analyzed for key characteristics viz. germination %, dry weight, seedling length, vigour index-I, vigour index-II and electrical conductivity. The OPAQUE tool is used for statistical analysis. Treatment details are given below in Table 1. The following parameters were tested on the seed obtained after adopting standard seed production and post-harvest practices.

Germination (%): One hundred seeds obtained from individual treatment plot in three replications were kept in between adequate moistened rolled towel papers (BP) and placed at 25^{0}C in seed germinator. On the 5th day first count was taken and final count was on 8th day. Only normal seedlings were measured for percent germination (ISTA2011).

Seedling length (cm): Seedling length of 10 arbitrarily selected normal seedlings was measured for germination test.

Dry weight (g): Seedling dry weight was evaluated for ten seedlings after the final count of the germination test (8 days). The seedlings of individual treatment were dried in a hot air oven for 24 h at 80±1^{0}C. The dried seedlings were weighed.

Vigour index I and II: Seedling vigour indices were calculated according to the method reported by (Abdul-Baki and Anderson1973).

a. Vigour index-I (on seedling length basis)= Standard Germination (%) X Average seedling length (cm)
b. Vigour Index–II (on seedling dry weight basis)= Standard Germination (%) X Average seedling dry weight (g)

Electrical conductivity (µS cm^{-1}g $^{-1}$): 50 healthy seeds in three replications were soaked in 75 ml distilled water. Seeds were immersed entirely in water and beakers were surrounded with foil. Subsequently, these samples were kept at 25°C for 24 h. The electrical conductivity of the seed leachates was recorded using a direct reading on conductivity meter and expressed in µS/cm/ gram.

RESULTS AND DISCUSSION

The germination percentage showed a significant decline subsequently five, ten and fifteen months of ambient storage. The maximum decline was after fifteen months of natural storage in all the treatment combinations. However, the maximum germination percentage (88.33) after fifteen months of ambient storage of field pea seed was observed in the treatment amalgamation of Rhizobium + PSB + 75% RDN and minimum (68) was recorded in control (Table 1).

Table 1. Effect of integrated nutrient management on standard germination (%) of field pea seeds stored at ambient condition

Treatments	Fresh seeds	5 months	10 months	15 months	Mean
T_0: Control	87.33	81.33	78.33	68.00	78.75
T_1: Rhizobium+FYM (100%)	93.00	91.33	87.00	81.33	88.17
T_2: Rhizobium+FYM (75%)	92.33	88.67	86.00	79.33	86.58
T_3: Rhizobium+Vermicompost (100%)	90.33	86.00	82.00	73.67	83.00
T_4: Rhizobium + Vermicompost (75%)	89.67	83.33	80.00	71.00	81.00
T_5: Rhizobium + Nitrogen (100%)	97.33	94.67	91.33	87.67	92.75
T_6: Rhizobium + Nitrogen (75%)	95.67	94.00	90.33	86.00	91.50
T_7: PSB+FYM (100%)	92.67	90.00	86.67	80.67	87.50
T_8: PSB+FYM (75%)	92.00	88.33	85.00	78.00	85.83
T_9: PSB+ Vermicompost (100%)	90.00	85.00	80.33	71.67	81.75
T_{10}: PSB+ Vermicompost (75%)	89.00	83.00	79.67	70.33	80.50
T_{11}: PSB+ Nitrogen (100%)	96.67	94.33	91.00	87.00	92.25
T_{12}: PSB+ Nitrogen (75%)	94.33	92.33	88.33	83.67	89.67
T_{13}: Rhizobium +PSB+100% FYM	95.00	93.33	89.33	85.33	90.75
T_{14}: Rhizobium +PSB+75% FYM	94.67	93.00	89.00	84.67	90.33
T_{15}: Rhizobium+PSB+100% Vermicompost	91.67	88.00	84.33	77.00	85.25
T_{16}: Rhizobium+PSB+75% Vermicompost	91.33	87.33	83.00	75.33	84.25
T_{17}: Rhizobium +PSB+75% Nitrogen	97.67	95.33	91.67	88.33	93.25
T_{18}: RDF	93.33	92.00	87.67	82.67	88.92
Mean	92.46	88.87	85.22	78.59	
CD (p=0.05)					
Treatments 0.536					
Storage 0.224					
Treatment X Storage 1.072					

RDF- 20kg N, 40 kg P_2O_5 per ha, Rhizobium- 50 ml/10 kg, PSB- 50 ml/10 kg, Nitrogen 100%- 20 kg/ha

The higher germination percentage in T_{17} during the period of natural storage might be because of the better accumulation of food reserves like protein and carbohydrates due to the inoculation of biofertilizers along with nitrogen at the time of seed development. There was decline in germination percent in all the nutrient combinations because of natural ageing irrespective of treatment leading to seed deterioration. These results are in accordance with that of Amjad and Arjun (2002), Khan et al (2013) and Singh et al (2015).

Seedling length and dry weight of all the treatment combinations showed a significant decrease with the advancement of ageing period and the highest decline in both the characters was observed after fifteen months of natural storage (Table 2). The highest seedling length (26.60) after fifteen months of ambient storage was with the application of Rhizobium + PSB + 75% RDN while the shortest was recorded in control (13.37cm). The highest dry weight after fifteen months of natural ageing in both the treatment combination of Rhizobium + PSB + 75% RDN and Rhizobium + 100% RDN (0.41) followed by PSB + 100% RDN (0.40) and the lowest was observed in control (0.22) (Table 3). Among all the treatments T_{17} and T_5 showed better seedling length and dry weight throughout storage. This might be due to the buildup of more quantities of seed elements like carbohydrates in the seed due to the nutrition of field pea plants by the co-inoculation of Rhizobium and PSB along with inorganic nitrogen and conversion of macromolecules into micromolecules due to release of certain enzymes (Yadav and Khurana 2005). Decline in seedling length and seedling dry weight during storage may be due to decline in utilization of reserve constituents during germination of the stored seeds (Dhakal and Pandey 2001). Ageing led to reduce in seedling length and seedling dry weight which is similar with findings of earlier researchers(Verma et al2003, Singh et al 2003 , Nagarajan et al 2004, Kumar and Verma 2008).

Vigour index -I and Vigour index -II declined significantly with the increase in period of ageing in all the nineteen treatment combinations of field pea seed (Fig. 1and 2). The vigour index-I and II after the fifteen months of natural ageing was maximum in Rhizobium + PSB + 75% RDN (2350 and minimum in control (909, 15). Similar results were reported

Table 2. Effect of integrated nutrient management on seedling length (cm) of field pea seeds stored at ambient condition

Treatments	Fresh seeds	5 months	10 months	15 months	Mean
T_0	23.37	22.07	17.10	13.37	18.98
T_1	28.93	26.90	23.90	21.17	25.23
T_2	27.87	25.70	22.20	19.80	23.89
T_3	26.17	24.07	19.07	16.97	21.57
T_4	25.80	23.90	18.90	16.20	21.20
T_5:	31.50	30.20	28.40	26.50	29.15
T_6	30.70	28.60	26.63	24.60	27.63
T_7	28.40	26.20	22.70	20.30	24.40
T_8	27.33	25.50	21.43	18.90	23.29
T_9	26.03	24.03	19.03	16.63	21.43
T_{10}	25.43	22.87	17.90	15.80	20.50
T_{11}	31.27	29.83	27.27	25.10	28.37
T_{12}	29.90	27.70	25.20	22.80	26.40
T_{13}	30.43	28.23	26.10	23.90	27.17
T_{14}	30.03	28.07	25.33	23.27	26.68
T_{15}	27.00	25.20	21.40	18.67	23.07
T_{16}	26.60	24.30	19.90	17.80	22.15
T_{17}	32.17	30.83	28.67	26.60	29.57
T_{18}	29.33	27.07	24.03	21.80	25.56
Mean	28.02	26.07	22.46	20.04	
CD (p=0.05)					
Treatments	0.148				
Storage	0.062				
Treatment X Storage	0.296				

See Table 1 for details

by Kumar and Verma (2008) and Singh et al (2015).

The alteration of electrical conductivity throughout seed soaking is usually used as an indicator for testing the integrity of plasma membrane. Electrical conductivity (µS/cm/g) of seed leachates enlarged significantly after ageing in every treatment combination of field pea (Table 4). The maximum electrical after fifteen months of ambient storage conductivity was in control (996 µS/ cm/g) while minimum (531 µS/cm/g) was in Rhizobium + PSB + 75% RDN. The better performance in T_{17} and T_5 may be due to the inoculation of biofertilizers along with the inorganic nitrogen which may have increased the cell membrane stability and decreased the leakage of solutes from the seeds because of availability of more nutrients for the growth of plant and seed development which ultimately led to intact seed coat (Namvar et al 2013). The increase in electrical conductivity

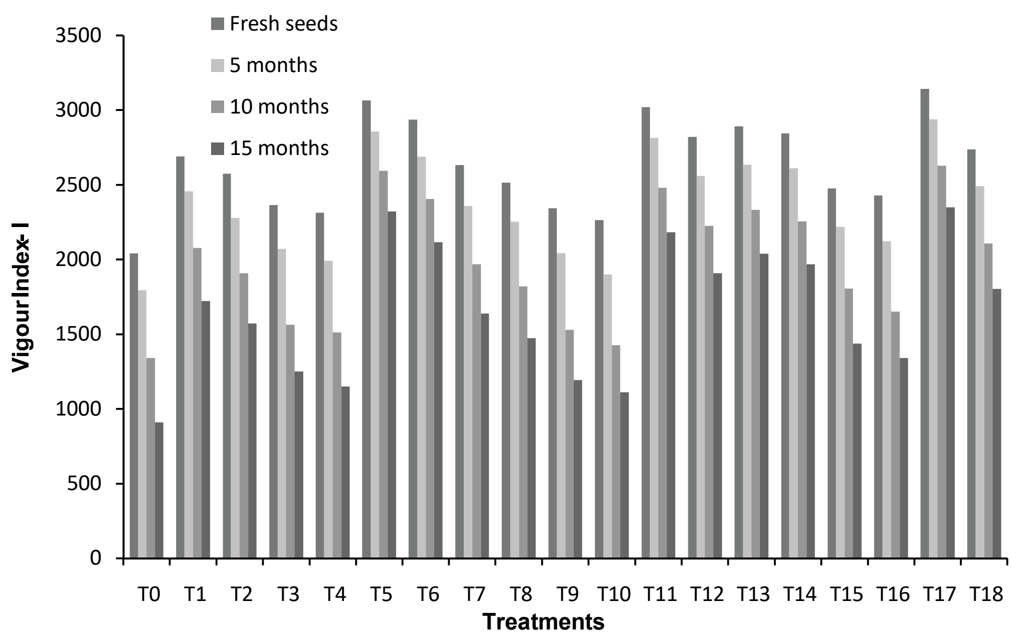

Fig. 1. Effect of integrated nutrient management on vigour index-I of field pea seeds stored at ambient condition

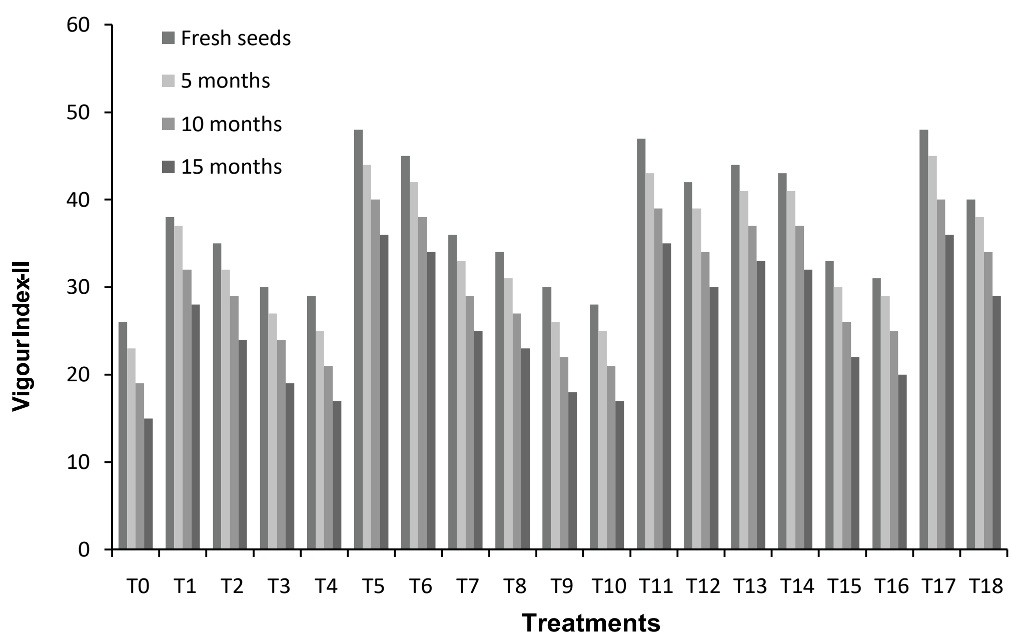

Fig. 2. Effect of integrated nutrient management on vigour index-II of field pea seeds stored at ambient condition

Table 3. Effect of integrated nutrient management on seedling dry weight (g) of field pea seeds stored at ambient condition

Treatments	Fresh seeds	5 months	10 months	15 months	Mean
T_0	0.30	0.28	0.25	0.22	0.26
T_1	0.41	0.40	0.37	0.34	0.38
T_2	0.38	0.36	0.33	0.30	0.34
T_3	0.34	0.32	0.29	0.26	0.30
T_4	0.32	0.30	0.27	0.24	0.28
T_5:	0.49	0.47	0.44	0.41	0.45
T_6	0.47	0.45	0.42	0.39	0.43
T_7	0.39	0.37	0.34	0.31	0.35
T_8	0.37	0.35	0.32	0.29	0.33
T_9	0.33	0.31	0.28	0.25	0.29
T_{10}	0.32	0.30	0.27	0.24	0.28
T_{11}	0.48	0.46	0.43	0.40	0.44
T_{12}	0.45	0.42	0.39	0.36	0.41
T_{13}	0.46	0.44	0.41	0.38	0.43
T_{14}	0.46	0.44	0.41	0.38	0.42
T_{15}	0.36	0.34	0.31	0.28	0.32
T_{16}	0.34	0.33	0.30	0.27	0.31
T_{17}	0.49	0.47	0.44	0.41	0.45
T_{18}	0.43	0.41	0.38	0.35	0.39
Mean	0.39	0.37	0.34	0.31	
CD (p=0.05)					
Treatments	0.020				
Storage	0.008				
Treatment X Storage	NS				

See Table 1 for details

Table 4. Effect of integrated nutrient management on electrical conductivity (µS $cm^{-1}g^{-1}$) of field pea seeds stored at ambient condition

Treatments	Fresh seeds	5 months	10 months	15 months	Mean
T_0	511	793	914	996	804
T_1	327	555	710	834	607
T_2	346	602	723	859	633
T_3	414	739	869	924	737
T_4	448	758	881	939	757
T_5:	233	378	455	558	406
T_6	289	412	523	641	466
T_7	334	589	718	846	622
T_8	373	656	770	886	671
T_9	433	742	878	932	746
T_{10}	458	762	887	946	763
T_{11}	257	391	465	571	421
T_{12}	312	538	688	798	584
T_{13}	304	427	538	652	480
T_{14}	311	470	584	698	516
T_{15}	401	724	846	896	717
T_{16}	412	738	855	913	730
T_{17}	206	347	434	531	380
T_{18}	326	552	700	813	598
Mean	362	602	720	812	
CD (p=0.05)					
Treatments	1.781				
Storage	0.743				
Treatment X Storage	3.562				

See Table 1 for details

during the period of ageing is because of the increase of leakage due to changes in the membranes of aged deteriorated seeds which directed to electrolyte leakage. The loss of membrane integrity due to destruction of phospholipids leads to increased membrane permeability and release of electrolytes, amino-acids and enzymes from cells (Zamani et al 2010). Similar results were also reported earlier by Goel et al2003 and Kumari et al2014.

CONCLUSION

The conjoint application of *Rhizobium* + PSB at 75% recommended dose of nitrogen (RDN) performed best in terms of seed quality parameters viz., germination%, dry weight, seedling length, vigour index-I and II and electrical conductivity. The experiment emphasized that to some extent reduced dose of inorganic nitrogen was best when applied in combination with bio-fertilizer (Rhizobium+PSB) for improving the storage potential of field pea seed as compared to the rest of treatments.

REFERENCES

Abdul-Baki AA and Anderson JD 1973. Vigour determination in soybean by multiple criteria. *Crop Science* **10**: 31-34.

Akbari KN, Ramdevputra, MV, Sutaria GS, Vora, VD and Padmani DR 2011. Effect of organics, bio and inorganic fertilizer on groundnut yield and its residue effect on succeeding wheat crop. *Legume Research* **34**: 45-47.

Amjad M and Anjum MA 2002. Effect of relative humidity and ageing period on the quality of onion seed. *International Journal of Agriculture and Biology* 4:291-296.

Aulakh MS and Adhya TK 2005. Impact of agricultural activities on emission of greenhouse gases- Indian perspective, pp. 319-335. In: *International Conference on Soil, Water and Environmental Quality: Issues and Strategies*, Indian Society of Soil Science: New Delhi.

Aulakh MS, Khurana MPS and Singh D 2009. Water pollution related to agricultural, industrial and urban activities, and its effects on food chain: Case studies from Punjab. *Journal of New Seeds* **10**: 112-137.

Chauhan JS, Amit LS and Rajendra PS 2015. Quality seed: A mega factor in enhancing crop productivity. *Recent advances in Crop Physiology* **2**: 16.

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Dhakal MR and Pandey AK 2001. Storage potential of niger (*Guizotia abyssinica*) seeds under ambient conditions, *Seed Science and Technology* **29**: 205-213.

ISTA 2011. International Rules for Seed Testing: *The Germination Test* pp. 53-58. In: International Seed Testing Association, Baserdorf, Switzerland.

Khan MM, Abbas M, Awan FS, Shahid M, Ali M and Ahmad S 2013. Physio-biochemical and genetic changes in stored pea (*Pisum sativum*) seeds. *International Journal of Agriculture and Biology* **15**: 951-956.

Kumar S and Verma SS 2008. Studies on viability and vigour in fenugreek seeds stored under ambient conditions. *Haryana Journal of Horticultural Sciences* **37**: 349-352.

Kumari S, Amar K and Tehlan SK 2014. Study on biochemical changes associated with seed viability and its deterioration under ambient conditions in fenugreek. *Annals of Agribio Research* **19**: 754-756.

Maruthi JB and Paramesh R 2016. Effect of integrated nutrient management on seed quality of vegetable soybean [*Glycine max* (L.) Merrill] cv. Karune. *Legume Research* **39**: 578-583.

Nagarajan S, Sinha JP and Pandita VK 2004. Accelerated ageing behaviour of okra seed lots conditioned to different moisture levels and its relation to seed water characteristics. *Seed Research* **32**: 113-117.

Namvar A, Rauf SS, Teymur K and Majid JM 2013. Seed inoculation inorganic nitrogen fertilization effects on some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) in irrigated conditions. *Journal of Central European Agriculture* **14**: 28-40.

Sangeeta S, Kumar VS and Kumar R 2014. Effect of integrated nutrient management on yield and quality of cauliflower. *The Bioscan* **9**: 1053-1058.

Singh B, Bhuker A, Mor VS, Dahiya OS and Punia RC 2015. Effect of natural ageing on seed quality of fenugreek (*Trigonella foenum-graecum* L.). *International Journal of Seed Science and Technology* **1**: 243-248.

Singh B, Singh, CB and Gupta PC 2003. Influence of seed ageing in Vigna species. *Journal of Farm Science* **12**: 4-7.

Verma SS, Verma U and Tomer RPS 2003. Studies on seed quality parameters in deteriorating seeds in brassica (*Brassica campestris*). *Seed Science and Technology* **31**: 389-396.

Yadav BD and Khurana SC 2005. Effect of growth substances and azotobacter on quality of seed produced by different order umbels in transplanted fennel. *Indian Journal of Horticulture* **62**: 52-55.

Zamani A, Sadat NSA, Tavakol, AR Iran, NH, Ali AG and Tavakoli A. 2010. Lipid peroxidation and antioxidant enzymes activity under natural and accelerated ageing in safflower (*Carthamus tinctorius* L.) seed. *Iranian Journal of Agriculture Science* **41**: 545-554.

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Adoption of Modern Agricultural Technologies Transferred through Farmer Field Schools in Bangladesh

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Abstract: The adoption of modern agricultural technologies has received a lot of attention in both developed and developing countries. FFS is now being implemented and adopted all over the world and helps to improve intermediate outcomes related to adoption of modern agricultural technologies. However, the rate of adoption of these technologies is not as rapid as expected. To the contrary, the intention of farmers influenced the adoption of these technologies. The theory of planned behaviour (TPB) has provided a useful framework for explaining farmers' intention to adopt agricultural technologies transferred through FFS. Thus, this paper aims to assess farmers' intention to adopt modern technologies implementing the TPB. As per the results of a structural equation model, the three TPB constructs i.e., attitude, subjective norm, and perceived behavioural control are significantly related to intention. Furthermore, intention is found to be significantly and positively related to actual behaviour (adoption). The findings of the study expected to provide additional insights to policymakers and agricultural professionals as they create appropriate strategies to increase adoption of modern agricultural technologies in developing countries.

Keywords: Adoption, Theory of planned behaviour, Intention, Structural equation model

The world's population is increasing day by day. It is no longer possible to meet the needs of increasing numbers of population and to achieve food security by expanding areas under cultivation since the fertile land is not increasing over time. But this problem can only be solved effectively by increasing agricultural productivity of farm households. However, achieving agricultural productivity growth will not be possible without developing and disseminating yield-increasing technologies and application of these technologies by farm households (Challa and Tilahun 2014). The success of any technology depends on its dissemination among the potential users, which is ultimately measured by the level of adoption of that technology (Rashid et al 2019), while adoption of new farm technology can improve the economic status of a household (Dhani et al 2019). Observations indicated that despite visible benefits many technologies are not adopted by the farmers resulting yield gap between the farmers' field and the possible output of a specific technology (Mottaleb 2018). Farmer Field School (FFS) is a participatory extension approach through which a large number of agricultural technologies can be transferred to the farmers. The aim of FFS is to build farmers' capacity to analyse their production systems, identify their potential problems, test possible solutions and eventually motivate them to adopt the technologies most suitable to their farming system. Basically, the FFS program was implemented in many countries to empower farmers with scientific knowledge, skills, positive attitudes and suitable technology. It is one of the most effective group approaches in Bangladesh mainly implemented by the Department of Agricultural Extension (DAE) under the Ministry of Agriculture addressing a range of topics: from IPM to sustainable production systems, agro pastoralism, value chains, nutrition and life skills (FAO 2020). The FFSs worked smoothly during the execution period and the participating farmers had better understanding, adoption, and practice than non-FFS farmers (Bunyatta et al 2019). But technologies should be disseminated to non-FFS farmers as well. Despite an effective extension strategy, the effectiveness of FFS in influencing farmers' understanding and adoption of different technologies remains questionable (Roy et al 2014). This change in farmers' behaviour is a significant threat to adoption of modern agricultural technologies. The reason behind this is that there are some psychological factors which may influence the adoption of a new practice. The Theory of Planned Behaviour (TPB) has provided a useful framework for explaining the farmers' intention to adopt these technologies transferred through FFS. As per the TPB, adoption is inspired by intention, which is influenced by three psychological factors: attitude, subjective norm, and perceived behavioural control (Fig. 1). Few studies focused directly on the adoption of modern agricultural technologies transferred through FFS, and most of the analyses ignored psychological factors. Thus, a research question arises, along with other factors, what psychological factors influence farmers to adopt agricultural technologies transferred through FFS.

The principles of TPB have been used in this study to define farmers' segments or typologies based on attitudes to predict behaviour and to analyse farmers' attitudes towards adopting modern agricultural technologies. In fact, attitudes are assumed to be causally related to rational behaviour when the decision-makers have control over decisions. However, this rational process is affected by both subjective norms and perceived behavioural control. In simple, a technology or a practice is judged for adoption by a farmer when build a positive attitude towards it, positive influence of the society around the individual about it (subjective norms), and have enough access to resources and the opportunities needed to adopt the technology or practice (perceived behavioural control). As per the TPB's theoretical foundation, the following hypotheses have been tested for the study:

H_1: There is a positive relationship between attitude towards behaviour and intention towards adoption of modern agricultural technologies (actual behaviour).

H_2: There is a positive relationship between subjective norms to perform the behaviour and intention towards adoption of modern agricultural technologies (actual behaviour).

H_3: There is a positive relationship between perceived behaviour control and intention towards adoption of modern agricultural technologies (actual behaviour).

H_4: There is a positive relationship between intention towards adoption and adoption of modern agricultural technologies (actual behaviour).

MATERIAL AND METHODS

The study was conducted at Kaliganj upazila (sub-district) in the northern part of Bangladesh, located between 25°54' and 26°04' north latitudes and between 89°07' and 89°22' east longitudes, where 52 Integrated Farm Management FFS (IFM-FFS) were implemented during 2013-2018. An experimental design was used in association with a cross-sectional survey. Using Cochran's (1977) sample size formula 182 FFS farmers were randomly selected from a population of 2600. As there was no list of non-FFS farmers and potential participants were hard to find, 156 non-FFS farmers were selected following snowball sampling procedure. Thus, a total of 338 farmers were selected as the sample for the study. Finally, ten technologies transferred through IFM-FFS were chosen based on judge rating. Data were collected by the researcher through face-to-face interviews using a pre-tested structured interview schedule from August to November, 2021. The interview schedule was formulated based on a series of activities, which include literature review, pilot study, and group discussions among academic experts, extension workers and researchers from various research institutes, extension agencies and universities. Questions related to the TPB were developed using a manual for constructing interview schedule based on the theory of planned behaviour (Francis et al 2004). Farmers' intention (INT) to adopt selected crop production technologies (INT_1, INT_2, INT_3, INT_4, INT_5, INT_6, INT_7, INT_8, INT_9 and INT_{10}) was measured with four degrees of intention towards adoption of the selected agricultural technologies ("currently use", "does not use, intends to use", "does not use, does not intend to use" and "does not use, does not apply") as used by Avemegah (2020). Ten statements on the instrument were used to directly measure attitude (ATT_1, ATT_2, ATT_3, ATT_4, ATT_5, ATT_6, ATT_7, ATT_8, ATT_9 and ATT_{10}). Farmers were asked if they agreed or disagreed with the statements about specific agricultural technologies. Four items (SN_1, SN_2, SN_3, SN_4) were used to measure farmers' subjective norms, which included the influence of the extension organization (DAE), important members of the community, and other farmers. However, five items of subjective norms were considered initially, but one was dropped out considering low value of Chronbach's alpha. Perceived Behavioural Control (PBC) was measured by five items (PBC_1, PBC_2, PBC_3, PBC_4, and PBC_5) that reflected farmers' confidence in their ability to adopt agricultural technologies on their farms. In total, 19 statements directly based on the TPB were used to create indices of each of the four constructs. Farmers' responses to these measurement items were captured on a 5-point Likert scale which ranged from 1 = strongly disagree to 5 = strongly agree, indicating the degree to which they agreed with the set of statements. On the other hand, adoption of the selected agricultural technologies was measured asking the respondents whether to adopt the technologies or not (coded: 1, 0).

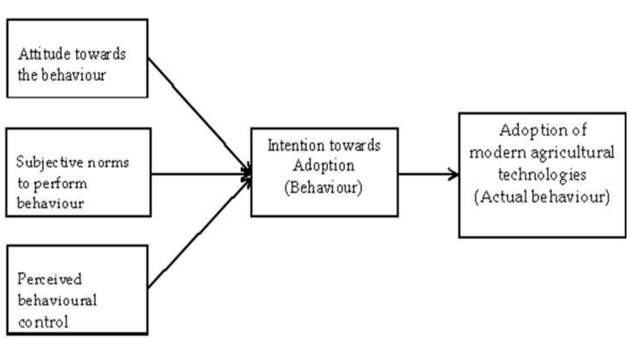


Fig. 1. Theory of planned behaviour (Source: Ajzen 1991)

Variables of the Model

Attitude: Attitude is defined as the degree to which a person perceives the behaviour based on favourable or unfavourable assessment of the behaviour. Since it lasts for a long time once it is formed, attitude often acts as a meaningful predictor of an individual's behavioural intention. In the context of this study, attitude refers to an individual farmer's positive or negative assessment of performing an action in relation to the adoption of modern agricultural technologies transferred through FFS methodology.

Subjective norms: In this study, subjective norms refer to the group norms influencing farmers' intention towards adoption of crop production technologies. For example, if a farmer perceives reference group-norm behaviour as good, the behaviour will be encouraged. Subjective norms were measured by whether the respondents agreed or disagreed that their colleague farmers and friends were increasingly using selective crop production technologies or which extension personnel motivated them, and whether it had an influence on them deciding to adopt the technologies or not.

Perceived behavioural control: Based on the theory of planned behaviour (TPB), perceived behaviour control is defined as an individual's confidence that he or she is capable of performing the behaviour. In this study, perceived behavioural control refers an external factor for a farmer's consciousness of the risks of adopting modern agricultural technologies that affects the actual behaviour (adoption) of farmers. Perceived behavioural control was measured by whether the respondents agreed or disagreed they had all the necessary skills and knowledge to engage in adopting modern crop production technologies.

Intention: This refers to the motivational factors that influence a given behaviour where the stronger the intention to perform the behaviour, the more likely the behaviour will be performed. It is defined as "indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour." Farmers' intention to adopt selected agricultural technologies measured with the degree of intention towards adoption of these technologies.

Adoption: Adoption is a decision to make full use of an innovation as the best course of action available. When an individual takes up a new idea as the best course of action and implements it, the phenomenon is known as adoption. In the present study, adoption refers to a farmer's decision to use an agricultural technology and continue the use it in future.

Data analysis: In this study, SPSS (version 20) and STATA (version 14) software were used to analyse the data. To test the research hypotheses, a Structural Equation Modelling (SEM) was constructed using STATA (version 14). A reliability analysis was performed to investigate the consistency of the latent variable items.

Reliability: Chronbach's Alpha value was used to assess the reliability of the items of the TPB variables as it is the most frequently used indicator of internal consistency. Chronbach's alpha values ranged from 0.846 (very reliable) to 0.580 (almost reliable) for the variables. Chronbach's alpha, which assesses internal consistency and reliability, revealed the majority of variables of the model display good levels of internal consistency (Table 1).

Validity: To make sure the scale items for each structure were valid, experts in the design and interpretation of statistical surveys were asked to review them. As the conclusions of a study are regarded as statistically valid if they are reasonable, both the construction and statistical validity were considered in this paper.

Fit indices: Various goodness-of-fit indices are typically advised for determining how well the observed data match the model. The model fit was evaluated using Chi-square value (χ^2), Comparative Fit Index (CFI), Standardized Root Mean Square Residual (SRMR), and Root Mean Square

Table 1. An overview and operationalization of variables used in the model

Variable	Operationalization	Scale	Chronbach's alpha
Attitude	Attitudes towards intention to adopt modern agricultural technologies that were transferred through IFM-FFS.	1-5 Likert Scale	0.707
Subjective Norms (SN)	The reference group-norms influencing farmer intention towards adoption of crop production technologies.	1-5 Likert Scale	0.580
Perceived Behavioural Control (PBC)	An external factor for a farmer's consciousness of the risks of adopting modern agricultural technologies that affects the actual behaviour (adoption) of farmers. Perceived behavioural control was measured by whether respondents agreed or disagreed they had all the necessary skills and knowledge to engage in adopting modern crop production technologies.	1-5 Likert Scale	0.846
Intention	Farmers' intention to adopt selected crop production technologies means the degree of intention towards adoption of the technologies (Currently use; Does not use, intends to use; Does not use, does not intend to use; and Does not use, does not apply; Avemegah, 2020).	0-4 Likert Scale	0.604

error of Approximation (RMSEA). R-square was employed to measure the variation explained by the endogenous variable (i.e., intention). The models were estimated using maximum likelihood procedures.

RESULTS AND DISCUSSION

The average attitude score for the statement about ideal seedbed practice was high, followed by the statements about organic manure use, crop rotation practice, applying vermicompost and rouging (Table 2). On the contrary, the statement about using Guti urea for rice cultivation showed lowest attitude score, followed by the statements about controlling insect pests using light traps, employing air tight containers for seed preservation, transplanting seedling at proper age and line sowing. The majority of the items had an attitude score larger than the median (4.00), indicating that the majority of farmers had positive attitude towards intention to adopt the technologies. Subjective norms influenced by DAE personnel had the highest mean value, followed by similar farmers in the community, friends, and farmers from other Farmer Field Schools (FFSs). All items of the subjective norms' score were higher than that of median value (SN1:

Table 2. Descriptive statistics of TPB variables

Variable	Item	Mean	SD
Attitude	Practicing ideal seedbed improve seedling health	4.31	0.567
	Crop rotation decrease pest infestation	4.10	0.448
	Application of Guti urea in rice cultivation is not better than using prilled urea	3.21	0.941
	Vermicompost improves soil fertility	4.07	0.355
	Rouging helps to produce good quality seed	4.05	0.210
	Transplanting seedling in proper age helps in increasing yield	4.01	0.336
	Light trap is not helpful for controlling insect pest	3.28	0.786
	I think for better yield line sowing is a good practice	4.03	0.507
	I think for seed conservation using air tight container is not necessary	3.47	1.191
	Organic manure improves soil health	4.21	0.431
Subjective Norms (SN)	DAE personnel (AEO, SAPPO, and SAAO) often advise me to adopt crop production technologies transferred through IFM-FFS.	4.10	1.086
	Farmers that are similar to me already adopt crop production technologies transferred through IFM-FFS	2.80	0.965
	My friends think practicing crop production technologies transferred through IFM-FFS would be much better than previous state	2.25	0.620
	Farmers of other FFS would approve my practicing crop production technologies	2.12	0.539
Perceived Behavioural Control (PBC)	I have knowledge and ability to adopt crop production technologies transferred through IFM-FFS	3.37	1.063
	Crop production technologies transferred through IFM-FFS were easy for me	3.05	1.070
	I am confident that I can continue to practice crop production technologies transferred through IFM-FFS	2.81	1.016
	I can overcome any problems related to adopt practice crop production technologies transferred through IFM-FFS	2.74	0.984
	It is mostly up to me whether or not I practice crop production technologies transferred through IFM-FFS	3.60	0.985
Intention	Preparation of ideal seed bed for rice cultivation	2.85	0.395
	Use of air sealed container for seed storage	2.96	0.200
	Transplanting seedling at proper age	2.93	0.332
	Line sowing or proper spacing of seedlings	2.82	0.435
	Practicing rogueing for seed production	2.74	0.441
	Use of crop rotation	2.55	0.533
	Preparation and use of FYM	2.32	0.537
	Preparation and use of Vermicompost	2.04	0.483
	Application of Guti urea in rice cultivation	1.70	0.841
	Use of light trap	0.55	0.891

4.00; SN2 to SN4=2.00). This indicated that, in general, farmers' intentions to implement the technologies conformed to expected norms.

In terms of perceived behavioural control, the statement about whether or not farmers used agricultural production procedures had the highest mean score, followed by the statements about farmer' knowledge and ability, ease of practice, farmers' confidence, and overcoming any problems associated with adopting the technologies. The intention score was high in adopting air sealed container for seed storage followed by transplanting seedling at proper age, preparation of ideal seed bed for rice cultivation line sowing or proper spacing of seedlings and practicing rogueing for seed production. In contrast, farmers had expressed a low intention to adopt light traps for pest followed by the application of Guti urea in rice production, the usage of vermicompost and FYM, and the practice of crop rotation. The correlation matrix reveals that there are significant correlations between the variables (Table 3).

The findings of the structural equation model predicting intention and adoption of crop production technologies are shown in Figure 2. The fit indices revealed that the overall goodness-of-fit to the data was good (Table 4).

The method of estimation was significant in both the test of the targeted model against the saturated model (χ^2=3.073; p < .010) and the test of the baseline model against the saturated model (χ^2= 723.147; p < .001), indicating that there is a significant difference between observed variables and the theoretical model. However, χ^2 is not usually the deciding factor in determining model fit, as it does not always provide relevant information, and other measures of fit should be considered. Rather, multiple fit indices allow a more comprehensive assessment of model fit (Alavi et al 2020). The comparative fit index (CFI) of the model was 0.997 indicating good fit. The RMSEA provides values between 0 and 1, with values closer to zero indicating a better fit. According to this study, it was 0.078. Moreover, the model in this study builds a convincingly good fit, as indicated by the value of SRMR = 0.008, as the value of SRMR ≤0.08 is universally acknowledged as a good fit for the SEM model.

This study modelled attitude toward intention to adopt the technologies, subjective norms that perform intention to adopt the technologies, perceived behavioural control leads to intention to adopt the technologies, the intention towards adoption that treated as behaviour and adoption (actual behaviour) of the technologies. The attitude, subjective norms, and PBC all have positive and significant relationships with intention (behaviour). Intention has a favourable and significant relationship with adoption of modern agricultural technologies. These variables (attitude, subjective norms, and PBC) are also significantly and positively interrelated.

All of these findings support the hypotheses. As per Hypothesis H_1, a positive attitude predicts farmers' intention to adopt modern agricultural technologies. Farmers' attitude toward the behaviour, i.e., their favourable or negative personal judgment of adopting agricultural technologies, is undoubtedly the most important predictor of intention (β=0.170, p <0.01). This might be due to the fact that farmers intend to engage in the technologies because they are aware of the benefits that can be obtained through the use of effective interventions by the extension agencies. Farmers having expected subjective norms are also more likely to adopt modern agricultural technologies. As a result, the H_2 is accepted, implying that there is a positive association between subjective norms for performing the behaviour and intention to adopt modern agricultural technologies (β=0.055, p <0.01). This may be because the extension agencies, other farmers in the community, including friends

Table 4. Overall results of SEM

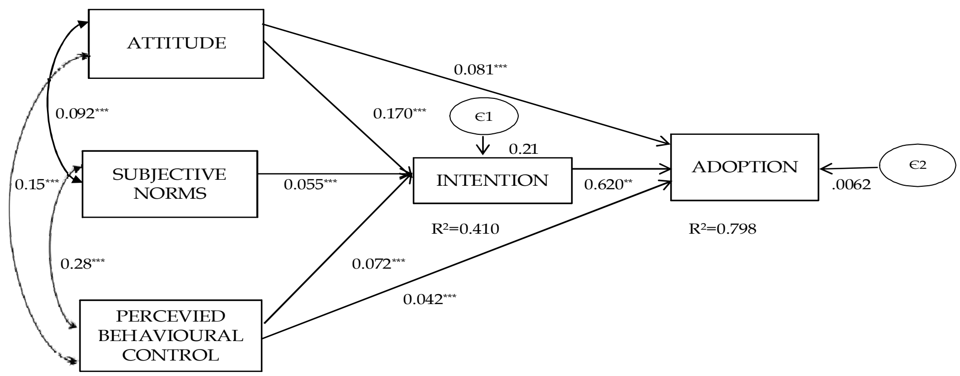
Path to	Path from	Coefficient (β)	Z value
Intention (R^2=0.410)	Attitude	0.170***	5.43
	Subjective norms	0.055***	3.44
	Perceived behavioural control	0.072***	5.38
Adoption (R^2=0.798)	Intention	0.620***	21.55
	Attitude	0.081***	4.65
	Perceived behavioural control	0.042***	5.95

Note: ** p < .05 level; *** p < .01 level.

Table 3. Descriptive statistics and correlations (N = 338)

Variables	Mean	SD	ATT	SN	PBC	INT	ADOP
1. Attitude towards the behaviour(ATT)	3.873	0.320	1.00				
2. Subjective norms to perform behaviour (SN)	3.89	0.621	0.463**	1.00			
3. Perceived behavioural control (PBC)	3.11	0.806	0.578**	0.566**	1.00		
4. Intention towards adoption (INT)	2.53	0.191	0.541**	0.480**	0.567**	1.00	
5. Adoption of modern agricultural technologies (ADOP)	0.555	0.176	0.622**	0.534**	0.659**	0.862**	1.00

** Correlation is significant at the 0.01 level, SD= Standard deviation



Significance Codes: *** = p < 0.01; ** = p < 0.05; * = p < 0.10.

Model fit: Chi^2_ms = 3.073; CFI = 0.997; RMSEA = 0.078; SRMR=0.008

Fig. 2. Structural Equation Modelling (SEM)

and neighbours, and farmers from other organizations exert constant pressure on farmers to adopt the technologies. The findings (Fig. 2) demonstrate a strong and positive relationship between perceived behavioural control and intention, supporting the H_3 and revealing that farmers' perception of their own capability affect their behavioural intention. Again, the H_4 is accepted since intention is positively and significantly associated to the adoption of modern agricultural technologies. Before performing any behaviour, intention is must and after determining their intentions, farmers are expected to take the opportunity to perform the actual behaviour (adoption). The inner model path coefficients of this study reveal that farmers' attitudes, subjective norms, and PBC are all important predictors of their intentions to adopt modern agricultural technologies, and that intention (behaviour) is a strong predictor of adoption (actual behaviour) of these technologies. Tama et al (2021) and Daxini et al (2018) observed similar result in their study. Van Dijk et al (2016) concluded statistically significant and positive effects of subjective norm on the intention to perform agro-environmental measures. In a different study, Bonke and Musshoff (2020) discovered positive and significant relationships between attitude to intention, as well as PBC and intention. The results obtained by Nguyen and Drakou (2021) showed that farmers' intention to adopt sustainable agricultural technologies is influenced by their perception of social pressure (SN) and their abilities to perform sustainable agriculture (PBC).

CONCLUSION

The findings indicate that farmers with favourable attitudes, expected subjective norms, and higher perceivable behavioural control were more likely than other farmers in the community to adopt agricultural technologies. Therefore, socio-psychological factors influencing the adoption, as outlined by TPB, may be considered while promoting the adoption of new technologies in the farming system. The findings of the study may be useful to the development of future research aimed at gaining a deeper understanding of psychological and other factors influencing technology adoption especially within the context of Bangladesh. This could lead to increased farm productivity and improved smallholder livelihoods in the country in a sustainable way. However, this study may have methodological shortcomings that create opportunities for future research.

REFERENCES

Ajzen I 1991. The theory of planned behaviour. *Organizational Behaviour and Human Decision Process* **50**: 179-221.

Alavi M, Visentin DC, Thapa DK, Hunt GE, Watson R and Cleary ML 2020. *Chi-square for model fit in confirmatory factor analysis*, DOI: 10.1111/jan.14399.

Avemegah E 2020. *Understanding South Dakota Farmers' Intentions to and Adoption of Conservation Technologies: An Examination of the Theory of Planned Behaviour.* Electronic Theses and Dissertations 4075.

Bonke V and Musshoff O 2020. Understanding German farmer's intention to adopt mixed cropping using the theory of planned behaviour. *Agronomy for Sustainaible Development* **40:** 48.

Bunyatta DK, Onyango CA and Kibett JK 2019. Impact of farmer field schools on soil and crop management among smallholders in North Rift, Kenya. *Journal of Agricultural Extension Management* **15**(2): 1-13.

Challa M and Tilahun U 2014. Determinants and impacts of modern agricultural technology adoption in West Wollega: The case of Gulliso District. *Journal of Biology, Agriculture and Healthcare* **4**(20): 63-77.

Cochran WG 1977. *Sampling Techniques*, 3rd Ed., New York: John Wiley and Sons, Inc.

Daxini A, O'Donoghue C, Ryan M, Barenes A, Buckley C and Daly K 2018. Which factors influence farmers' intentions to adopt nutrient management planning? *Journal of Environmental Management* **224**: 350-360.

Dhanai R, Negi, RS, Sing S and Rawat S 2019. Technological adoption for livelihood security of small holder farmer' in Uttarakhand, India: Issues and opportunities. *Indian Journal of Ecology* **45**(3): 638-641.

FAO 2020. *Global Farmer Field School Platform,* http://www.fao.org/farmer-eld- schools Global FFS D-group.

Francis J, Eccles MP, Johnston M, Walker A, Grimshaw J and Foy R 2004. *Constructing Questionnaires Based on The Theory of Planned Behaviour, A Manual for Health Services Researchers,* Centre for Health Services Research, University of Newcastle, Newcastle, England, pp 10-24.

Mottaleb KA 2018. Perception and adoption of a new agricultural technology: Evidence from a developing country. *Technology in Society* **55**: 126-135.

Nguyen N and Drakou EG 2021. Farmers intention to adopt sustainable agriculture hinges on climate awareness: The case of Vietnamese coffee. *Journal of Cleaner Production* **303**, DOI: 10.1016/j.jclepro.2021.126828.

Received 30 August, 2022; Accepted 15 September, 2022

Rashid MH, Rony MKI, Mahalder D and Goswami PC 2019. Adoption of improved production practices in low land rice through community training. SAARC *Journal of Agriculture* **17**(1): 1-11.

Roy D, Farouque MG and Rahman M 2014. Problem Confrontation of the FFS Farmers in Participating Farmer Field School Training Session. *Progressive Agriculture* **24**(1-2): 273-280.

Tama RAZ, Ying L, Yu M, Hoque M, Adnan KM and Sarker SA 2021. Assessing farmers' intention towards conservation agriculture by using the extended theory of planned behaviour. *Journal of Environmental Management* 280, DOI: 10.1016/j.jenvman. 2020.111654.

Van Dijk WFA, Lokhorst AM, Berendse F and de Snoo GR 2016. Factors underlying farmers' intentions to perform unsubsidised agrienvironmental measures. *Land Use Policy* **59**: 207-216.

Van Dijk WFA, Lokhorst AM, Berendse F and De Snoo GR 2016. Factors underlying farmers' intentions to perform unsubsidised agrienvironmental measures. *Land Use Policy* **59**: 207-216.

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Effect of Different Stabilization Methods on Proximate and Mineral Composition of Wheat Bran

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Abstract: Wheat bran, a byproduct of wheat milling industry which is commonly used for feeding animals has dense nutritional composition and potential application in human diet that have attracted market interest. However, its preservation for safe use is still challenging. Therefore, the objective of the present study was to identify the best stabilization method which would safely preserve the bran. For the stabilization of wheat bran different methods (microwave, hot air oven, roasting and chemical method) were used. The assessment of proximate and mineral characteristics of wheat bran depicted that the highest crude protein (15.56%), ash (6.31%) and crude fibre (12.52%) were observed in microwave stabilized wheat bran, while as the minimum protein (13.61%), ash (5.32%) and crude fibre (11.72%) content were in unstabilized wheat bran (control). During storage period, the mean moisture content increased from 7.19 to 7.88 per cent, while as crude protein, ash, crude fat and crude fibre decreased from 15.29 to 14.01 per cent, 5.87 to 5.58 per cent, 5.96 to 5.39 per cent and 12.58 to 11.81 per cent, respectively. Based on overall proximate and mineral composition and stability, microwave stabilized wheat bran was more effective than hot air oven, autoclave, roasting and chemical methods.

Keywords: Stability, Inactivation, Nutritional, Fortification, Consumption

Wheat is the largest cereal grain crop of the world and the second largest in India, corresponding to annual production of approximately 109 million tons during the year 2021 (Anonymous 2022a). Wheat grain consists of three main parts-endosperm, germ, and bran. The bran fraction, which is generally produced as a milling by-product, constitutes about 13-19 per cent of total wheat grain weight (Laukova et al 2016) and has food (Curti et al 2013) and non-food applications (Apprich et al 2013). It is estimated that 796 thousand metric tonnes of wheat bran are produced annually (Anonymous 2019b). Wheat bran is the outer layer of wheat kernel, sub-divided into three distant layers, viz., testa, aleurone and pericarp**.** It contains about 53 per cent dietary fibre (cellulose, lignin, galactan, xylans, and fructans). It is also rich in bioactive components such as ferulic acid, alkylresorcinols, carotenoids, lignans, flavonoids, and sterols (Onipe et al 2015). Other components include vitamin B (thiamin, riboflavin, pyridoxine, and folate) and Vitamin E (Fardet 2010). Besides, it contains minerals iron, zinc, manganese, magnesium, and phosphorous (Brouns et al 2012). The pericarp is divided into inner and outerlayers, which comprises of phenolic acids in bound state and insoluble dietary fibre (Apprich et al 2013). These nutrition-rich components are often discarded during milling out of ignorance, organoleptic reasons, or rancidity problems. Knowingthe phytochemical constituents and pharmacological profile of bran is expected to give insight to their potential application in promotion of health. Wheat bran, the by product obtained in large amounts in wheat milling is considered as inedible material for humans and is mostly used as animal feed (Dar, 2011). Besides, these nutritional ingredients, wheat bran contains lipase. High lipase activity in bran leads to rapid deterioration of lipids by rancidification during storage and is the most common problem of raw bran (Ertas 2015). Once the bran is removed from the kernel, the lipid substrate and enzymes are brought together, and enzymatic hydrolysis proceeds rapidly. Since bran contains high fat content, rapid deterioration of crude fat by lipase immediately occurs, following the milling process and yields free fatty acids and glycerol. The fat hydrolysis causes the bran unsuitable for human consumption and lowers the oil yield (Patil et al 2016). The reaction between molecular oxygen and lipids results in oxidative rancidity that led to spoilage. The reaction occurs at the double bonds of unsaturated fatty acids and can be accelerated by free radicals, singlet oxygen, radiation, metal ions (iron, copper and cobalt), enzymes and light, containing a transition metal prosthetic group like lipoxygenase (Malekian et al 2000). Therefore, it necessitates inactivation of lipase and inhibition of the formation of free fatty acids immediately after milling process. During the storage, rancidification can reduce the nutritional value of food and cause some quality changes involving appearance, flavor, and texture. Lipid hydrolysis in wheat bran may affect baking, nutritional and sensory properties (Ertas 2015). Therefore, stabilization of bran is important to inactivate lipases and peroxidases.

MATERIAL AND METHODS

Stabilization of wheat bran: The study was carried out in Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu using wheat bran purchased from Amar flour mills, Gangyal, Jammu. The sample was exposed to different five stabilization methods, viz., hot air oven, microwave, roasting, autoclave, and chemical while one was kept as such. Stabilized wheat bran samples were stored for a period of 3 months (Table 1).

Analysis of proximate composition: The crude protein, crude fat, ash, crude fibre and moisture, were determined according to AOAC (2005). After ashing of samples, calcium, phosphorous and magnesium content was determined according to AOAC method. For determination of minerals, ashing was done followed by digestion using solution of perchloric acid and nitric acid at ratio of 1:4, followed by cooling. Solution was filtered using Whatman filter paper 42, and volume of each sample was made to 25 ml using distilled water. Total dietary fibre and phytic acid was determined according to AOAC (2005) and Sadasivam and Manickam (2008), respectively.

Table 1. Experimental conditions for thermal treatments

Stabilization method	Sample code	Operating conditions
Control	Raw	None
Microwave	MW	2450 MHz for 3 minutes
Hot air oven	HAO	120℃for 20 minutes
Autoclave	AC	121℃ at 15 psi
Roasting	RO	190℃ for 20 minutes
Chemical	CH	Ethanol (5ml/100g WB)

Statistical analysis: The results obtained were statistically analyzed at 5 per cent level of significance using completely randomized design and through analysis of variance (ANOVA) using software OPSTAT.

RESULTS AND DISCUSSION

Proximate Components

Crude protein: Stabilization of wheat bran resulted in an increase in crude protein content in comparison to control (Table 2). Mean crude protein content of 15.56% was in MW stabilized wheat bran, which was significantly higher than other methods and is in agreement with Fahmida et al (2015). The short exposure times and uniform heating associated with microwave heating might be responsible for lesser deterioration of proteins in contrast to other stabilization methods (Sun et al 2019). Roasted samples had significantly less crude protein than hot air oven and autoclave treated samples. During roasting, the high temperatures employed might be responsible for protein denaturation and subsequent protein loss in comparison to autoclave and hot air oven, which have better retention of crude protein content (Arumuganathan et al 2010). The crude protein content of chemical treated wheat bran samples was lower than thermal treated wheat bran samples but higher than control, which was consistent with Bagchi et al (2014) and Younas et al (2011) in rice bran. The reason behind this increase might be due to reduction in the activity of enzymes involved in degradation of proteins (Gopinger et al 2015).

Ash: All stabilization methods resulted in a significant increase in ash content (Table 3). An increase in ash content after thermal processing might be attributed to non-volatile nature of minerals, which do not get destroyed on heating (Mahirah et al 2018). On considering the effect of stabilization methods on ash content, the highest ash content was observed in microwave stabilized wheat bran. Similar results

Table 2. Effect of stabilization methods and storage period on crude protein (%) of wheat bran

Stabilization method	Storage days				Mean
	0	30	60	90	
Control	14.25	13.79	13.43	12.97	13.61
MW	16.15	15.75	15.51	14.85	15.56
HAO	15.90	15.34	14.93	14.54	15.17
AC	15.58	15.18	14.60	14.37	14.93
RO	15.42	15.05	14.47	14.23	14.79
CH	14.45	14.07	13.52	13.14	13.78
Mean (Storage)	15.29	14.86	14.41	14.01	

CD (p=0.05)
Stabilization method (SB) 0.07
Storage (S) 0.05
SB x S 0.14

were reported by Siswanti et al (2019) in rice bran. This increase in ash content may be due to decrease in moisture content (Chauhan et al 2015).

Crude fat: The stabilization methods resulted in an increase in crude fat content of wheat bran (Table 4), which could be attributed to denaturation of proteins that results in formation of complex structures, leading to lesser exposure of hydrophobic domains (Lee et al 2019). The microwave stabilization method retained higher amount of mean crude fat content (6.87%) when compared to other stabilization methods like results of Fahmida et al (2019) and Siswanti et al (2019) reporting better retention of fat content in microwave than roasting, hot air oven, and autoclave. This increase in crude fat content might be attributed to opening of bonds within short period of time due to disturbance in fat complex and protein or fat and carbohydrates (Siswanti et al 2019). The hot air oven stabilized wheat bran, in contrast to roasted wheat bran, depicted a higher mean crude fat content of 6.30% coinciding with the results reported by El-Hady (2013) in rice bran. The higher mean crude fat content of chemical treated wheat bran (5.44%) than control (3.72%) might be due to better extractability of oil by solvents (El-Hady, 2013). Premkumari et al (2012also observed increase in fat content of alcohol treated rice bran.

Crude fibre: The different stabilization methods had a significant impact on the crude fibre content of wheat bran (Table 5). This might be attributed to the formation of protein-fibre complex (Nyangena et al 2020). Crude fibre content followed the order of microwave >roasting>hot air oven >autoclave>chemical>control. Fahmida et al (2019) reported higher crude fibre content in microwave stabilized rice bran than the samples subjected to roasting, steaming, and autoclave. Higher crude fibre content in microwave stabilized wheat bran in contrast to other methods might be due to increased susceptibility of lignocellulose substances to enzymatic activity in response to microwaves .The hot air oven retained higher crude fibre content as compared to autoclave and chemical stabilization, which might be due to

Table 3. Ash content (%) of wheat bran stabilized by different methods

Stabilization method	Storage days				Mean
	0	30	60	90	
Control	5.50	5.44	5.30	5.20	5.32
MW	6.45	6.37	6.27	6.18	6.31
HAO	5.87	5.79	5.68	5.59	5.73
AC	5.83	5.66	5.61	5.53	5.66
RO	5.98	5.90	5.83	5.75	5.87
CH	5.60	5.50	5.46	5.37	5.46
Mean (Storage)	5.87	5.78	5.68	5.58	

CD (p=0.05)
Stabilization method (SB) 0.05
Storage (S) 0.04
SB x S Non significant (NS)

Table 4. Effect of storage period and stabilization methods on crude fat content of wheat bran(%)

Stabilization method	Storage days				Mean
	0	30	60	90	
Control	4.00	3.83	3.64	3.39	3.72
MW	7.00	6.92	6.83	6.74	6.87
HAO	6.71	6.29	6.17	6.03	6.30
AC	5.91	5.72	5.51	5.32	5.61
RO	6.39	6.17	5.94	5.65	6.04
CH	5.72	5.50	5.35	5.19	5.44
Mean (Storage)	5.96	5.74	5.57	5.39	

CD (p=0.05)
Stabilization method (SB) 0.06
Storage (S) 0.04
SB x S 0.10

greater cellular disruption leading to greater susceptibility to enzymatic activity, thereby increasing the crude fibre content (Hameed 2016).

Moisture content: All the stabilization methods reflected a decrease in moisture content (Table 6). Reduction in moisture content due to stabilization methods might be due to the fact that moisture, being a bipolar molecule, gets heated up and subsequently evaporated from the bran samples (Patil et al 2016). Initially, the highest moisture content of 8.95 per cent was found in control, followed by chemical method depicting the moisture content of 7.35 per cent. Premkumari et al (2012) also reported lesser moisture content in ethanol treated rice bran than control, hence supporting our findings. The mean moisture content of 5.90 per cent was observed in roasting lower than the microwave (7.33%) and autoclave (8.56%). Fahmida et al (2019) also observed similar results in rice bran. The difference in moisture content of stabilized wheat bran samples might be due to different temperature conditions used (Filho et al 2016). The moisture content follows the order of control>autoclave>chemical> microwave>hot air oven>roasting, which is consistent with the findings of Thanonkaew et al (2012) in rice bran. Higher moisture content in microwave than in roasting might be due to the fact that during microwave heating, the air adjacent to the food product is cold and water vaporizing from products gets condensed on contact with cold air (Chandrasekaran et al 2013). The lower moisture content in the microwave compared to autoclave could be attributed to the microwave's high intensity heating (Chauhan et al 2015).

Available carbohydrates: Stabilization methods resulted in a significant decrease in available carbohydrates of treated wheat bran samples as compared to control which might be attributed to an increase in crude protein, crude fat, and ash content (Nyangena et al 2020). Carbohydrate content of control sample was 67.91 percent which is in the range (60-75 %) given by Javed et al (2012). The available

Table 5. Crude fibre content of wheat bran as affected by stabilization methods and storage period (%)

Stabilization method	Storage days				Mean
	0	30	60	90	
Control	12.46	11.75	11.46	11.20	11.72
MW	12.79	12.62	12.44	12.25	12.52
HAO	12.59	12.42	12.21	11.89	12.28
AC	12.52	12.39	12.13	11.79	12.20
RO	12.65	12.49	12.28	12.10	12.38
CH	12.49	12.03	11.79	11.63	11.98
Mean (Storage)	12.58	12.28	12.05	11.81	

CD (p=0.05)
Stabilization method (SB) 0.03
Storage (S) 0.02
SB x S 0.06

Table 6. Effect of stabilization methods and storage period on moisture (%) of wheat bran

Stabilization method	Storage days				Mean
	0	30	60	90	
Control	8.95	9.20	9.50	9.95	9.40
MW	6.95	7.28	7.43	7.67	7.33
HAO	5.95	6.20	6.37	6.65	6.29
AC	8.25	8.43	8.67	8.90	8.56
RO	5.67	5.76	5.95	6.20	5.90
CH	7.35	7.50	7.69	7.92	7.62
Mean (Storage)	7.19	7.40	7.60	7.88	

CD (p=0.05)
Stabilization method (SB) 0.06
Storage (S) 0.04
SB x S 0.11

carbohydrates followed the order as control>chemical >roasting>hotairoven>autoclave>microwave (Table 7). Siswanti et al (2019) also reported lesser carbohydrate content in microwave stabilized wheat bran than ones subjected to hot air oven and autoclave. In comparison to autoclave stabilized wheat bran, roasted wheat bran samples exhibited higher available carbohydrate content. This is consistent with the findings of Fahmida et al (2019) where higher carbohydrate in rice bran samples stabilized by roasting. Available carbohydrate content of wheat bran samples stabilized by roasting exhibited higher carbohydrate content than those stabilized by hot air oven and microwave, which was quite consistent with the findings of El-Hady (2013) in stabilized rice bran. Available carbohydrate content of chemical treated wheat bran was higher than autoclave and control.

Phytic acid: Phytic acid content of fresh wheat bran was 39.69 mg per g, which is comparable with the results reported by Kaur et al (2011a). All the stabilization methods resulted in a significant decrease in phytic acid content (Table 8). The reason behind this decline might be due to heat liable nature of phytic acid (Kaur et al 2011b). Ertas (2016) also reported similar decrease in phytic acid content of wheat bran stabilized with microwave, hot air oven and autoclave. Laukova et al (2020) also reported the maximum reduction in phytic acid content of microwave stabilized wheat bran than hot air oven, similar to the present study. Roasting of wheat bran resulted in significantly higher reduction in phytic acid content of wheat bran than autoclave. The findings for chemical treated wheat bran is supported by Zhonget al (2015).

Minerals: Wheat bran is a good source of minerals which are present in varied amounts. Minerals found in higher amounts are phosphorous and magnesium. Stabilization of wheat bran resulted in a significant increase in the calcium, phosphorous, and magnesium content (Table 9). Faria et al (2012) also reported increase in mineral content of stabilized

Table 7. Effect of stabilization methods and storage period on available carbohydrates (%) of wheat bran

Stabilization method	Storage days				Mean
	0	30	60	90	
Control	67.30	67.74	68.13	68.49	67.91
MW	63.45	63.68	63.96	64.56	63.91
HAO	65.57	66.38	66.85	67.19	66.50
AC	64.43	65.01	65.61	65.88	65.23
RO	66.54	67.12	67.81	68.17	67.41
CH	66.88	67.43	67.98	68.38	67.67
Mean (Storage)	65.60	66.23	66.72	67.11	

CD (p=0.05)
Stabilization method (SB) 0.04
Storage (S) 0.03
SB x S 0.08

Table 8. Effect of stabilization methods and storage period on phytic acid (mg/g) of wheatbran

Stabilization method	Storage days				Mean
	0	30	60	90	
Control	39.69	37.27	35.42	33.31	36.42
MW	16.45	14.12	12.67	10.95	13.55
HAO	18.92	16.78	14.49	11.59	15.44
AC	19.47	17.86	15.84	13.34	16.62
RO	18.72	16.31	14.23	11.29	15.13
CH	21.78	19.22	17.45	15.47	18.48
Mean (Storage)	22.50	20.26	18.35	15.99	

CD (p=0.05)
Stabilization method (SB) 0.03
Storage (S) 0.03
SB x S 0.06

rice bran. Increase in the mineral content of wheat bran due to stabilization methods might be attributed to reduction in anti-nutritional factors, which are inhibitors of mineral absorption, thereby increasing the mineral extractability and bioavailability (Nkundabombi et al 2016). Ertas (2016) observed that microwave stabilized wheat bran samples had significantly higher mineral content than hot air oven and autoclave samples.

Total dietary fibre: The total dietary fibre content of wheat bran increased significantly across all the stabilization methods (Table 10). This increase in total dietary fibre content due to stabilization might be attributed to either aggregation of proteins or formation of protein fibre complexes that remains resistant to protease treatment during determination of fibre content of sample, or it is believed that thermal processing made a small amount of the starch less available to enzymes that might cause increase in total dietary fibre. On assessing the mean total dietary fibre content of stabilized wheat bran, microwave stabilized wheat bran reflected higher total dietary fibre content and chemical treated wheat bran reflected lower total dietary fibre in contrast to other stabilization methods that are similar to findings of Premkumari et al (2012). The results for higher total dietary fibre content in microwave than autoclave has been confirmed by Dong et al (2019).

Color: Color is an important characteristic for determining the consumer acceptance of any product. The color is measured in three coordinates: L^*, a^* and b^*. The L^*, a^* and b^* values for freshly milled wheat bran were recorded as 58.50, 3.65 and 15.75, respectively, which were similar to the results reported by Sharma et al (2014) in wheat bran. Stabilization methods resulted in a decreased L^* value and increased a^* and b^* values (Table 11). The decrease in L^* value due to stabilization might be due to the fact that heat treatment causes the maillard reaction between sugar and protein content of bran by generation of certain browning products

Table 9. Effect of stabilization methods and storage period on mineral content (mg/100 g) of wheat bran

SB		0	30	60	90	Mean
Control	Ca	542.21	542.17	542.10	541.95	542.11
	P	641.10	641.03	640.95	640.89	640.99
	Mg	333.90	333.82	333.70	333.56	333.74
MW	Ca	547.45	547.41	547.37	547.29	547.38
	P	645.32	645.28	645.23	645.18	645.25
	Mg	340.47	340.41	340.33	340.23	340.36
HAO	Ca	545.74	545.69	545.63	545.58	545.66
	P	643.67	643.61	643.58	643.53	643.60
	Mg	338.70	338.62	338.50	338.35	338.54
AC	Ca	543.79	543.74	543.68	543.63	543.71
	P	642.56	642.51	642.47	642.41	642.49
	Mg	336.52	336.47	336.36	336.20	336.39
RO	Ca	546.74	546.70	546.64	546.58	546.66
	P	644.34	644.29	644.25	644.18	644.26
	Mg	339.28	339.21	339.12	339.00	339.15
CH	Ca	542.43	542.39	542.34	542.28	542.36
	P	642.21	642.17	642.09	642.00	642.12
	Mg	334.45	334.36	334.24	334.06	334.28
Mean	Ca	544.72	544.68	544.63	544.55	
	P	643.20	643.15	643.09	643.03	
	Mg	337.22	337.14	337.04	336.90	
CD (p=0.05)		Stabilization method (SB)	Storage (S)	SB x S		
	Ca	0.06	0.05	NS		
	P	0.07	0.05	NS		
	Mg	0.05	0.04	NS		

(Kim et al2014). An increase in b* value in treated wheat bran than untreated bran might be due to lesser rate of lipid oxidation reactions in stabilized bran, since lipid degradation is directly proportional to carotenoid degradation (Jia et al 2007). Our findings are supported by Kaur et al (2011b) in cereal brans. Gopinger et al (2015) reported similar results while studying the whole rice stabilization using short chain organic acid mixture. Thanonkaew et al (2012) also reported

Table 10. Effect of stabilization methods and storage period total dietary fibre (%) of wheat bran

Stabilization method	Storage days				Mean
	0	30	60	90	
Control	44.50	41.72	37.70	32.95	39.22
MW	50.23	48.15	45.86	42.76	46.75
HAO	46.90	44.65	42.13	38.78	43.12
AC	46.45	44.10	41.15	38.02	42.43
RO	48.70	46.52	44.10	40.85	45.04
CH	45.10	42.35	38.50	34.38	40.08
Mean (Storage)	46.98	44.58	41.57	37.96	

CD (p=0.05)	
Stabilization method (SB)	0.06
Storage (S)	0.04
SB x S	0.11

Table 11. Effect of stabilization methods and storage period on L*, a*, and b* value of wheat bran

SB		0	30	60	90	Mean
Control	L*	58.50	56.25	54.76	52.29	55.45
	a*	3.65	3.71	3.89	4.10	3.84
	b*	15.75	16.10	16.53	16.76	16.28
MW	L*	56.65	54.86	51.79	48.28	52.89
	a*	4.16	4.29	4.43	4.58	4.36
	b*	16.91	17.19	17.34	17.65	17.27
HAO	L*	50.25	48.75	42.10	39.87	45.24
	a*	4.49	4.68	4.85	5.01	4.76
	b*	17.36	17.62	17.89	18.03	17.72
AC	L*	53.20	50.46	46.47	43.87	48.50
	a*	4.37	4.57	4.76	4.89	4.65
	b*	17.12	17.28	17.51	17.82	17.43
RO	L*	42.84	39.28	35.40	31.96	38.87
	a*	4.93	5.29	5.44	5.70	5.34
	b*	17.78	17.96	18.29	18.47	18.12
CH	L*	47.50	44.57	40.78	36.14	42.25
	a*	4.72	4.96	5.21	5.47	5.09
	b*	17.54	17.79	17.96	18.25	17.88
Mean	L*	51.16	49.03	45.22	42.07	
	a*	4.39	4.58	4.76	4.96	
	b*	17.10	17.32	17.58	17.83	
CD (p=0.05)	Stabilization Method (SB)	Storage (S)	SB x S			
L*	0.06	0.04	0.09			
a*	0.07	0.04	0.11			
b*	0.06	0.04	0.15			

decrease in L^* value and increase in a^* value by microwave heating during stabilization of rice bran.

Storage studies: On accessing the storage mean vales, a significant reduction was recorded in crude protein, crude fat, ash, crude fibre, total dietary fibre, phytic acid while moisture and available carbohydrates increased. With increase in storage period, increase in moisture content might be attributed to hygroscopic nature of wheat bran and storage environmental conditions (Nagi et al 2012). Decrease in crude protein content with increase in storage period might be attributed to gain in moisture, resulting in hydrolysis of peptide bonds with the help of protease enzyme, that cause splitting of protein molecules (Kumar and Thakur 2017). During the 90 days of storage, ash content decreased from initial level of 5.87 to 5.58%. Interaction with other food components like protein and carbohydrates during storage might be responsible for decrease in ash content (Akhter et al 2005). The decrease in crude fat content during storage might be attributed to increase in moisture content that influences the activity of endogenous enzyme lipase and lipoxygenase to a great extent, which splits fat into fatty acids and glycerol (Akhter et al 2005). With the increase in storage period, crude fiber and total dietary fibre decreased significantly, which might be attributed to degradation of structural polysaccharides and also dietary fibre becomes less recognizable due to breakage of weak bonds between polysaccharide chains and glycosidic linkages (Sharon and Usha, 2006). Phytic acid content decreased with the increase in storage period from 22.50 to 15.99 mg per g. This decrease in phytic acid content with the increase in storage period might be attributed to increased metabolic activity, inactivation of phytase and membrane degradation.

Storage studies of stabilized wheat bran revealed a significant decrease in L^* value from an initial mean level of 51.16 to 42.07 while a^* and b^* values increased from 4.39 to 4.96 and 17.10 to 17.83, respectively, during 90 days of storage. This might be due to lipid oxidation and Maillard reaction that results in decrease in lightness of bran and an increase in yellowness and redness during storage (Park et al 2012). Similar results for color value were reported by Kim et al (2014) who reported decrease in L* value and an increase in a* and b* value in rice bran during storage.

CONCLUSION:

The stabilization of wheat bran resulted in increase in proximate constituents viz., crude protein, fat and ash and decrease in moisture and carbohydrates. Furthermore, increase was observed in total dietary fibre, calcium, phosphorous and magnesium and decrease in phytic acid content. All the stabilization methods resulted in increase in proximate composition, but Microwave stabilization method was most effective in increasing crude protein, fat, ash, minerals, total dietary fibre without affecting the physical appearance of wheat bran.

REFERENCES

Akhter S, Anjum FM and Rehman SU 2005. Effect of zinc and iron fortification on chemical composition of whole flour. *Journal of Research* **16**(2): 95-103.

Anonymous 2022a. https://www.statista.com/statistics/1140239/india-production-volume-of-wheat-during-rabi-season/

Anonymous 2019b. *AICRP on wheat and barley*. pp 27-32. ICAR-Indian Institute of Barley and Wheat Research, Karnal.

AOAC 2005. *Official Methods of Analysis.* 17th edn, Association of Offficial Analytical Chemists, Washington, D.C.

Apprich S, Tirpanalam O and Hell J 2013. Wheat based borefinary-2: Valorization of products. *LWT-Journal of Food Science and Technology* **56**(2): 222-231.

Arumuganathan T, Manikantan MR, Indurani C, Rai CD and Kamal S 2010. Texture and quality parameters of oyster mushroom as influenced by drying method. *International Agrophysics* **24**(4): 339-349.

Bagchi TB, Adak T and Chattopadhyay K 2014. Process standardization for rice bran stabilization and its nutritive value. *Journal of Crop and Weed* **10**(2): 303-307.

Brouns F, Hemery Y, Price R and Anson NM 2012. Wheat aleurone: Separation, composition, health aspects and potential food use. *Critical Reviews in Food Science and Nutrition* **52**(6): 553-568.

Chandrasekaran S, Ramanathan S and Basak T 2013. Microwave food processing-A review. *Food Research International* **52**(1): 243-261.

Chauhan A, Tanwar B and Arenja I 2015. Influence of processing on physico-chemical, nutritional and phytochemical composition of *Carissa Spinarium* (karonda) fruit. *Asian Journal of Pharmaceutical and Clinical Research* **8**(6): 254-259.

Dar, BN 2011. *Antioxidant potential of cereal brans and their potential food applications*. Ph.D. thesis, Punjab Agricultural University, Ludhiana, Punjab, India.

Dong JL, Yang M, Shen RL, Zhai YF, Yu X and Wang Z 2019. Effects of thermal processing on the structural and functional properties of soluble dietary fiber from whole grain oats. *Food Science and Technology International* **25**(4): 282-294.

El-Hady SR 2013. Effect of some thermal processing on stability of rice bran during storage at room temperature. *Journal of Agricultural Research* **39**(1): 92-107.

Ertas N 2016. The effect of microwave, autoclave and hot air oven stabilized wheat bran substitution on nutritional and sensorial properties of flat breads. *Journal of Food and Health Science* **2**(4): 147-158.

Fahmida N, Alauddin M, Rahman T, Zinnah MA, Khan TA and Howlader ZH 2019. Stability-indicating stabilization of rice bran food value by heat treatment. *Journal of Nutritional Health and Food Science* **7**(1): 1-9.

Fardet A 2010. New hypotheses for the health protective mechanisms of whole-grain cereals: What is beyond fibre? *Nutrition Research Reviews* **23**(1): 65-134.

Faria SASC, Bassinello PZ and Penteado MV 2012. Nutritional composition of rice bran submitted to different stabilization procedures. *Brazilian Journal of Pharmaceutical Sciences* **48**(4): 1-7.

Filho CPH, Goneli ALD, Masetto TE, Martins AS and Oba GC 2016. The effect of drying temperatures and storage of seeds on the growth of soybean seedlings. *Journal of Seed Science* **38**(4): 287-295.

Gopinger E, Zieglar V, Catalan AS, Krabbe EL, Elias MC and Xavier EG 2015. Whole rice bran stabilization using short chain organic acid and mixture. *Journal of Stored Products Research* **61**: 108-113.

Hameed BO 2016. *Standardization of drying techniques for the development of tomato slices.* Ph.D. thesis. Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India.

Javed M, Zahoor S, Shafaat S, Mehmooda I, Gul A, Rasheed H, Bukhari AI, Aftab MN and Haq IU 2012. Wheat bran as brown gold: Nutritious value and its biotechnological applications. *African Journal of Microbiology Research* **6**(4): 724-733.

Jia M, Kim HJ and Min DB 2007. Effects of soyabean oil and oxidized soyabean oil on stability of beta carotene. *Journal of Food Chemistry* **103**(3): 695-700.

Karn JF 1991. Chemical composition of forage and faces as affected by microwave oven drying. *Journal of Range Management* **44**(5): 512-515.

Kaur S, Sharma S and Nagi HPS 2011a. Functional properties and anti-nutritional factors in cereal brans. *Asian Journal of Food and Agro-Industry* **4**(2): 122-131.

Kaur S, Sharma S, Dar BN and Singh B 2011b. Optimization of process for reduction of anti-nutritional factors in edible cereal brans. *Journal of Food Science and Technology* **18**(5): 445-454.

Kim SM, Chung HJ and Lim ST 2014. Effect of various treatments on rancidity and some bioactive compounds of rice bran. *Journal of Cereal Science* **60**(1): 243-248.

Kumar P and Thakur NS 2017. Studies on the changes in quality characteristics of Indian horse chestnut flour (*Aesculus indica* Colebr) flour during storage. *Journal of Applied and Natural Science* **9**(1): 445-450.

Laukova M, Karovicova J, Minarovicora L and Kohajdova Z 2020. Effect of thermal stabilization on physico-chemical parameters and functional properties of wheat bran. *Potravinarstvo Slovak Journal of Food Science* **14**(1): 170-177.

Laukova M, Karovicovaa J, Kohajdovaa Z, Babulicovab M, Ruckschlossb M and Veronika L 2016. Potential of bran from various wheat variety for cookies production. *Acta Chimica Slovaca* **9**(2): 95-99.

Lee H, Kim J, Ji DS and Lee C 2019. Effects of heating time and temperature on functional properties of yellow mealworm larvae (*Tenebrio molitor* L.). *Journal of Food Science of Animal Resources* **39**(2): 296-308.

Lv, SW, He, LY and Sun LH 2018. Effect of different stabilization treatments on the preparation and functional properties of rice bran properties. *Czech Journal of Food Science* **36**(1): 57-65.

Mahirah YS, Rabeta MS and Antora RA 2018. Effects of different drying methods on the proximate composition and antioxidant activities of *Ocimum basilicum* leaves. *Food Research* **2**(5): 421-428.

Malekian, F, Rao RM, Prinyawiwatkul W, Marshall WE, Windhauser M and Ahmedna M 2000. Lipase and lipoxygenase activity, functionality and nutrient losses in rice bran during storage.Technical Bulletin 870. pp. 1-69. Lousiana State University Agriculture Centre, Baton Rouge, L.A.

Nagi HPS, Dar BN and Sharma S 2012. Effect of storage period and packaging on the shelf life of cereal bran incorporated biscuits. *American Journal of Food Technology* **7**(5): 310-310.

Nkundabombi MG, Nakimbugwe D and Muyonga JH 2016. Effect of processing methods on nutritional, sensory and physicochemical characteristics of biofortified bean flour. *Journal of Food Science and Nutrition* **4**(3): 384-397.

Nyangena DN, Mutungi C, Imathiu S, Kinyuru J, Affognon H, Ekesi S, Nakimbugwe D and Fiaboe K 2020. Effects of traditional processing techniques on the nutritional and microbiological quality of four edible insect species used for food and feed in East Africa. *Foods* **9**(5): 574-590.

Onipe O, Jideani AIO and Beswa D 2015. Composition and functionality of wheat bran and its application in some cereal food products. *International Journal of Food Science and Technology* **50**(12): 2509-2518.

Park CE, Kim YS, Park KJ and Kim BK 2012. Changes in physico-chemical characteristics of rice bran during storage at different temperatures. *Journal of Stored Products Research* **48**: 25-29.

Patil S, Kar A and Mohapatra D 2016. Stabilization of rice bran using microwave: Process optimization and storage studies. 2016. *Journal of Food and Bioproducts Processing* **99**(1): 204-211.

Premkumari S, Balasasirekha R, Gomathi K, Supriya S, Jagmohan R and Alagusunduram K 2012. Development and acceptability of fibre enriched ready mixes. *International Journal of Pure and Applied Science Technology* **9**(2): 74-83.

Sadasivam S and Manickam A 2008. Anti-nutritional factors In: *Biochemical Methods*, pp 215-216. New International (IP) Ltd, New Delhi, India.

Sharma S, Kaur S, Dar BN and Singh B 2014. Storage stability and quality assessment of processed cereal brans. *Journal of Food Science and Technology* **5**(3): 583-588.

Sharon CL and Usha V 2006. Effect of storage on nutritional and sensory qualities of bread fruit flour. *Journal of Food Science and Technology* **43**(3): 256-258.

Siswanti, Anandito RBK, Nurhartadi E and Iskander BD 2019. Effect of various heat treatments on physical and chemical characteristics of red rice bran (*Oryza nivara* L.) rojolele. *Material Sciences and Engineering* **633**(1): 46-52.

Sudha ML, Ramasarma PR and Rao V 2011. Wheat bran stabilization and its use in the preparation of high fibre pasta. *Food Science and Technology International* **17**(1): 47-53.

Sun, Y, Lv F, Tian J, Ye XQ, Chen J and Sun P 2019. Domestic cooking methods affect nutrient, phytochemicals, and flavor content in mushroom soup. *Food Science and Nutrition* **7**(6): 1969-1975.

Thanonkaew A, Wongyai S, David J and Decker EA 2012. Effect of stabilization of rice bran by domestic heating on mechanical extraction yield, quality and antioxidant properties of cold pressed rice bran oil (*Oryza Saltive* L). *LWT- Journal of Food Science and Technology* **48**(2): 231-236.

Tuncel B, Yilmaz N, Kocabiyik H and Uygur A 2014. The effect of infrared stabilized rice bran substitution on B vitamins, minerals and phytic acid content of pan breads: Part II. *Journal of Cereal Science* **59**(2): 162-166.

Younas A, Bhatti MS, Ahmed A and Randhawa MA 2011. Effect of rice bran supplementation on cookie baking quality. *Pakistan Journal of Agricultural Science* **48**(2): 129-134.

Zhong Y, Wang Z and Zhao Y 2015. Impact of radiofrequency, microwave and high hydrostatic pressure at elevated temperatures on the nutritional and anti-nutritional components in black soybeans. *Journal of Food Science* **80**(12): 2732-2739.

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Relationship between Climate Change Perception of Local Communities, Agriculture and Gender Variations in Fozal Valley of Kullu District, Himachal Himalayas

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Abstract: The climate change perception of local communities is an integral component of the decision-making process. Several attempts have been made to understand the local communities' perceptions towards climate change in the Indian Himalaya. However, limited information is available on how gender affects the local communities' climate change perception. The present study was an attempt to cover this knowledge gap. A semi-structured questionnaire survey was conducted in 4 villages in the upper Beas valley of Himachal Pradesh to document their perception towards climate change impacts in the region. The local inhabitants perceive that advancing developmental activities are enhancing the climate change impacts in the valley. The inhabitants are experiencing changes in local climate conditions such as an increase in annual temperature while precipitation, annual snowfall, and number of chill units are decreasing, which is a determining factor for a higher yield of traditional mountain crops. The annual average temperature, average annual maximum, and minimum temperature for the period 1990-2010 also show an increasing trend. A significant variation was noted between men and women's responses to climate change. The present study suggests that local communities' suggestions and issues need to be incorporated while designing and implementing climate change adaptation and mitigation strategies.

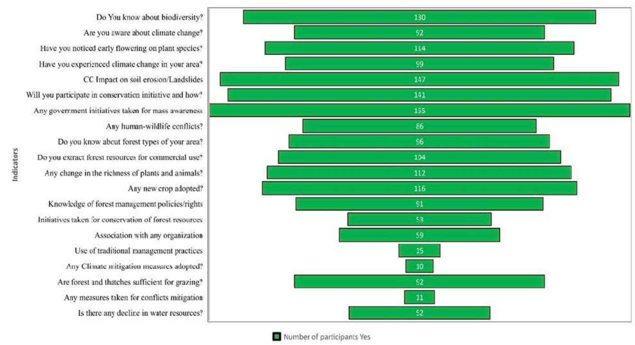
Keywords: Community perception, Climate change, Gender, Fozal valley, Adaptation and mitigation

The Himalaya and the people inhabiting the Himalayan region are perceived to be the most vulnerable to the impacts of global and regional climate change. Thus, assessing the local community's perception of climate change is critically important for designing the adaptation and mitigation strategies. Climate change perception is determined by the social, cultural, economic, and institutional make-up of the surrounding environment (Carr 2008). A large body of literature exists that clearly demonstrates that within the community, perception was influenced by factors such as gender, ethnicity, and caste system and it is observed that women perceive the climate change challenge differently. In the Indian Himalayan Region, women are more dependent on natural resources and are at the front of climate change challenges (Nellemen et al 2011). Adzawla et al. (2019) also highlighted that climate change severely impacts women due to their low adaptive capacity. In the eastern Himalaya, women have admitted that climate change has negatively impacted their regular practices of collection of forest foods, crop harvesting, fermenting, and food storage (Bhadwal et al 2019). Parties to the UNFCC have also identified the role of women in climate change responses due to their traditional knowledge and direct relationship with nature. It has also emphasized developing gender-responsive national climate policies. Understanding the socioeconomic status of women in mountain communities and ensuring power equity are thus critical for effective adaptation and mitigation strategy implementation (Drenkelman 2010, Eastin 2018). The women in the Indian Himalaya are responsible for all household activities, livestock management, and agricultural activities and should be placed at the center of climate change adaptation and mitigation planning due to their intense involvement with nature and its resources (Nellemen et al 2011). Women's underrepresentation in decision-making and adaptation planning processes may result in the continuation of current vulnerabilities in the future. To address this issue, the present study aims to present the varied inter-group responses of local communities with a focus on how women's responses differ from men's responses towards climate change and the various adaptation strategies as suggested by the local communities.

MATERIAL AND METHODS

Study area: Fozal Valley is a biodiversity-rich region located in the Kullu district of Himachal Pradesh. The valley is dominated by an agro-pastoral economy, with agriculture, horticulture, and animal husbandry as the main sources of income, followed by employment in the private and public sector. Almost every household owns agricultural land and livestock for their day-to-day requirements. Apple (*Malus pumila*) and cash crops (*Phaseolus vulgaris, Brassica oleracea, Allium sativum*, *Pisum sativum* and *Diasporus kaki*) are the main agricultural crops. Agriculture is of subsistence type and is dependent on climatic conditions for good yield. Agricultural fields are too small for mechanization to increase production. Apart from this, the collection and trade of important medicinal and aromatic plants provides vocational income to the rural communities of the valley. The region is undergoing moderate urbanization and a transition from the traditional agriculture-based economy to modern livelihood options such as small-scale business development. The valley has been inhabited for generations by indigenous and tribal communities like *Jehcchas, Gaddis, Gurjars* along with other communities The social structure of the area represented a higher proportion of younger population in the age group 18-45 years. However, the older population with age between 50-80 years are always preferred to be a better information resource for climate change perception exercises in the IHR as they are witnesses of gradually changing climate conditions at the local level. The traditional knowledge of local communities can provide valuable information and management options to mitigate climate change in their areas.

Household survey: The household surveys were conducted in four villages of Fozal valley, Kullu district, Himbari, Dhara, Runga, and Beasar (Fig. 1) and collected information from 127 participants, 61 male and 66 female, using semi-structured questionnaires. Different indicators were used for collecting information on the socioeconomic status such as age, gender, education, income source, and perception of local communities. However, only 22 indicators through 3 responses; Yes, No, and Can't say are discussed in this paper (Graph 1).



Graph 1. Indicators used to assess perception of local communities towards climate change

Respondents above the age of 18 or the head of the household were preferred for information collection. Key informants in each village, such as the village head (Sarpanch, Pradhan, Mahila mandal, or affiliated to any local governing body) were identified and interviewed using the same semi-structured questionnaire. The semi-structured questionnaire was followed by an open-ended discussion to document any additional information not included in the questionnaire. The survey was conducted as part of a larger study focused on the assessment and valuation of high-altitude ecosystems in Himachal Pradesh in relation to climate change. All information was collected with the consent of local communities and is shared with them, and the communities understand and agree that some of the

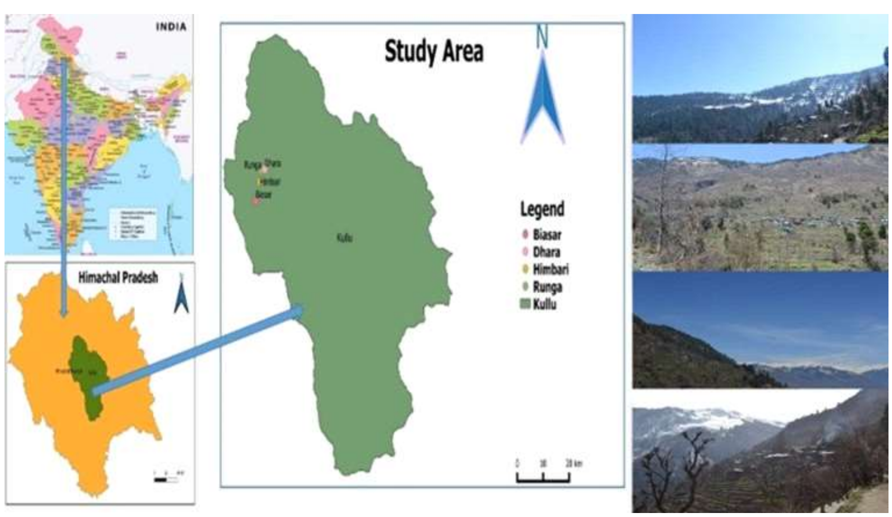


Fig. 1. Right corner: Map of study area; Left corner from top to bottom: General view of Himbri, Beasar; Dhara and Runga

information may be published with proper acknowledgment.

Analysis of socioeconomic data and response to climate change: The collected data was analyzed by calculating the percentage for each indicator. A mixed effects model was used to explore the possible effect of socioeconomic factors on climate change perception. The study includes 7 explanatory variables in the analysis-age, gender, education level of respondent, number of crops cultivated, number of sources of income, land type, and village size-which were referred to as independent variables or predictor variables, while response variables are the variables one would be interested in predicting or forecasting. Village size was used as a fixed variable in the analysis. A set of 4 questions from the semi-structured interview was selected for the analysis. A negative, positive, or neutral score was assigned for each response to the questions, which were later added to calculate a mean perception score. Perception scores of 1 were considered negative. Scores > 1 were considered positive, scores of 0 were considered neutral (Suryawanshi et al. 2014). The range of the mean perception score varies from -4 to 4, with -4 representing the most negative perception and 4 representing the most positive perception.

Mixed effect model: A mixed effect model was used to identify the factors influencing the difference in perception of men and women towards climate change. The perception score was used as a response variable and the socioeconomic factors-age, education, number of crops cultivated, number of sources of income, land type, and sources of income were used as explanatory variables. Village size was used as a fixed variable and gender was used as a random effect. The lmer command from the package lme4 in R version 3.3.2 (2016-10-31) was used. Each model included individual and village-level explanatory variables (Johnson and Omland 2004, Suryawanshi et al 2014). The effect of gender on perception of climate change was interpreted based on the parameter estimate from this model. Residuals of this model were regressed against gender to assess its effect on perception. The Chi square test was used to test the significance of the obtained response.

Recent studies have collected information on traditional knowledge in the eastern Himalayas (Sharma and Shrestha 2016, Chaudhary and Bawa 2011, Chaudhary et al 2011) and western Himalayas (Sharma and Uniyal 2020, Shukla et al 2019, Pandey et al 2018, Basannagari et al 2013). A total of 22 indicators were used to assess the perception of local communities towards climate change in the Fozal valley (Fig. 1). The information was collected through 3 responses; Yes, No, and can't say. The analysis reveals that a significant proportion of respondents are aware of biodiversity (74.2%) and forest types (54.85%) of their area and half of the respondents are experiencing climate change (56.57%) in the form of early flowering in agricultural and horticultural crops (65.14%), soil erosion or landslides (84%), and change in species richness of plants and animals (64%). More than half of the respondents have adopted new crops (66.28%). Although a few respondents admitted exploiting forest resources on smaller scales, a large portion of them expressed their willingness to participate in the conservation initiatives (80.57%).

RESULTS AND DISCUSSION

Local perception towards climate change: A significant proportion of the community (72%) perceive that mainly developmental activities, road construction, dam construction, infrastructural developments, intensified tourism and agricultural activities, land use change, deforestation, and soil degradation through intensive use of pesticides in agricultural fields are enhancing the pressure on the carrying capacity of natural resources and thus resulting in changes in climate conditions, temperature, precipitation, and snowfall pattern (Fig. 2). However, 22% of the respondents believe that developmental activities along with natural factors are responsible for this change in climatic conditions. The majority of the villagers mentioned that the temperature has become warmer and snowfall has decreased in their area in the last decade. The local communities' perception that the climate is warming is in accordance with various other studies claiming that the temperature is showing an increasing trend while precipitation and annual snowfall are showing a decreasing trend in the district (Sen and Aditya 2015, Chaudhary and Bawa 2011, Rana et al 2011).

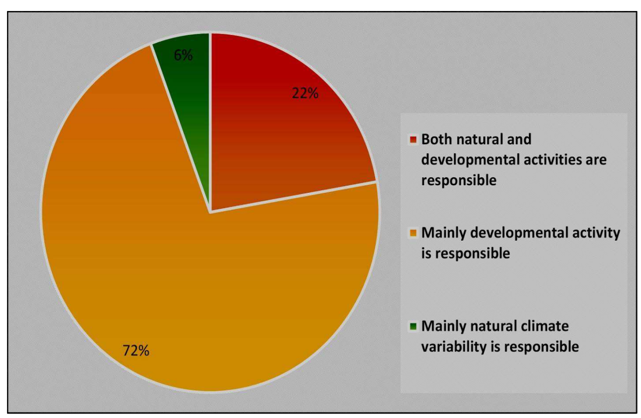


Fig. 2. Climate change perception of local communities

Climate change impact on forest resource availability and agriculture and horticulture productivity: Most of the respondents admitted a decrease in the forest resource availability, mostly due to increased encroachment in the forest area, land use change, and conversion of forest area to agricultural fields (Fig. 3). The changing climate conditions are making the environment suitable for invasive species and changing the natural community composition of the forest. Increased temperature trends and decreased snowfall have also resulted in changes in agricultural patterns such as crop selection, seed sowing season, and harvesting time. Farmers are moving towards cash crop cultivation (rajmah, cauliflower, garlic, peas, diasporus kaki). The local communities perceive that there is a decrease in the number of chill units as compared to previous years. Chilling units are essential for many traditional agricultural and horticultural crops in the mountain regions. A decrease in chill units is also one of the factors influencing agricultural practises to change. In lower elevations, farmers have switched to alternate crops or shifted their orchards to higher elevations.

Differences in perception towards climate change as a variation of gender: Men and women have culturally designated roles in the surveyed area. Women were intensely involved in household practices and livestock management and agricultural practices. Henceforth, women are perceived to be highly vulnerable to climate change. A significant difference is noted between men and women's perception towards climate change (Fig. 3). More than 50% of the women respondents have perception score in the range 0 to -4 indicating a comparatively negative perception towards climate change impacts. 40.38 % of the total variance of the random effects is attributed to the nested effects (Chi-square, X-squared = 47.005, p-value = 9.422e-07). The random variable gender was negatively correlated with age, education, total sources of income, total crops cultivated. The negative perception score was supported by the views that there is loss in agricultural productivity, drying of tradition water sources, increased incidences of natural disasters, change in flowering and fruiting phenology of agricultural crops and adoption of new crop plants preferably cash crops due to climate change.

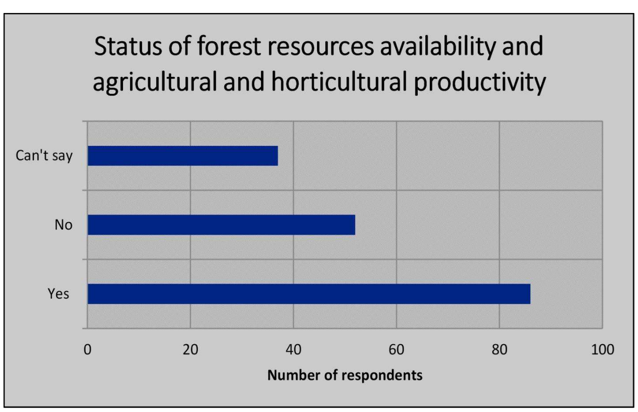


Fig. 3. Climate change impact on forest resource availability and agriculture and horticulture productivity

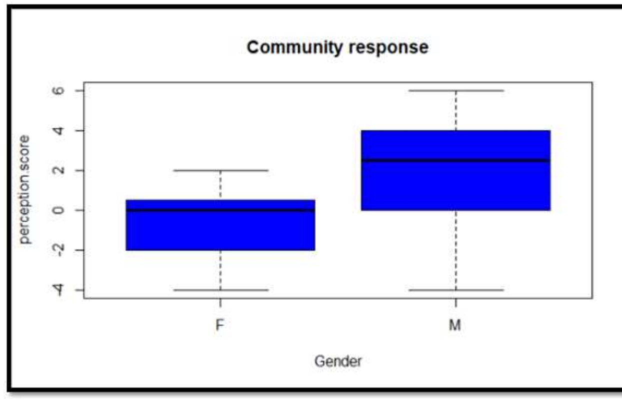


Fig. 4. Perception of climate change from gender perspective

CONCLUSION

A large proportion of the surveyed population is aware of climate change, biodiversity and forest types of their area, mainly dominant conifers (Cheed), Quercus forest (Kharshu, Banjh) and Cedrus forest (Deodar). However, the species richness has decreased substantially. Collection of forest resources is a regular practice in the valley. However, most of the collected produce is used for meeting household demands rather than economic gains. The local communities are experiencing climate change through irregular and extreme rainfall patterns, a reduction in the number of winter days, increased landslide incidences, and the drying up of natural water resources. The local communities reflected that many of the farmers are shifting to modern agricultural practices, use of intensive pesticides, and mixed farming of horticultural and cash crops to cope with climate change. Traditional crops like *Sesamum indicum*, *Vigna mungo*, *Gossypium sp*., pulses, *Indigofera cassioides* (Kathi), *Paspalum scrobiculatum* (Kodra) and *Lens culinaris* are now not grown due to poor yield, productivity, reduced market demand and changed climatic conditions. The traditional disease and pest tolerant varieties of wheat, maize, and paddy are now being replaced by hybrid/high yielding varieties (HYV). The hybrid varieties are more prone to diseases and require a huge amount of pesticide application. This shift to modern agriculture has resulted in the complete erosion of some of the important genetic resources and decreased soil fertility. A few of the crops which have suffered a loss in productivity and are rarely cultivated by farmers due to climate change include *Eleusine coracana* (Marua, Mandal), *Setaria italica* (Kangani), *Panicum miliaceum* (Cheena) and other crops such as grain amaranth, grain chenopods, buckwheat, barley (hulled and hull less). Changing climate conditions have also made the environment suitable for some of the invasive species (*Ageratum spp., Parthenium spp.*) to grow in the area. Human population growth necessitates more resources for survival, resulting in human encroachment on forest areas and increased conversion of forest areas to agricultural and grazing lands, as well as incidents of human-wildlife conflict with wild boars and brown bears. Night guarding, occasional killing of wildlife, were some of the measures listed for conflict mitigation by the local communities. Formally designed plantation activities were observed in the survey area, but gaps in knowledge of forest management policies and rights at the grassroot level were discovered. It demonstrates the potential for involving local communities in management practices. Despite their close relationship with the area's natural resources, women are less aware of climate change adaptation measures. Women's participation in decision-making and adaptive strategies is under represented. It reflects on the scope of improvising the adaptation strategies with equal representation of gender in the planning process.

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REFERENCES

Adzawla W, Azumah, SB, Anani PY and Donkoh SA 2019. Gender perspectives of climate change adaptation in two selected districts of Ghana. *Heliyon* **5**(11):

Basannagari B and Kala CP 2013. Climate change and apple farming in Indian Himalayas: A study of local perceptions and responses. *PLoS One* **8**(10): 77976.

Bhadwal S, Sharma G, Gorti G and Sen S 2019. Livelihoods, gender and climate change in the Eastern himalayas. *Environmental Development* **31**: 68-77.

Carr ER 2008. Between structure and agency: Livelihoods and adaptation in Ghana's Central Region. *Global Environmental Change* 18: 689-699.

Chaudhary P and Bawa KS 2011. Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biology Letters* **7**(5): 767-770.

Chaudhary P, Rai S, Wangdi S, Mao A, Rehman N, Chettri S and Bawa, KS 2011. Consistency of local perceptions of climate change in the Kangchenjunga Himalaya landscape. *Current Science* 504-513.

Dankelman I 2010. (eds). *Gender and climate change: An introduction*. London: Earthscan

Eastin J 2018. Climate change and gender equality in developing states. *World Development* **107**: 289-305.

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Detection of Nontuberculous Mycobacterial Species in Mastitic Milk Samples from Cattle and Buffaloes by PCR and PCR-Restriction Fragment Length Polymorphisms (PRA)

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***Abstract*:** The present study was conducted to detect nontuberculous mycobacterial species (NTM) in milk samples with a history or incidence of mastitis from cattle. A total of 30 milk samples were collected from cattle and buffaloes from dairy farms in Ludhiana. The presence of NTM species was detected by polymerase chain reaction (PCR) and PCR-restriction fragment length polymorphisms (PRA) using two restriction enzymes *BstEII* and *HaeIII*. Out of 30 milk samples, *M. smegmatis* (n=2) and *M. kansasii* (n=1) were detected positive by both PCR and PRA. The results show the role on NTM in mastitis in which could also lead to a possible transmission to human being.

***Keywords*:** *M. kansasii*, *M. smegmatis*, Nontuberculous Mycobacteria (NTM), PCR, PRA

Nontuberculous mycobacteria (NTM) are ubiquitous organisms and cause disease in animals and humans (Kankya et al 2011). Some NTM species are zoonotic in nature with a wide range of mammalian hosts (Konuk et al 2007). They are widely distributed in environment mostly found in soil and water sources and have also been considered as potential pathogens for animals and humans (Bercovier and Vincen 2001). NTM species have also been reported to cause cross-reactive immune responses that interfere with the diagnosis of bovine tuberculosis (bTB) in both livestock and wildlife (Gcebe and Hlokwe 2017). In addition, these organisms have been recognized as significant cause of infection in both immunocompetent and immunocompromised patients (Bodle et al 2008). The transmission to humans from the environment can occur by ingestion of contaminated milk, food, water etc. (Konuk et al 2007). Faulty pasteurization, contamination during milking and bottling process may favor the survival of certain bacterial species including nontuberculous mycobacteria (Sgarioni et al 2014). Pulmonary infection caused by nontuberculous mycobacteria are recognized worldwide. Disease including mastitis in cattle and cutaneous mycobacterial granuloma in cats and dogs is caused by number of organisms such as *Mycobacterium chelonei, M. fortuitum, M. kansasii, M. phlei, M. smegmatis* and *M. thermoresistible* (Waters et al 2006). The NTM species can be identified based on their phenotypic characteristics of biochemical testing, pigment production, growth characteristics and colonial morphology but these traditional methods are time-consuming. Thus, more advanced techniques for rapid identification of NTM such as commercial nucleic acid probes, 16S ribosomal DNA sequencing, (Butler and Guthertz 2001) and PCR-restriction enzyme pattern analysis (PRA) methods have been developed. The emergence of NTM, as significant environmental pathogens, has attracted more attention (Moore et al 2010). Research on NTM transmission sources and mechanisms will help epidemiologists better understand the diseases carried on by these mycobacteria. Some works show that animal products such as milk, seems to be reservoir of mycobacteria and may pose a risk to the public (Carvalho et al 2009). Keeping in view the possible role of NTM in causing mastitis was evaluated in this study

MATERIAL AND METHODS

Sample collection: Raw milk samples (n=30) from cattle (n=18) and buffaloes (n=12) with a history or incidence of mastitis were collected from dairy farms Ludhiana.

Molecular Diagnosis

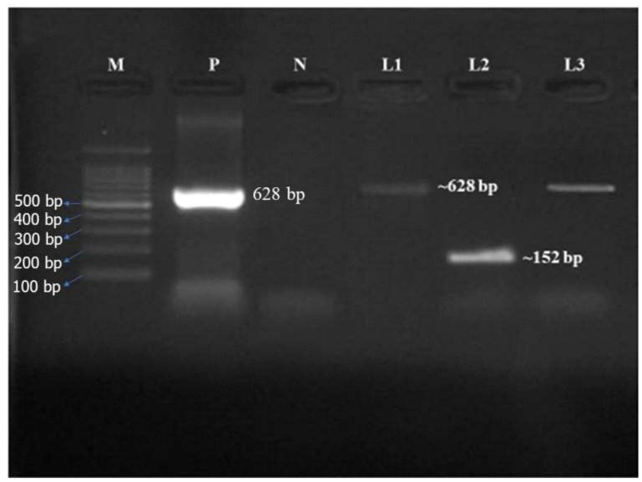
Polymerase chain reaction (PCR): DNA from the milk samples was extracted using PowerFood Microbial DNA isolation kit (MoBio). The extracted DNA was then amplified using specific primers for *M. kansasii*, *M. smegmatis*, *M. vaccae*, *M. fortuitum*, *M. intracellulare* (Table 1). In addition to the test sample DNA, a known positive control DNA was also amplified using specific primers in a reaction volume of 25 µl, which also contained 12.5 µl of GoTaq® Green Master mix, 1 µl of forward primer (10 pmol/l), 1 µl of reverse primers (10 pmol/l), 2.5 l of nuclease-free water, and 8 µl of DNA template.. Thermal cycling was performed in research thermal cycler and cycling conditions were as follows, initial denaturation at 94°C for 5 minutes, followed by 30 cycles of denaturation at 94°C for 1 minute, annealing of primers at 60°C for 1 minute, extension at 72°C for 1 minute and final extension at 72°C for 10 minutes. The amplified PCR products were then run by agarose gel electrophoresis and visualized in Gel Documentation System (Alpha Innotech).

PCR-Restriction fragment length polymorphism analysis (PRA): Initial step was the amplification of *hsp*65 gene. For the amplification, the reaction volume of 25 µl was made containing 12.5 µl of GoTaq® Green Master mix, 1 µl each of forward and reverse primers (10 pmol/µl), 2.5 µl of nuclease free water and 8 µl of DNA template along with the test sample DNA, a known positive control DNA was also amplified using specific primers (Table 1). The reaction was subjected to 45 cycles of amplification which includes denaturation for 1 min at 94°C, annealing for 1 min at 56°C and extension for 1 min at 72°C and the final extension was done at 72°C for 10 min. Restriction enzymes *BstEII* and *HaeIII* were used to digest the 439 bp amplified PCR product. RFLP of the standard cultures of *M. kansasii, M. smegmatis, M. vaccae, M. fortuitum* and *M. intracellulare* was also done. The digestion of PCR products with two restriction enzymes was done as per Telenti et al (1993). The products were then visualized using 1.5% agarose gel and visualized in Gel Documentation system 40 (AlphaImager 3400HP, AlphaInnotech). The results were interpreted as per Telenti et al (1993) and PRA site (http://app.chuv.ch/prasite/index.html).

RESULTS AND DISCUSSION

Direct detection of NTM from milk samples by PCR : The 30 mastitic milk samples were subjected to PCR for detection of NTM. Out of 30 samples 3 samples were positive. *M. kansasii* (n=1) and *M. smegmatis* (n=2) were detected (Fig. 1). Siqueira et al (2016) also detected *M. smegmatis* from raw milk samples collected from cattle.

Differentiation of NTM by PCR-Restriction fragment length polymorphism analysis (PRA): An efficient and accurate method for identifying various mycobacteria



M: marker (100 bp DNA ladder), P: positive (*M. smegmatis*), N: negative
L1 and L3: Positive sample for *M. smegmatis* from milk samples
L2: Positive sample for *M. kansasii* from milk sample

Fig. 1. Agarose gel electrophoresis showing an amplicon of~ 628 bp of *M. smegmatis* and *M. kansasii*~152 from milk samples

Table 1. Primer sequences of different NTM species and *hsp*65 gene

Organism	Primer	Primer sequence	Product size	Reference
M. kansasii	Forward (ITS)	5- GCAAAGCCAGACACACTATTG -3	152 bp	Esfahani et al (2012)
	Reverse (ITS)	5- AAGAACACGCTACCCGTAGG - 3		
M. smegmatis	Forward	5- ACCATGTCTATCTCAGTGTGCT -3	628 bp	Brahma et al (2017)
	Reverse	5- ACGCTCGAGGTCCACTACAA - 3		
M. fortuitum	Forward	5- GACTGCCAGACACACTATTGG -3	172 bp	Park et al (2000)
	Reverse	5- GTGAGACCACACGATTCTGC - 3		
M. intracellulare	Forward	5- CCT TTA GGC GCA TGT CTT TA -3	450 bp	Park et al (2006)
	Reverse	5- ACC AGA AGA CAT GCG TCT TG - 3		
M. vaccae	Forward (ITS-F1)	5- CGAAGCCAGTGGCCTAACCC – 3	500 bp	Park et al (2006)
	Reverse (ITS-R)	5- TGGATCCTGCCAAGGCATCCACCAT -3		
*hsp*65	Forward (TbII)	5- ACCAACGATGGTGTGTCCAT – 3	439 bp	Telenti et al (1993)
	Reverse (Tb12)	5-CTTGTCGAACCGCATACCCT – 3		

species is PCR-RFLP (PRA). Based on the separation of DNA segments by restriction endonucleases, PCR-PRA generates fragments that are used to categorize different species of mycobacteria. The nucleotide sequence of locus hsp65 was the method's primary target. In PRA method, 439 bp PCR product of *hsp*65 gene (present in all the mycobacterial species which can be used for the differential identification of Mycobacterial species as per Telenti et al (1993) and Chimara et al (2008) and was amplified and digested with the *BstEII* and *HaeIII* restriction enzymes. The restriction patterns were analyzed for species identification (Saifi et al 2013).

PCR for presence of *hsp65* gene: Among the clinical samples processed, three out of 30 mastitic milk samples (10%), were positive for *hsp*65 gene (Fig. 2). Similar study was conducted by Telenti et al (1993) in which 65-kDa protein (*hsp*65 protein) was used for differentiation of mycobacterial species. Chang et al. (2002) also used *hsp*65 gene PCR product (439 bp) for identification of NTM up to species level. Wang et al (2005) used same procedure for identification of RGM (rapidly growing mycobacteria) from clinical samples.

Restriction enzyme analysis of the *hsp65* gene : The PCR product of *hsp*65 gene amplicon of standard cultures along with the isolates was subjected to digestion with restriction enzyme using *BstEIII* and *HaeIII*. Specific band patterns were seen which helped in the species level differentiation of these *Mycobacteria* (as per the algorithm given by Telenti et al. (1993) and PRA site (http://app.chuv.ch/prasite/index.html). The standard cultures used in this study showed the following RFLP patterns, *M. smegmatis* (*BstEIII*) (235/130/85) and *M. smegmatis* (*HaeIII*) (145/125/60), *M. kansasii* (*BstEIII*) (245/220) and *M. kansasii* (*HaeIII*) (140/105/70), *M. fortuitum* (*BstEIII*) (245/125/80) and *M. fortuitum* (*HaeIII*) (155/135), *M. intracellulare* (*BstEIII*) (245/125/100) and *M. intracellulare* (*HaeIII*) (155/150/60), *M. vaccae* (*BstEIII*) (440) and *M. vaccae* (*HaeIII*) (140/115/70) (Slathia et al 2022). From 30 milk samples, 3 samples were positive for *hsp*65 gene out of which 1 sample was identified as *M. kansasii* having the RFLP pattern as 245/220 bp when digested with *BstEIII* and 140/105/70 bp when digested with *HaeIII* and two samples were identified as *M. smegmatis* having the RFLP pattern as 245/145/85 bp when digested with *BstEIII* and 160/130 bp when digested with *HaeIII* (Fig. 3). A collection of opportunistic mycobacterial species that do not belong to the M. TB complex are known as nontuberculous mycobacteria (Brode et al 2017). Prior research on raw milk and dairy products suggested that some developing nations have high levels of NTM species (Konuk et al 2007).

Similar study was conducted by Sgarioni et al. (2014) detected 15 percent *M. smegmatis* from milk samples**.** Siqueira et al. (2016) described *M. smegmatis* as a cause of pyogranulomatous mastitis and isolated *M. smegmatis* from 68.75% milk samples. *M. smegmatis* is widely found in water and soil and makes up the majority of the NTM. *M. smegmatis* has not been mentioned in disseminated infections, even in immunocompromised animals, despite the possibility that this species is connected to posttraumatic soft-tissue infections (Bohsali et al 2010). *M. kansassii* along with other NTM species *viz*., *M. terrae*, *M. agri* and *M. haemophilum* were present in 35 samples of raw milk tested by in Turkey for

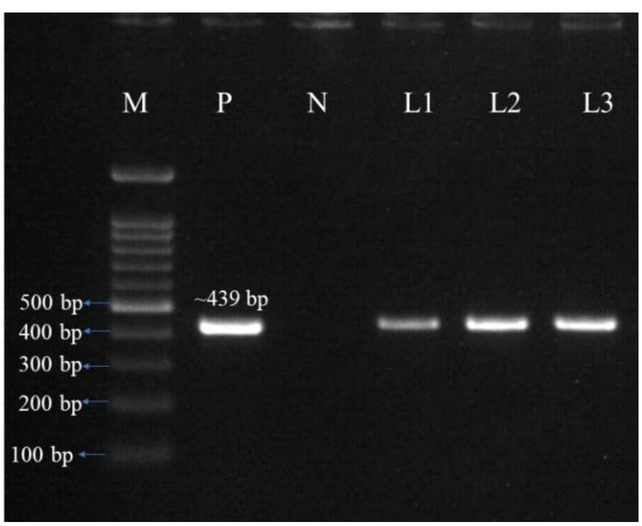
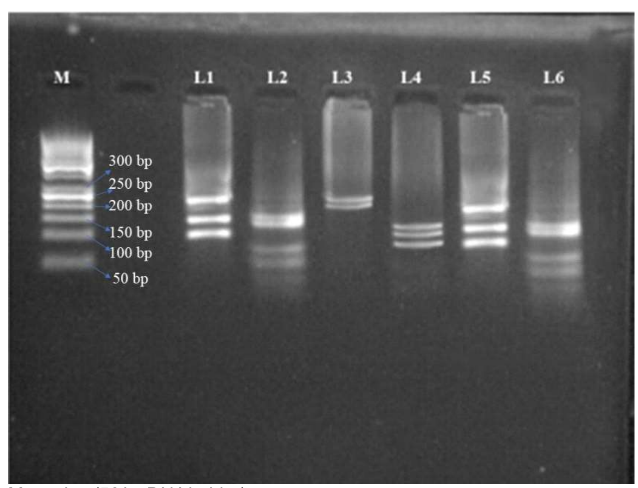


Fig. 2. Agarose gel electrophoresis showing an amplicon of ~439 bp from milk samples



M: marker (50 bp DNA ladder)
L1: *M. smegmatis* (*BstEIII*)(235/130/85)
L2: *M. smegmatis* (*HaeIII*) (145/125/60)
L3: *M. kansasii* (*BstEIII*) (245/220)
L4: *M. kansasii* (*HaeIII*)(140/105/70)
L5: *M. smegmatis* (*BstEIII*)(235/130/85)
L6: *M. smegmatis* (*HaeIII*) (145/125/60)

Fig. 3. Agarose gel electrophoresis showing RFLP pattern of NTM species in milk samples

the presence of mycobacteria using phenotypic techniques and verified by PCR-PRA (Konuk et al2007).

CONCLUSIONS

M. smegmatis is the most predominating NTM followed by *M. kansasii* in milk samples. NTM can cause disease in animals and consumption of milk from infected animals remains a risk factor for exposure to NTM. The implementation of measures that prevent milk contamination during and post milking with NTM are also needed to avoid spreading of diseases.

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REFERENCES

Bercovier H and Vincent H 2001. Mycobacterial infections in domestic and wild animals due to *Mycobacterium marinum, M. fortuitum, M. chelonae, M. porcinum, M. farcinogenes, M. smegmatis, M. scrofulaceum, M. xenopi, M. kansasii, M. simiae* and *M. genavense*. *Revue Scientifique et Technique* **20**(1): 265-290.

Bodle E, Cunningham JA, Della-Latta P, Schluger NW and Saiman L 2008. Epidemiology of nontuberculous mycobacteria in patients without HIV infection, New York City. *Emerging Infectious Diseases* **14**(3): 390-396.

Bohsali A, Abdalla H, Velmurugan K and Briken V 2010. The non-pathogenic mycobacteria *M. smegmatis* and *M. fortuitum* induce rapid host cell apoptosis via a caspase-3 and TNF dependent pathway. *BMC Microbiology* **10:** 237.

Brahma D, Narang D, Chandra M, Gupta K, Singh A and Kaur G 2017. Diagnosis of Mycobacterial infections (Tuberculosis and Paratuberculosis) in tissue samples using molecular (inhouse multiplex PCR, PCR and TaqMan real-time PCR), histopathology and immunohistochemical techniques. *Tropical Biomedicine* **34**(4): 911-27.

Butler WR and Guthertz LS 2001. Mycolic acid analysis by high-performance liquid chromatography for identification of mycobacterium species. *Clinical Microbiology Reviews* **14:** 704-726.

Carvalho A, Silva Jr. A, Campos VEB and Moreira MAS 2009. Short communication: Detection of *Mycobacterium avium* subspecies *paratuberculosis* by polymerase chain reaction in bovine milk in Brazil. *Journal of Dairy Science* **92**: 5408-5410.

Chang CT, Wang LY, Liao CY and Huang SP 2002 Identification of nontuberculous Mycobacteria existing in tap water by PCR-restriction fragment length polymorphism. *Applied and Environmental Microbiology* **68**(6): 3159-61.

Chimara E, Ferrazoli F, Ueky SYM, Martins MC, Durham AM, Arbeit RD and Leao SC 2008. Reliable identification of mycobacterial species by PCR-restriction enzyme analysis (PRA)-*hsp65* in a reference laboratory and elaboration of a sequence-based extended algorithm of PRA-*hsp65* patterns. *BioMed Central Microbiology* **8**: 48.

Esfahani BN, Yazdi HR, Moghim S, Safaei HG and Esfahani HZ 2012. Rapid and accurate identification of *Mycobacterium tuberculosis* complex and common non-tuberculous mycobacteria by multiplex real-time PCR targeting different housekeeping genes. *Current Microbiology* **65**: 493-499.

Gcebe N and Hlokwe TM 2017. Nontuberculous mycobacteria in South African wildlife: Neglected pathogens and potential impediments for bovine tuberculosis diagnosis. *Frontiers in Cellular and Infection Microbiology* **1**: 74-84.

Kankya C, Muwonge A, Djonne B, Munyeme M, Opuda-Asibo J, Skjerve E, Oloya J, Edvardsen V and Johansen TB 2011. Isolation of non-tuberculous mycobacteria from pastoral ecosystems of Uganda: public health significance. *BioMed Central Public Health* **11**: 320.

Konuk M, Korcan E, Dulgerbak S and Altindis M 2007. Isolation and identification of Mycobacteria from raw milk samples in Afyonkarahisar district of turkey. *International Journal of Food Microbiology* **115**: 343-347.

Moore JE, Kruijshaar ME, Ormerod LP, Drobniewski F and Abubakar I 2010. Increasing reports of non-tuberculous mycobacteria in England, Wales and Northern Ireland, 1995-2006. *BMC Public Health* **10:** 612-617.

Slathia P, Narang D and Chandra M 2022. Detection of Nontuberculous Mycobacterial species from tissue samples of cattle and buffaloes by PCR and PRA (PCR-RFLP). *Indian Journal of Animal Research* **56**(6): 730-735.

Park H, Jang H, Kim C, Chung B, Chang CL, Park SK and Song S 2000. Detection and identification of mycobacteria by amplification of the internal transcribed spacer regions with genus- and species-specific PCR primers. *Journal of Clinical Microbiology* **38**(11): 4080-485.

Park H, Kim C, Park KH and Chang CL 2006. Development and evaluation of triplex PCR for direct detection of mycobacteria in respiratory specimens. *Journal of Applied Microbiology* **100**(1): 161-167.

Roosevelt JJ, Jenkins DE and Hsu KHK 1965. Raw milk as a source of mycobacteria. *Canadian Journal of Microbiology* **12**(10): 979-984.

Saifi S, Jabbarzadeh E, Bahrmand AR, Karimi A, Pourazar S, Fateh A, Masoumi M and Vahidi E 2013. *Hsp65*-PRA identification of non-tuberculosis mycobacteria from 4892 samples suspicious for mycobacterial infections. *Clinical Microbiology and Infection* **19**: 723-728.

Schinnick T 1987. The 65-kilodalton antigen of *Mycobactenium tuberculosis*. *Journal of Bacteriology* **169**: 1080-1088.

Sgarioni SA, Hirata RDC, Hirata MH, Leite CQF, Prince KA, Leite SRA, Filho DV, Siqueira VLD, Caleffi-Ferracioli KR and Cardoso RF 2014. Occurrence of *Mycobacterium bovis* and non-tuberculous mycobacteria (NTM) in raw and pasteurized milk in the northwestern region of Parana, Brazil. *Brazilian Journal of Microbiology* **45**(2): 707-711.

Siqueira VLD, Caleffi-Ferracioli KR and Cardoso RF 2014. Occurrence of *Mycobacterium bovis* and non-tuberculous mycobacteria (NTM) in raw and pasteurized milk in the northwestern region of Parana, Brazil. *Braz*alian Journal of Microbiology **45**(2): 707-711.

Siqueira FM, Lopes CE, Snell GG and Gomes MJP 2016. Identification of *Mycobacterium smegmatis* in bovine mastitis. *Acta Scientiae Veterinariae* **44**(1): 166.

Telenti A, Marchesi F, Balz M, Bally F, Bottger EC and Bodmer T 1993. Rapid identification of mycobacteria to the species level by polymerase chain reaction and restriction enzyme analysis. *Journal of Clinical Microbiology* **31**(2): 175-178.

Wang SX, Tay L and Sng LH 2005. Rapid identification of pathogenic rapidly growing mycobacteria by PCR-Restriction Endonuclease analysis. *Annals Academy of Medicine Singapore* **34**: 137-140.

Waters WR, Palmer MV, Thacker TC, Payeur JB, Harris NB and Minion FC 2006. Immune response to defined antigens of Mycobacterium bovis in cattle experimentally infected with *Mycobacterium kansasii*. *Clinical and Vaccine Immunology* **13**: 611-619.

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Evaluation of Short Duration Varieties of Paddy through Frontline Demonstrations in Punjab

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Abstract: Groundwater depletion in Punjab is at alarming stage due to technological (long duration varieties) and policy (free electricity) factors. Short duration varieties can give a relief in this situation by using less water for paddy production. So, since 2016-17, frontline demonstrations of rice varieties PR 121 and PR 126 were conducted by Punjab Agricultural University under Farmer FIRST Programme of the Indian Council of Agricultural Research (ICAR) for popularization of these varieties. A study was conducted to evaluate the performance of these varietal demonstrations. Findings revealed that cost of cultivation of PR 121 and PR 126 was lower than the check variety (Pusa 44) and giving similar yield. In terms of economic returns, these short duration varieties are giving similar or higher net returns than Pusa 44 resulting higher benefit to cost ratio.

Keywords: Water, Short duration, Yield, Returns, PR 121, PR 126

Development of irrigation facilities is one of the major factors behind success of the Green Revolution in Punjab which eradicated the hunger and ensured food security in India (Singh and Kohli 1997). During the Green Revolution era, focus was shifted to the pumping groundwater to ensure continuous irrigation supply (Balkrishna et al 2022) and since then, most of irrigation demand in Punjab is fulfilled by installing tube wells to extract groundwater (Perveen et al 2012). The number of tube wells increased enormously in last five decades in Punjab from 1.92 lakh in 1970-71 (Bajwa et al 2017) to14.76 lakh in 2020-21 (GoP 2021). Further minimum support prices (MSP) provided by the government made the farmers habitual to growing only paddy and wheat crops which resulted in the depletion of ground water table in Punjab.Punjab is producing about 139.91 lakh metric tonnes of paddy from the area of 31.49 lakh hectares (GoP 2021). Study conducted by Kaur (2021) revealed that farmers are applying 2033 litres of water to produce one kg of paddy, so high irrigation water requirement coupled with large area under paddy is eroding the groundwater resources of Punjab.To meet the water demand in Punjab, 35.78 BCM water is being withdrawal every year having availability of only 21.58 BCM, leading to the 166 per cent extraction rate as percentage of total percolation and at such withdrawal rate, ground water resources of Punjab are likely to be used in 20-25 years(Anonymous 2018).

With such scarcity of ground water resources in Punjab, unrecommended long duration varieties are increasing the threat to water resources. So Punjab Agricultural University (PAU) has developed short duration varieties of paddy, which can sustain the water resources as well as give sufficient produce as compared to long duration varieties (Singh et al 2022). Further to transfer various sustainable technologies to farmers fields' and popularize among them, Farmer FIRST Programme (FFP) was started by ICAR, and under this programme two villages in Sangrur District of Punjab were adopted by the PAU, Ludhiana in the year 2016-17. To convince the farmers through the grass root level methodology, frontline demonstrations (FLDs) of PR 121 and PR 126 were conducted in the adopted villages. So, this study was conducted to evaluate the performance of these short duration varieties as compared to other long duration varieties such as Pusa 44 to generate the research feedback and policy interventions.

MATERIAL AND METHODS

Farmer FIRST Programme was implemented in Punjab in 2016-17, and two villages from district Sangrur were selected under this programme. To sensitize the farmers regarding water saving and popularization of recommended short duration varieties, 300 FLDs having an area of 0.4 ha for each demonstration of PAU recommended short duration varieties (PR 121 & PR 126) were conducted on farmers' fields in each year from 2017-18 to 2021-22 thus totaling 1500 FLDs in last five years (Table 1).

The necessary steps for selection of site, selection of farmers, layout of demonstrations etc. were followed as suggested by Choudhary (1999) and Venkatasubramanian et al (2009). Farmers were provided with the trainings as per requirement and guidance through the field visits from time to time. To evaluate the performance of FLDs, adjacent local checks of Pusa 44 were selected to record the data. Data regarding yield, cost of cultivation, returns were collected for the FLDs and check plots. B:C ratio was calculated using the net returns and cost of cultivation.

RESULTS AND DISCUSSION

Varietal characteristics: Farmers were growing water guzzling long duration unrecommended varieties of paddy in the village before the commencement of FFP, so PR 121 and PR 126 which take much less time and give comparable yield to the Pusa 44 were introduced in the adopted village. Both PR 121 and PR 126 are resistant to bacterial blight and matures in 110 and 93 Days after Transplanting (DAT), respectively.

Performance of PR 121 FLDs: The study evaluated the performance of PR 121 on the basis of yield as compared to Pusa 44 (Table 3) and findings revealed that farmers obtained the comparable yield of PR 121 to the Pusa 44. Although a slightly higher yield of Pusa 44 is not advantageous while taking into consideration the maturity time of varieties, which is 25-30 days more for Pusa 44. Further it can be observed from the data that FLDs yield for each year is higher the average potential yield, which revealed the good performance of FLDs. Singh et al (2022) also revealed the similar finding regarding the yield comparison of PR 121 and Pusa 44.

Recommended short duration varieties are taking much less time and resources than Pusa 44, so it is not advisable to compare the both varieties only on the basis of yield, but ultimate net returns can be the suitable indicator. So data in Table 4 highlights the performance of PR 121 in economic terms. Finding showed that cost of cultivation for the FLDs is lower than check plot ranging from Rs 2766 to Rs 4650 per ha in each year. Gross returns from the PR 121 FLDs on is somewhat lower (Rs 2653 to Rs 8780 per ha) due to slight difference in yield except the in2019-20, when yield of PR 121 surpassed the yield of Pusa 44 and fetched Rs. 2464 per ha higher gross returns. The net returns from thePR 121 FLDs were similar or more than Pusa 44 in each year due to the lower cost of cultivation leading to the higher benefit cost ratio of PR 121.

Table 1. Frontline demonstrations of short duration varieties conducted under Farmers FIRST Programme

Year	Paddy variety (No. of FLDS)	
	PR 121	PR 126
2017-18	100	200
2018-19	100	200
2019-20	100	200
2020-21	150	150
2021-22	-	300
Total	450	1050
Grand total	1500	

Table 2. Characteristics of short duration varieties selected for FLDs

Character	PR 121	PR 126
Plant height	98 cm	102 cm
Maturity	110 DAT	93 DAT
Resistance	Bacterial blight	Bacterial blight
Average yield	76.25 q/ha	75.00 q/ha

Source: PAU (2022); DAT= Dates of transplanting

Table 3. Yield performance of PR 121 FLDs

Year	Yield (q/ha)	
	FLDs (PR 121)	Local check (Pusa 44)
2017-18	80.69	82.52
2018-19	78.69	80.52
2019-20	79.90	78.50
2020-21	77.80	82.50

Table 4. Economic analysis of PR 121 FLDs

Particulars	FLDs (PR 121)	Local check (Pusa 44)	Change
2017-18			
Cost of cultivation (Rs/ha)	28199	31139	-2940
Gross returns (Rs/ha)	117001	119654	-2653
Net returns (Rs/ha)	88801	88515	+286
B.C ratio	3.15	2.84	+0.31
2018-19			
Cost of cultivation (Rs/ha)	34779	38039	-3260
Gross returns (Rs/ha)	137707	140910	-3203
Net returns (Rs/ha)	102928	102871	+57
B.C ratio	2.96	2.70	+0.26
2019-20			
Cost of cultivation (Rs/ha)	36628	39394	-2766
Gross returns (Rs/ha)	140624	138160	+2464
Net returns (Rs/ha)	103996	98766	+5230
B.C ratio	2.84	2.51	+0.33
2020-21			
Cost of cultivation (Rs/ha)	40780	45430	-4650
Gross returns (Rs/ha)	145330	154110	-8780
Net returns (Rs/ha)	104550	108680	-4130
B.C ratio	2.56	2.39	+0.17

Performance of PR 126 FLDs: Finding from the FLDs (Table 5) reveal that farmers obtained the similar yield in PR 126 FLDs as of Pusa 44. PR 126 variety of paddy gained much popularity among the farmers due to its short maturity period and comparable yield to the other varieties and due to its enormous popularity, only PR 126 variety was selected for FLDs in 2021-22. In 2017-18, 2018-19, 2020-21 & 2021-22, PR 126 gave slightly lower but comparable yield to the check variety (Pusa 44), but in 2019-20, PR 126 outperformed Pusa 44 with slight increase inyield. Findings regarding the yield were in line with Singh (2022), who also found that yield of PR 126 was slightly lower than Pusa 44.

Table 5. Yield performance of PR 126 FLDs

Year	Yield (q/ha)	
	FLDs (PR 126)	Local check (Pusa 44)
2017-18	80.60	82.03
2018-19	78.60	80.30
2019-20	79.60	78.30
2020-21	78.50	82.20
2021-22	79.50	81.20

Table 6. Economic analysis of PR 126 FLDs

Particulars	FLDs (PR 126)	Local check (Pusa 44)	Change
2017-18			
Cost of cultivation (Rs/ha)	28943	32486	-3543
Gross returns (Rs/ha)	116866	118940	-2074
Net returns (Rs/ha)	87923	86454	+1469
B.C ratio	3.04	2.66	0.38
2018-19			
Cost of cultivation (Rs/ha)	35905	40003	-4098
Gross returns (Rs/ha)	137550	140052	-2502
Net returns (Rs/ha)	101645	100049	+1596
B.C ratio	2.83	2.50	+0.33
2019-20			
Cost of cultivation (Rs/ha)	36920	40772	-3852
Gross returns (Rs/ha)	140096	137333	+2763
Net returns (Rs/ha)	103176	96561	+6615
B.C ratio	2.79	2.36	+0.43
2020-21			
Cost of cultivation (Rs/ha)	40380	46324	-5944
Gross returns (Rs/ha)	146638	153549	-6911
Net returns (Rs/ha)	106258	107225	-967
B.C ratio	3.63	3.31	+0.32
2021-22			
Cost of cultivation (Rs/ha)	38200	44625	-6425
Gross returns (Rs/ha)	154230	157528	-3298
Net returns (Rs/ha)	116030	112903	+3127
B.C ratio	3.04	2.53	+0.51

Further economic data (Table 6) revealed that farmers spent about Rs 3500 to Rs 6500 less on the cultivation of PR 126 than Pusa 44 in each year. Gross returns from the PR 126 were also somewhat lesser than Pusa 44 due to yield differences except in 2019-20. The maximum gross returns difference was in 2019-20 of Rs 6911 per ha. But FLDs on PR 126 proved to obtain similar net returns as Pusa 44 due to the lower cost of production and similar yield. The maximum increase in net returns was in the year 2019-20 of Rs 6615 per ha due higher yield and lower cost of cultivation of PR 126. This ultimately resulted to the higher benefit cost ratio of PR 126.

CONCLUSION

Short duration varieties can be a measure for respite in ground water depletion in Punjab through water saving and generating sustainable produce. So under FFP, the varieties PR 121 and PR 126 were evaluated through frontline demonstrations in adopted villages in Sangrur (Punjab) under Farmer FIRST Programme. Findings proved the comparable yield and similar or higher economic returns from these varieties as compared to the other non- recommended varieties. It can be concluded that farmers can generate good income using less resources in terms of water and time from these varieties.

REFERENCES

Anonymous. 2018. *Groundwater resources of Punjab state.* Draft report. Water Resources & Environment Directorate, Water Resources Department, Punjab, Mohali and Central Ground Water Board North Western Region Chandigarh. Retrieved from https://dswcpunjab.gov.in/contents/docs/publications/Draft%20Report%20Punjab%20Groundwater%20Resources%202017.pdf on 25.07.2022.

PAU 2022. *Package of Practices: Kharif.* Punjab Agricultural University, Ludhiana

Bajwa S, Aggarwal R and Brar M 2017.*Groundwater Depletion In Punjab, India*. *Encyclopedia of Soil Science, Third Ed*. Taylor and Fracis.

Balkrsihna A, Sharma G, Sharma N, Rawat N, Kumar A and Arya V 2022. Transition of agriculture from gloriuos past to challenging future: A serious concern. *Indian Journal of Ecology* **49:** 977-986.

Choudhary BN. 1999. *Krishi Vigyan Kendra: A guide for KVK managers.* Pp. 73-78. Division of Agricultural Extension, ICAR, New Delhi, India.

GOP 2021. Statistical Abstract of Punjab. Economic and Statistical Organization, Department of Planning, Government of Punjab, India. Retrieved from https://esopb.gov.in/static/PDF/Abstract2021.pdf on 25.07.2022.

Perveen S, Krishnamurthy C and Vatta K 2012. Restoring *Groundwater in Punjab, India's Breadbasket : Finding Agricultural Solutions for Water Sustainability*. Report. Columbia Water Centre, Earth Institute, Columbia University.

Singh JM, Sachdeva J, Bhangu PKS, Singh J, Kaur B and Kumar H 2022. Groundwater saving in Punjab: Role of short duration varieties in agricultural sustainability. *Indian Journal of Ecology* **49:** 358-362.

Singh N and Kohli DS 1997. The green revolution in Punjab, India: The economics of technological change. *Journal of Punjab Studies* **12**(2): 285-306.

Venkatasubramanian V, Sajeev MV and Singha AK. 2009. *Concepts, approaches and methodologies for technology application and transfer - A resource book for KVKs*. pp 83-98. Zonal Project Directorate, Zone – III, Indian Council of Agricultural Research, Umiam, Meghalaya.

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CONTENTS

Indian Journal of Ecology (2022) 49(5) (Supplementary Issue)

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CONTENTS

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