Indian Journal of Ecology (2022) 49(5): 1561-1575
DOI: https://doi.org/10.55362/IJE/2022/3698

Manuscript Number: 3698
NAAS Rating: 5.79

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

Sagar Dhakal and Prem Kumar Khosla
School of Biological and Environmental Sciences, Shoolini University, Solan-173 229, India
E-mail: sagardhakal@shooliniuniversity.com

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

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

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

MATERIAL AND METHODS

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

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

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

Table 1. Geographic distribution of research sites

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

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

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

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

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

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

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

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

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

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

RESULTS AND DISCUSSION

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

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

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

Bulk Density: Soil bulk density varied significantly between

Table 2. Procedure for analysis in study forest

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

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

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

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

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

Table 3. Soil pH in study forests

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

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

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

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

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

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

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

Table 5. Bulk density in study forests

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

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

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

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

Table 7. Soil compactionat studied forests

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

See Table 6 for details

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

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

Litter Biomass: The aboveground living biomass of leaves,

Table 8. Soil organic carbonin study forests

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

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

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

See Table 6 for details

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

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

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

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

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

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

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

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

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

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

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

Table 12.1. Phytosociological attributes in Himri forest

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

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

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

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

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

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

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

Table 12.2. Phytosociological attributes in Narkanda forest

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

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

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

Table 12.3. Phytosociological attributes in Pabbas forest

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

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

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

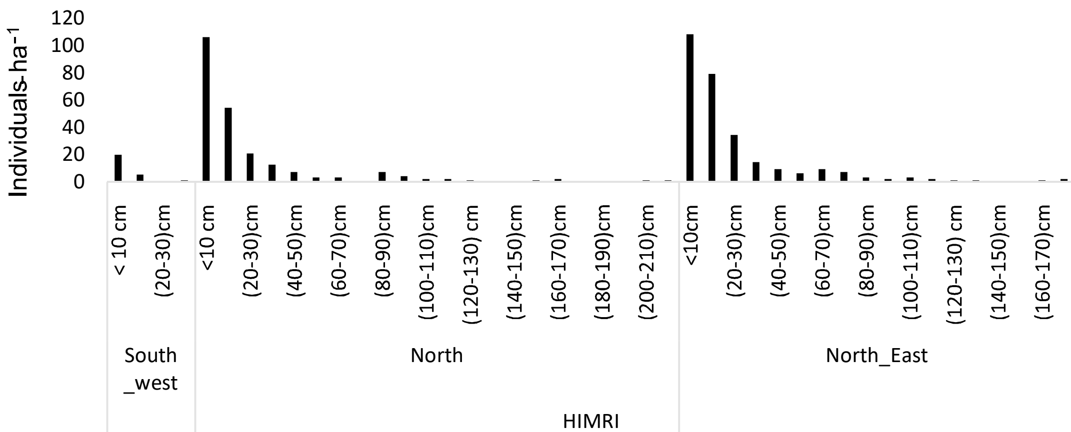

Fig. 1. Diameter distribution classes (cm) of *T. contorta* in Himri forest

Table 12.4. Phytosociological attributes in Nankhari forest

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

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

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

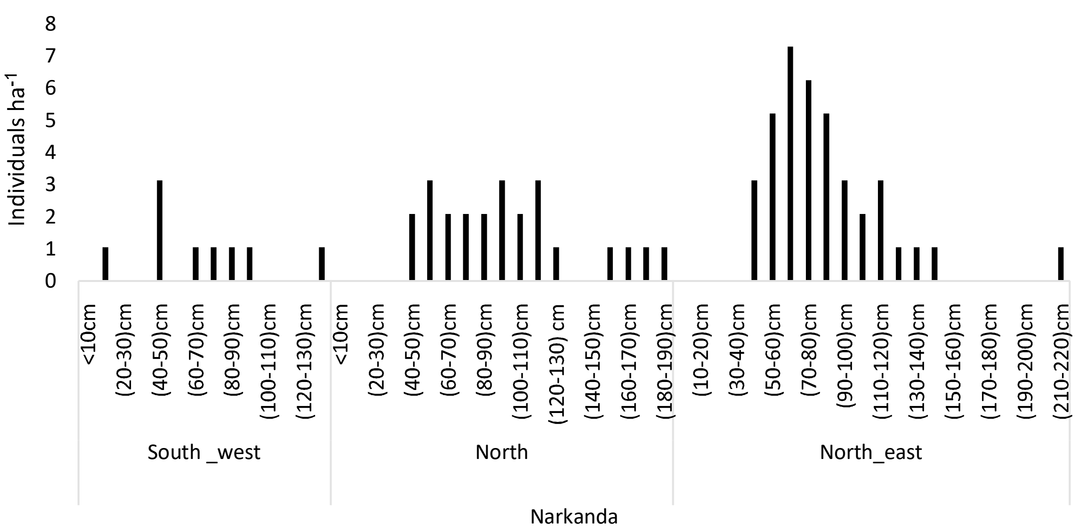

Fig. 2. Diameter distribution classes (cm) of *T. contorta* in Narkanda forest

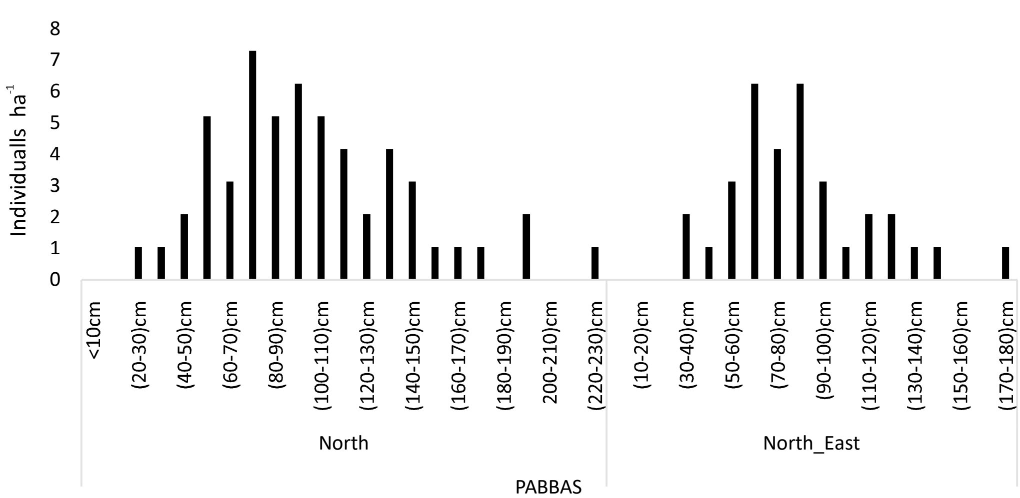

Fig. 3. Diameter distribution classes (cm) of *T. contorta* in Pabbas forest

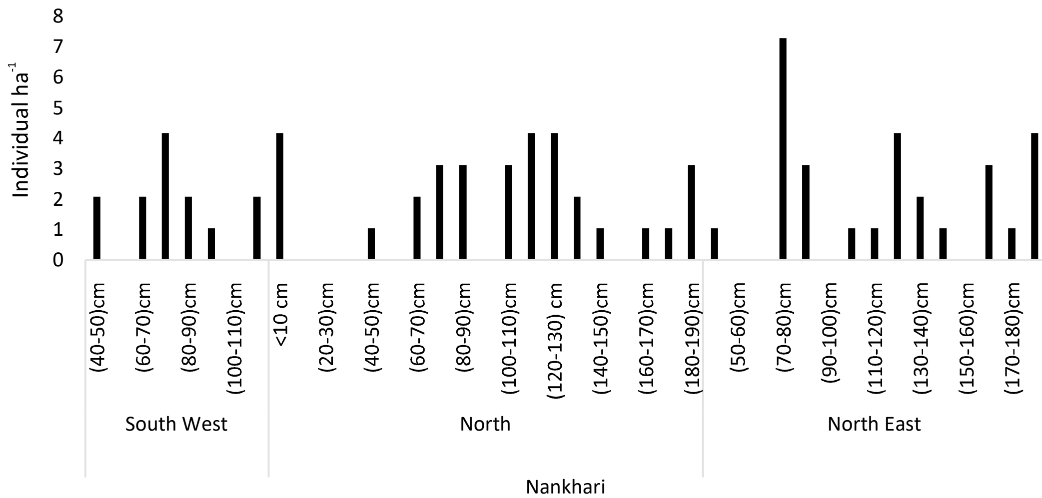

Fig. 4. Diameter distribution classes (cm) of *T. contorta* in Nankhari

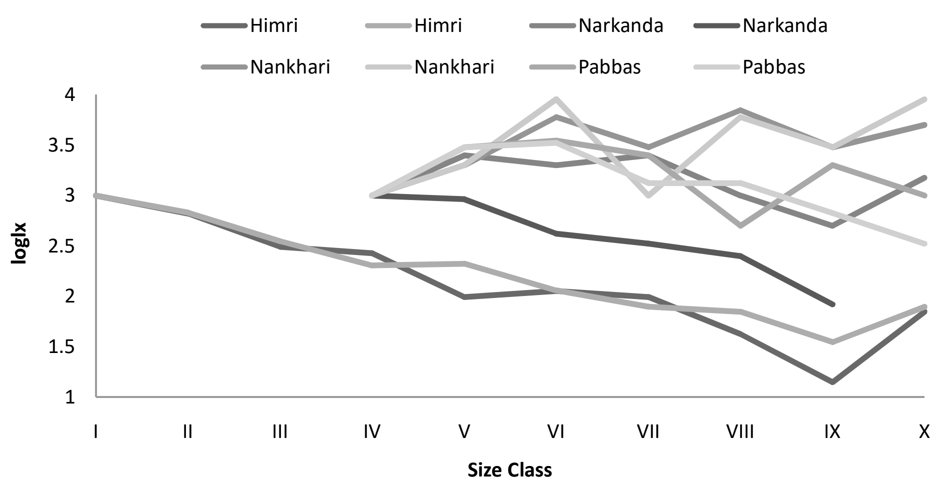

Fig. 5. Log lx and the number of dead trees of *T. contorta* in study forests

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

CONCLUSIONS

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

REFERENCES

Abha Manohar K, Shukla G, Roy B and Chakravarty S 2022. Effects of plant growth regulators and growing media on propagation and field establishment of *Stevia rebaudiana*: A medicinal plant of commerce. *CABI Agriculture and Bioscience* **3(**1): 1-12.

Adhikari P, Joshi K, Singh M and Pandey A 2020. Influence of altitude on secondary metabolites, antioxidants, and antimicrobial activities of Himalayan yew (*Taxus wallichiana*). *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology* **44**(4): 1-9.

Ahmadi K, Jalil Alavi S, Zahedi Amiri G, Mohsen Hosseini S, Serra-Diaz JM and Svenning JC 2020. Patterns of density and structure of natural populations of *Taxus baccata* in the Hyrcanian forests of Iran. *Nordic Journal of Botany* **38**(3): 1-10.

Alshammary AAG, Kouzani AZ, Kaynak A, Khoo SY, Norton M, Gates WP, Al-Maliki M and Rodrigo-Comino J 2020. The performance of the des sensor for estimating soil bulk density under the effect of different agronomic practices. *Geosciences* **10**(4): 117.

Bargali SS 2021. Composition , structure and productivity of the herbaceous vegetation of five forest stands varying in soil moisture and nitrogen in Central Himalaya, India. *Journal of Forest Science* **9**(1): 29-42.

Bassett TJ, Landis DA and Brudvig LA 2020. Effects of experimental prescribed fire and tree thinning on oak savanna understory plant communities and ecosystem structure. *Forest Ecology and Management* **15**(464): 118047.

Bisane KD 2017. Population diversity and cyclicityof fruit fly (*Bactrocera* spp.) in sapota orchard under south Gujarat condition. *Indian Journal of Ecolgy* **44**(2): 369-374.

Brokaw N and Thompson J 2000. The H for DBH. *Forest Ecology and Management* **129**(1-3): 89-91.

Cai J, Xu K, Zhu Y, Hu F and Li L 2020. Prediction and analysis of net ecosystem carbon exchange based on gradient boosting regression and random forest. *Applied Energy* **15**(262): 114566. https://doi.org/10.1016/j.apenergy.2020.114566

Castro J, Zamora R, Hódar JA, Gómez JM and Gómez-Aparicio L 2004. Benefits of using shrubs as nurse plants for reforestation in Mediterranean mountains: A 4-year study. *Restoration Ecology* **12**(3): 352-358.

Chandra N, Singh G, Lingwal S, Rai ID and Tewari LM 2021. Alpine medicinal and aromatic plants in the Western Himalaya, India: An ecological review. *Indian Journal of Ecology* **48**(2): 319-331.

Chettri A, Barik SK, Pandey HN and Lyngdoh MK 2010. Liana diversity and abundance as related to microenvironment in three forest types located in different elevational ranges of the Eastern Himalayas. *Plant Ecology and Diversity* **3**(2): 175-185.

Chybicki IJ, Oleksa A and Burczyk J 2011. Increased inbreeding and strong kinship structure in *Taxus baccata* estimated from both AFLP and SSR data. *Heredity* **107**(6): 589-600.

Coughlan P, Carolan JC, Hook ILI, Kilmartin L and Hodkinson TR 2020. Phylogenetics of Taxus using the internal transcribed spacers of nuclear ribosomal DNA and plastid trnL-F regions. *Horticulturae* **6**(1): 19.

Dangal SP, Das AK and Paudel SK 2017. Effectiveness of management interventions on forest carbon stock in planted forests in Nepal. *Journal of Environmental Management* **1**(196): 511-517.

Dhakal S, Mohanty A and Rijal K 2021. Assessment of Carbon Sequestration and Tree Diversity in Gokarna Forest, Kathmandu, Nepal. In: S*ustainable Climate Action and Water Management* pp.167-180. http://www.springer.com/series/13113

Farris E and Filigheddu R 2008. Effects of browsing in relation to vegetation cover on common yew (*Taxus baccata* L.) recruitment in Mediterranean environments. *Plant Ecology* **199**(2): 309-318.

García D, Zamora R, Hódar JA, Gómez JM and Castro J 2000. Yew (*Taxus baccata* L.) regeneration is facilitated by fleshy-fruited shrubs in Mediterranean environments. *Biological Conservation* **95**(1): 31-38.

Ghazali MF, Wikantika K, Harto AB and Kondoh A 2020. Generating soil salinity, soil moisture, soil pH from satellite imagery and its analysis. *Information Processing in Agriculture* 7(2): 294-306.

Hai Yen HP, Viet Ha NT, Pham BT, Prakash I, van Manh L, Thuy Dung NT, Quoc Manh PB and Tuyen TT 2020. Ecosystem services in mountainous area: A case study of Nghe An, Vietnam. *Indian Journal of Ecology* **47**(1): 109-116.

Iqbal J, Meilan R and Khan B 2020. Assessment of risk, extinction, and threats to Himalayan yew in Pakistan. *Saudi Journal of Biological Sciences* **27**(2): 762-767.

Iszkuło G, Didukh Y, Giertych MJ, Jasińska AK, Sobierajska K and Szmyt J 2012. Weak competitive ability may explain decline of *Taxus baccata* L. *Annals of Forest Sciences* **69**(6): 705-712.

Jensen DA, Rao M, Zhang J, Grøn M, Tian S, Ma K and Svenning JC 2021. The potential for using rare, native species in reforestation: A case study of yews (Taxaceae) in China. *Forest Ecology and Management* **15**(482): 118816.

Joshi VC, Sundriyal RC and Arya D 2021. Forest floor diversity, distribution and biomass pattern of oak and chir-pine forest in the indian western himalaya. *Indian Journal of Ecology* **48**(1): 232-237.

Kirby KJ, Goldberg EA, Isted R, Perry SC and Thomas RC 2016. Long-term changes in the tree and shrub layers of a British nature reserve and their relevance for woodland conservation management. *Journal for Nature Conservation* **1**(31): 51-60.

Kumar ML, Nag A, Malakar S and Joshi HG 2020. Population structure and diversity of trees in amarkutir, a tropical dry deciduous forest of West Bengal, India. *Indian Journal of Ecology* **47**(1): 150-154.

Kumar T, Bishwas AJ, Khare PK and Garg N 2021. Invasive alien flora of tropical dry deciduous forest of nauradehi wildlife sanctuary, central India. *Indian Journal of Ecology* **48**(1): 219-225.

Lanker U, Malik AR, Gupta NK and Butola JS 2010. Natural regeneration status of the endangered medicinal plant, *Taxus baccata* Hook. F. syn. *T. wallichiana*, in northwest Himalaya. *International Journal of Biodiversity Science, Ecosystm Services & Management* **6**(1-2): 20-27.

Lau WKM, Kim KM, Shi JJ, Matsui T, Chin M, Tan Q, Peters-Lidard C and Tao WK 2017. Impacts of aerosol–monsoon interaction on rainfall and circulation over Northern India and the Himalaya Foothills. *Climate Dynamics* **49**(5): 1945-1960.

Linares JC 2013. Shifting limiting factors for population dynamics and conservation status of the endangered English yew (*Taxus baccata* L., Taxaceae). *Forest Ecology and Management* **291**: 119-127.

Martínez D and García D 2017. Role of avian seed dispersers in tree recruitment in woodland pastures. *Ecosystems* **20**(3): 616-629.

Mittal A, Singh N and Tewari A 2020. Quantitative analysis and regeneration status of forest trees species in Kumaun Central Himalaya. *Indian Journal of Ecology* **47**(2): 507-513.

Mownika S, Sharmila S and Ramya EK 2021. Documentation of ethnomedicinal plants used for treating rheumatoid arthritis disorder by aboriginal communities of manar beat, karamadai range, western ghats, India. *Indian Journal of Ecology* **48**(1): 75-84.

Naithani S, Singh A and Verma A 2018. Mapping of natural hazards and expected incidences in Great Himalayan National Park Conservation area, Himachal Pradesh. *Indian Journal of Ecology* **45**(3): 483-488.

Nayak S and Sahoo UK 2020. Tree diversity and ecological status of *Madhuca latifolia* (Roxb.) J.F. MacBR in forests of Odisha. *Indian Journal of Ecology* **47**(1): 138-149.

Pant S and Samant SS 2012. Diversity and regeneration status of tree species in Khokhan Wildlife Sanctuary, north-western Himalaya. *Tropical Ecology* **53**(3): 317-331.

Pattnayak S, Kumar M, Dhal NK and Sahu SC 2021. Estimation of carbon pools in secondary tropical deciduous forests of Odisha, India. *Journal of Forestry Research* **32**(2): 663-673.

Pers-Kamczyc E, Iszkuło G, Rabska M, Wrońska-Pilarek D and Kamczyc J 2019. More isn't always better – The effect of environmental nutritional richness on male reproduction of *Taxus baccata* L. *Environmental and Experimental Botany* **1**(162): 468-478.

Poudel RC, Gao LM, Möller M, Baral SR, Uprety Y, Liu J and Li DZ 2013. Yews (Taxus) along the Hindu Kush-Himalayan region: Exploring the ethnopharmacological relevance among communities of Mongol and Caucasian origins. *Journal of Ethnopharmacology* **147**(1): 190-203.

Poudel RC, Möller M, Gao LM, Ahrends A, Baral SR, Liu J, Thomas P and Li DZ 2012. Using Morphological, Molecular and Climatic Data to Delimitate Yews along the Hindu Kush-Himalaya and Adjacent Regions. *PLoS One* **7**(10): p.e46873.

Qin Q, Wang H, Lei X, Li X, Xie Y and Zheng Y 2020. Spatial variability in the amount of forest litter at the local scale in northeastern China: Kriging and cokriging approaches to interpolation. *Ecology and Evolution* **10**(2): 778-790.

Quinn CJ, Price RA and Gadek PA 2002. Familial concepts and relationships in the conifers based on rbcL and matK sequence comparisons. *Kew Bulletin* **57**(3): 513-531.

Rai A, Singh AK, Singh N and Ghoshal N 2020. Effect of elevated CO_2 on litter functional traits, mass loss and nutrient release of two subtropical species in free air carbon enrichment facility. *Environmental and Experimental Botany* **1**(172): 103994.

Rana SK and Rawat GS 2017. Database of himalayan plants based on published floras during a century. *Data* **2**(4): 36.

Shankar U 2001. A case of high tree diversity in a sal (*Shorea robusta*)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Current Science* **81**(7): 776-786.

Sharma H and Garg M 2015. A review of traditional use, phytoconstituents and biological activities of Himalayan yew, *Taxus wallichiana*. *Journal of Integrative Medicine* **13**(2): 80-90.

Sharma CM, Tiwari OP, Rana YS, Krishan R and Mishra AK 2018. Elevational behaviour on dominance–diversity, regeneration, biomass and carbon storage in ridge forests of Garhwal Himalaya, India. *Forest Ecology and Management* **15** (424): 105-120.

Sheikh MA, Tiwari A and Anjum J 2020. Dynamics of nutrients in temperate coniferous forests of north western himalaya with special reference to available and total phosphorus. *Indian Journal of Ecology* **47**(2): 446-451.

Su J, Yan Y, Song J, Li J, Mao J, Wang N, Wang W and Du FK 2018. Recent fragmentation may not alter genetic patterns in endangered long-lived species: Evidence from *Taxus cuspidata*. *Frontiers of Plant Science* **31**(9): 1571.

Tanioka Y, Cai Y, Ida H and Hirota MA 2020. Spatial relationship between canopy and understory leaf area index in an old-growth cool-temperate deciduous forest. *Forests* **11**(10): 1037.

Thomas P and Polwart A 2003. *Taxus baccata* L. *Journal of Ecology* **91**(3): 489-524.

Wang J, Wang Y, Feng J, Chen C, Chen J, Long T, Li Junqing, Zang R and Li Jingwen 2019. Differential responses to climate and land-use changes in threatened Chinese *Taxus* species. *Forests* **10**(9): 766.

Wei Li 2011. Difference in photoinhibition and photoprotection between seedings and saplings leaves of *Taxus cuspidata* under high irradiance. *African Journal of Microbiology Research* **5**(32): 1-7.

Zhang JT and Ru W 2010. Population characteristics of endangered species *Taxus chinensis* var. *mairei* and its conservation strategy in Shanxi, China. *Population Ecology* **52**(3): 407-416.

Zhou K, Li J, Zhang T and Kang A 2021. The use of combined soil moisture data to characterize agricultural drought conditions and the relationship among different drought types in China. *Agricultural Water Management* **243**: 106479.

Received 02 June, 2022; Accepted 09 September, 2022