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Tree species diversity, distribution and population structure of Fraxinus xanthoxyloides in Western Himalayas

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Abstract

The present study was conducted in West Himalayan Dry Juniper Forest, in Chamoli district, Uttarakhand and Dry Broadleaved and Coniferous Forest, Kinnaur district, Himachal Pradesh, India, to investigate the population structure and regeneration status of Afghan Ash tree species. The results of population status of the Afghan ash in Uttarakhand and Himachal Pradesh indicated the dominance of *F. xanthoxyloides*. In Uttarakhand, maximum IVI value of *F. xanthoxyloides* was recorded in Malari (170.26), followed by Jhelum (160.13), whereas in Himachal Pradesh, maximum IVI value 161.50 was recorded in Ribba, while, in Jhangi site 128.68 IVI value was recorded. Density and total basal area in all the sites of the Afghan ash ranged from 344.44 individuals ha^{-1} to 482.22 individuals ha^{-1} and 18.77 m^2 ha^{-1} to 35.65 m^2 ha^{-1}, respectively. The natural regeneration status of *F. xanthoxyloides* was found to be quite good in all the selected sites/ranges. The maximum number of seedlings were recorded from Himachal Pradesh with (837.78 individual's ha^{-1}) in Jangi, while minimum number of seedlings per hectare (70.37 individual's ha^{-1}) was recorded in Jhelum, Uttarakhand. The reverse J-shaped curve was observed in all the CBH classes which signify regeneration at the stand level was good and maximum portion of curve with more than one-half of the individual's occurrence was found to be higher between the girth classes 10.1–20 cm to 20.1–30 cm and decreased with the increase of girth in all the study stands. Anthropogenic disturbances resulted to be declined in populations of Afghan ash and may lead this species to endangered, rare and threatened categories. Therefore, proper conservation and management initiatives with active involvement of local people are urgent need to protect this keystone plant species in their habitat particularly in cold desert regions of Western Himalayas.

Introduction

The Indian Himalayan Region (IHR) is one of the world's richest biological diversity reservoirs and is known as a 'store house' for important plant species (Samant and Dhar 1997; Samant et al. 1998; Vidhyarthi et al. 2013; Bodh et al. 2018). Western Himalaya has long been recognized as a distinct floristic region in India. The mountain ranges situated on the western side of river Sharda (or west of 77° E longitude) in north-western India, constitutes the 'Indian Western Himalaya' which includes the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. This region harbours a rich regional flora due to its diverse topography, wide altitudinal range and location at the intersection of several biogeographical units. The flora of Western Himalaya exhibits affinities with that of Mediterranean, Siberian, Tibetan and Indo-Malayan regions (Chawla et al. 2012). The Indian cold desert flora is sparse, dominated by a few dwarf bushes. Tree line is more or less absent in this zone, however, annual and perennial herbs followed by stunted shrubs and bushes dominate the flora (Chauhan et al. 2020). The total geographical area under cold deserts in Himachal Pradesh is about 11,000 km2, out of which 3,400 km2 lies in Kinnaur district (Verma and Tewari 2016) while Uttarakhand contributes approximately > 1,000 km2 (Sharma et al. 2006). Medicinal plants in these regions have been used as a major source of therapeutic agents by human for thousands of years. India is a one of the richest medicinal plant resources of the world. This vast wealth is widely distributed in different parts of the country having specific phytogeographical entities. In India, out of 17,000 species of flowering plants about 17% are considered to be of medicinal value. As per an estimate, out of over 1600 species of medicinal plants traditionally used in India, more than 50% species come from the Himalayan region (Uniyal et al. 2002). The World Health Organization has estimated that some 80% of the developing world relied on their traditional medicines and that of these 85% use plants or their extracts as the active substance. Earlier, only the local people used these plants resources for their own consumption, but in recent years there has been a sudden rise in the demand of herbal products and plant based drugs across the world resulting in the heavy exploitation of medicinal plants (Verma and Tewari 2016). The inhabitants use this rich diversity for their sustenance. The increase in human population has increased the demand of economically important biodiversity elements. This has caused the over exploitation and habitat degradation of many economically important

biodiversity elements and led the rapid loss of these elements (Singh and Samant 2010). The present study was conducted in the Niti valley (Jhelum and Malari village), a buffer zone of NDBR, Western Himalaya and Kinnaur Forest Division (Ribba and Jangi village), Himachal Pradesh to evaluate the population structure and regeneration status of *Fraxinus xanthoxyloides* commonly known as Afghan ash, is a traditional medicinal plant, found in trans- Indus regions, India, Pakistan, Algeria, Morocco, Afghanistan and Baluchistan (Anon 1956, Younis et al. 2016). In India, it is mostly occurs in the inner dry tracts of Western Himalayas especially in Kinnaur district of Himachal Pradesh and Chamoli district of Uttarakhand (Negi and Sharma 2015; Kumar 2016; Kukreti et al. 2022). It is a large deciduous shrub to medium sized tree up to 8m height and it occurs in tree form in its lower distribution range; however, it exists in shrubby form with the rise in altitude in interior parts of cold desert areas (Troup 1921; Negi and Sharma 2015). The flowers *F. xanthoxyloides* are polygamous and wind-pollinated but male flowers lack calyx (Wallender, 2008). Afghan ash fruits are elongated samaras which are borne in clusters, winged, single-seeded. The length of the samara varies from 2.5 to 7.5 cm (Kukreti et al. 2022). *Fraxinus xanthoxyloides* is a multipurpose tree species that is widely used for making agricultural implements, tool handles, walking sticks and consumed as fuel wood and it is also lopped for fodder (Troup 1921). It has substantial economic and livelihood value, often being used as fodder for livestock or being traded nationally and internationally for timber. The plants parts have been extensively used as traditional and folklore medicines to cure various human ailments in India. The different parts of this plant viz., leaves, roots and bark, etc. is utilize to cure patients of malaria, pneumonia and jaundice (Kukreti et al. 2022). Till date, very less systematic work has been done in India on the population structure and natural regeneration of *Fraxinus xanthoxyloides*. To our knowledge, ours is the first study that evaluate population structure and natural regeneration status of *Fraxinus xanthoxyloides* in Indian Western Himalayan Region. Thus, the main objective of the study was to evaluate the population structure and natural regeneration of the species, which is crucial for understanding of their future maintenance and developing improvement and conservation programs.

Material And Methods

The study was focused on the temperate forests of Nanda Devi Biosphere Reserve, Uttarakhand and Kinnaur Forest Division, Himachal Pradesh of India (Fig. 1a and 1b). Assessment of the floristic diversity present in the Afghan ash bearing forests was done by using complete enumeration method employing contiguous quadrat method. It was carried out to cover the altitudinal ranges varying from 2300–2910 m above amsl in Uttarakhand and 2200–3100 m amsl in Himachal Pradesh. The study area of the selected forests is broadly divisible into following classes: (i) West Himalayan Dry Juniper Forest, 13/C5 in Uttarakhand (30.69694444N 79.88611111W), ii) Dry Broadleaved and Coniferous Forest (31.601594N 78.336028W), characterized by open forest of Neoza pine (*Pinus gerardiana*), 13/C1 according to Champion and Seth (1968). The phytosociological studies were carried out by laying out contiguous quadrats of the size 10m x 10m covering all possible aspects and elevations. The observations for trees were recorded laying down by 10m x 10m quadrate size in each tree sample plot. The various ecological parameters were determined from the basic data viz., number, girth/diameter, height, and basal area collected for Afghan ash, using standard formulae (Misra 1968). The tree species data were quantitatively analyzed for density, per cent frequency and abundance whereas, relative frequency, relative density and relative dominance were determined and at last Importance Value Index (IVI) was calculated following Misra (1968). In order to study the regeneration pattern of Afghan ash tree species, in each 10x10 m size quadrat, individuals having > 31.5 cm girth were considered trees whereas tree species of 10.5–31.5 cm girth were considered as ‘saplings’ and those with girth < 10.5 cm were treated as seedlings (Knight, 1963). The regeneration status of the sampled species was assessed based on phytosociological data (Uma Shankar 2001) as, good regeneration, if seedlings > saplings > trees; fair regeneration, if seedlings > or ≤ saplings ≤ trees; fair regeneration, if the species survives only in the sapling stage, but no seedlings (saplings may be <, > or = trees). Specific details of locations including latitude and longitude were recorded using

global positioning system (GPS). Population structure of Afghan ash tree on different sites were analyzed across ten girth classes *viz.*, 0–10, 10.1–20, 20.1–30, 30.1–40, 40.1–50, 50.1–60, 60.1–70,70.1–80,80.1–90 and 90.1–100 cm respectively. The density diameter distribution has been done as per UNESCO/UNEP/FAO (1978) to represent population structure of the forest area.

Table 1
Location of Study areas

S. No	Study sites	Mean Altitude (m)	Species distribution (ha)	No. of quadrates
1	Jhelum	2300	0.31	27
2	Malari	2910	0.73	61
3	Ribba	2200	1.28	94
4	Jangi	3000	0.57	45
	Total		**2.89**	**227**

Results

Floristic diversity

The vegetation types in all the study sites mostly comprised of temperate forests. *F. xanthoxyloides* form the dominant tree species between 2300–2910 m in Uttarakhand and 2200–3100 m in Himachal Pradesh, respectively. The presence of families such as Asteraceae, Oleaceae, Fabaceae, Rosaceae, Berberidaceae and Balsaminaceae could be attributed to the mesic conditions in all the sites. In Uttarakhand, *Fraxinus xanthoxyloides* and *Cupresses torulosa* was dominated in tree layer, the shrub layer consist of *Berberis* spp., *Rosa macrophylla, Caragana gerardiana*, *Lonicera* spp., *Cotoneaster* spp. and *Hippophae* spp. the undergrowth was consist of *Impatiens* spp., *Saussurea* spp., *Cirsium wallichii*, *Carduuse delbergii*, *Artemisia* spp. *Ajania tibetica*, *Kobresia* spp., etc. (Table 2). Whereas in Himacha; Pradesh (Table 3), the dominated tree species were *Fraxinus xanthoxyloides, Alnus nitida, Pinus gerardiana, Juniperus polycarpos* and *Cedrus deodara*, the shrub layer consists of *Cotoneaster microphylla*, *Coriaria nepalensis, Elaeagnus parviflolia, Rubus spp., Buddleja spp,. Daphne spp., Debregeasia saeneb, Ephedra gerardiana, etc.*, the herb layer was consisting of *Artemisia* spp., *Astragalus chlorostachys, Boerhavia diffusa, Cirsium* spp., *Impatiens brachycentra, Silene falconeriana, Thalictrum chelidonii*, etc.

Table 2
List of plant species found in study area (Jhelum and Malari) in Nanda Devi Biosphere Reserve, Chamoli district, Uttarakhand

S. No.	Tree	Family	Shrub	Family	Herb	Family
	Jhelum					
1	*Fraxinus xanthoxyloides*	Oleaceae	*Berberis* spp.	Berberidaceae	*Impatiens* spp.	Balsaminaceae
2	*Cupressus torulosa*	Cupressaceae	*Rosa macrophylla*	Rosaceae	*Saussurea* spp.	Asteraceae
3					*Cirsium wallichii*	Asteraceae
4					*Carduus edelbergii*	Asteraceae
	Malari					
1	*Fraxinus xanthoxyloides*	Oleaceae	*Berberis* spp.	Berberidaceae	*Artemisia* spp.	Asteraceae
2	*Cupressus torulosa*	Cupressaceae	*Caragana gerardiana*	Fabaceae	*Ajania tibetica*	Asteraceae
3			*Lonicera* spp.	Caprifoliaceae	*Aster albescens*	Asteraceae
4			*Rosa macrophylla*	Rosaceae	*Carduus edelbergii*	Asteraceae
5			*Cotoneaster* spp.	Rosaceae	*Brachyactis roylei*	Asteraceae
6					*Cirsium wallichii*	Asteraceae
7					*Dolomiaea macrocephala*	Asteraceae
8					*Lactuca dolichophylla*	Asteraceae
9					*Saussurea* spp.	Asteraceae
10					*Taraxacum officinale*	Asteraceae
11					*Impatiens* spp.	Balsaminaceae
12					*Myriactis javanica*	Asteraceae
13					*Picris hieracioides*	Asteraceae
14					*Kobresia* spp.	Cyperaceae

Table 3
List of plant species found in study area (Ribba and Jangi) in Kinnaur Forest Division, Kinnaur district, Himachal Pradesh.

S. No.	Trees	Family	Shrub	Family	Herb	Family
Ribba						
1	*Fraxinus xanthoxyloides*	Oleaceae	*Cotoneaster microphylla*	Rosaceae	*Artemisia* spp.	Asteraceae
2	*Alnus nitida*	Betulaceae	*Coriaria nepalensis*	Coriariaceae	*Astragalus chlorostachys*	Fabaceae
3	*Pinus gerardiana*	Pinaceae	*Elaeagnus parviflolia*	Elaeagnaceae	*Boerhavia diffusa*	Nyctaginaceae
4			*Rubus* spp.	Rosaceae	*Cirsium* spp.	Asteraceae
5			*Plectranthus rugosus*	Lamiaceae	*Impatiens brachycentra*	Balsaminaceae
6			*Indigofera* spp.	Fabaceae	*Silene falconeriana*	Caryophyllaceae
7					*Thalictrum chelidonii*	Ranunculaceae
8					*Verbascum thapsus*	Scrophulariaceae
Jangi						
1	*Fraxinus xanthoxyloides*	Oleaceae	*Cotoneaster microphylla*	Rosaceae	*Bupleurum candollii*	Apiaceae
2	*Juniperus polycarpos*	Cupressaceae	*Coriaria nepalensis*	Coriariaceae	*Impatiens brachycentra*	Balsaminaceae
3	*Cedrus deodara*	Pinaceae	*Buddleja* spp.	Scrophulariaceae	*Euphorbia pilosa*	Euphorbiaceae
4	*Pinus gerardiana*	Pinaceae	*Daphne* spp.	Thymelaeaceae	*Vicia pallida*	Fabaceae
5			*Debregeasia saeneb*	Urticaceae	*Dictamnus albus*	Rutaceae
6			*Ephedra gerardiana*	Ephedraceae	*Buddleja crispa*	Scrophulariaceae
7			*Rubus* spp	Rosaceae	*Artemisia* spp.	Asteraceae
8			*Rosa moschata*	Rosaceae		

Tree Species Composition Of Afghan Ash Forest

Nanda Devi National Park

Jhelum Site

The data tabulated in Table 4, exhibiting the ecological status of tree species in Afghan ash bearing site of Jhelum revealed that, *F. xanthoxyloides* was the dominating species. Out of the two tree species present in the area, *F. xanthoxyloides* had the highest value of IVI with 160.13 followed by *Cupressus torulosa* with IVI 139.87. The maximum total basal area m^2 per hectare (30.61) was recorded for *C. torulosa*, whereas minimum (28.95) was recorded for *F. xanthoxyloides*. Similarly, maximum density/ha was recorded for *F. xanthoxyloides* (344.44 individuals/ha) while minimum was recorded for *C. torulosa* (174.07 individuals/ha). The highest abundance was recorded in *F. xanthoxyloides* (3.44), while lowest was found in *C. torulosa* (2.76). The distribution pattern on the basis of abundance frequency ratio (A/F ratio) showes *F. xanthoxyloides* had random distribution.

Table 4
Phytosociological status of *Fraxinus Xanthoxyloides* bearing forests trees of Nanda Devi Biosphere Reserve, Chamoli district, Uttarakhand state.

Scientific Name	Density/ha	Total basal area m^2/ha	Relative frequency	Relative density	Relative dominance	IVI	Abundance	A/f
Jhelum (2400 m)								
Fraxinus xanthoxyloides	344.44	28.95	61.36	66.43	32.34	160.13	3.44	0.03
Cupressus torulosa	174.07	30.61	38.64	33.57	67.66	139.87	2.76	0.04
Malari (2900 m)								
Fraxinus xanthoxyloides	460.66	19.00	65.59	82.89	21.78	170.26	4.61	0.04
Cupressus torulosa	95.08	14.08	34.41	17.11	78.22	129.74	1.81	0.03

Malari Site

The data collected in this site revealed the presence of two tree species (Table 4). Between tree species, *F. xanthoxyloides* was having maximum dominance, with IVI value of 170.26 while minimum was recorded for *C. torulosa* (129.74). Similarly the maximum share to density/ha (460.66 individuals/ha), total basal area m^2 per hectare (19.00) and abundance (4.61) was contributed by *F. xanthoxyloides*, while minimum density/ha (95.08), total basal area m^2 per hectare (14.08) and abundance (1.81) was recorded by *C. torulosa*. The distribution pattern of both the tree species indicated random pattern of distribution.

Kinnaur Forest Division

Ribba Site

Ecological status (Table 5) in Ribba forest revealed a total number of three tree species with *F. xanthoxyloides* being the dominant species with respect to density/ha (480.85 individuals/ ha), total basal area m^2 per hectare (35.65),

abundance (4.81) and IVI (161.50) values. This was followed by *Pinus gerardiana* and *Alnus nitida* with IVI value of 81.43 and 57.07, respectively in the decreasing order.

Table 5
Phytosociological status of *Fraxinus Xanthoxyloides* bearing forests trees of Kinnaur Forest Division, Kinnaur district Himachal Pradesh.

Scientific Name	Density/ha	Total basal area m^2/ha	Relative frequency	Relative density	Relative dominance	IVI	Abundance	A/f
Ribba (2100 m)								
Fraxinus xanthoxyloides	480.85	35.65	58.02	77.40	26.08	161.50	4.81	0.05
Alnus nitida	45.74	4.46	15.72	7.36	34.28	57.07	1.72	0.06
Pinus gerardiana	94.68	10.67	27.04	15.24	39.64	81.43	2.07	0.05
Jangi (2600 m)								
Fraxinus xanthoxyloides	482.22	18.77	44.55	68.03	16.10	128.68	4.82	0.05
Cedrus deodara	48.89	6.10	13.00	6.90	51.60	71.50	1.69	0.06
Pinus gerardiana	135.56	9.65	28.00	19.12	29.45	76.57	2.18	0.04
Juniperus polycarpos	42.22	0.29	15.00	5.96	2.85	23.81	1.27	0.04

Jangi Site

The data collected in the Jangi site revealed the presence of four tree species in the forest (Table 5). Among tree species, *F. xanthoxyloides* was the prominent one having maximum dominance with IVI value of 128.68 followed by *Pinus gerardiana* (76.57), *Cedrus deodara* (71.50) and *Quercus ilex* (23.81). The maximum density/ha (482.22 individuals/ ha), total basal area m^2 per hectare (18.77) and abundance (4.82) was recorded for *F. xanthoxyloides* followed by *Pinus gerardiana*, *Cedrus deodara* and *Juniperus polycarpos*.

Population Structure and Natural Regeneration of F. xanthoxyloides

Overall population structure of tree species depending on size-class distribution yielded reverse J-shaped curve. Population structure of Afghan ash tree on different sites were analysed across ten girth classes viz., 0–10, 10.1–20, 20.1–30, 30.1–40, 40.1–50, 50.1–60, 60.1–70,70.1–80,80.1–90 and 90.1–100 cm respectively. With respect to natural regeneration of Afghan ash, the existence of a sufficient number of seedlings within a population shows good regeneration, whereas the complete lack of seedlings and saplings of Afghan ash tree species in a forest indicates poor regeneration.

Nanda Devi National Park, Joshimath Forest Range, Uttarakhand

Jhelum Site

In Jhelum, the maximum portion of curve of the individual's occurrence (31 individuals) was constituted by 20.1–30 cm DBH class, while only two individuals of total individuals exceeded a girth of 70.1 to 80 cm (Fig. 2). Data revealed that, Afghan ash frequency distribution had the highest frequency in the lower diameter classes and a relatively decrease toward the higher classes. The present investigations for regeneration studies were carried out on seedlings, saplings and trees of Afghan ash (Fig. 3). Overall data on density/ha of seedlings, saplings and trees were recorded as seedlings (70.37 individuals/ha), saplings (200.00 individuals/ha) and trees (144.44 individuals/ha), respectively.

Malari Site

The maximum individuals (139 individuals) was observed in lower diameter class (10.1–20 cm), which were followed by (20.1–30 cm), (30.1–40 cm) and (40.1 to 50 cm) diameter classes (Fig. 4). The girth size structure of *F. xanthoxyloides* populations presented an inverted J form that is, skewed to the left, which indicates a high frequency of small individuals with few adult reproductive individuals. In Malari, the overall data on density/ha of Afghan ash at different stages viz., seedlings, saplings and trees were (604.92 individuals/ha), (373.77 individuals/ha) and (86.89 individuals/ha), respectively. The natural regeneration of *F. xanthoxyloides* in both the sites of Uttarakhand are presented in (Fig. 5).

Kinnaur Forest Division

Ribba site

The DBH class distribution of Afghan ash species in all distribution classes reflected a somewhat reversed J-shape (L-shape). The population structure of Afghan ash in Ribba showed a successive decline in number of individuals from a lower to the next higher girth class (Fig. 6). About more than one-half of individuals occurred between 10.1 and 40 cm. The maximum individuals (152 individuals) were found in lower diameter class 10.1 to 20 cm followed by 20.1 to 30 cm (117 individuals) and 30.1 to 40 cm classes (81 individuals). Overall density per hectare of Afghan ash at different stages like tree, saplings and seedlings were (711.70 individuals/ha), (296.81 individuals/ha) and (184.04 individuals/ha) respectively. Hence, the regeneration at the stand level was good (Fig. 7).

Jangi Site

The reverse J-shaped curve was observed in all the diameter classes (Fig. 8). The maximum individuals (110 individuals) was observed in lower diameter class 10.1–20 cm, which was followed by 20.1–30 cm (59 individuals) and 30.1–40 cm (33 individuals) diameter classes. The regeneration status of Afghan ash in jangi site revealed that the overall density per hectare of Afghan ash at different stages like seedlings, saplings and trees were (837.78 individuals/ha), (377.78 individuals/ha) and (88.89 individuals/ha) respectively (Fig. 9).

Discussion

The diverse topography and elevation range in the mountainous forest ecosystem had a significant impact on the environmental microclimate (Qanbari, and Jamali, 2015), vegetation cover, and soil properties over a relatively short distance, frequently with sudden transitions (ecotone) in the vegetation sequences. The most important environmental elements that may contribute to the decline in growth and developmental features along an altitudinal gradient include

temperature, light intensity, soil moisture, and fertility status in the alpine ecosystem (Kumar et al. 2022b). Due to changes in abiotic variables such as climate, soil, and temperature as well as the altitudinal gradient, especially in undisturbed mountain ecosystems, the altitudinal gradient is thought to be a significant influence impacting species composition and structure (Rawat 2022). Compared to topographic parameters (e.g., aspect, slope), it influences the distribution patterns of vegetation in mountainous locations. For the purpose of creating better management plans and resource conservation, biodiversity inventories are primarily used to identify the types and distribution of forest resources (Sagar et al. 2003). Effective forest conservation and management plans require an understanding of species composition, knowledge of the forest structure, and understanding of the pattern of regeneration. Contiguous growth followed by random growth was typically seen in the distribution patterns for tree layers among the analysed sites. Contiguous distribution, according to Odum (1971), is prevalent in nature and developed as a result of minor but important differences in ambient environmental circumstances, whereas random distribution is present in uniform environments (Mandal *et al*., 2014; Negi et al. 2018). According to Chawla et al. (2012), in Kinnaur district, the ten most dominant families were Asteraceae (122 species), Poaceae (69), Rosaceae (58), Leguminosae (49), Lamiaceae (38), Ranunculaceae (30), Brassicaceae (29), Polygonaceae (29), Apiaceae (25) and Caryophyllaceae (22). Altogether, they constitute 53.4% of the total number of species in Kinnaur and 48.7% of the genera occurring in this region. The diversity of species in a forest is influenced by climatic, edaphic, and biotic factors that vary along altitudinal gradients (Rawat 2022). In the present study, the mosaics of *Caragana* scrub alone and amidst *Rosa macrophylla*, *Berberis* spp., add a peculiar appearance to the landscape in the Jhelum and Malari regions of Uttarakhand. Moreover, the presence of cushioned dwarf herbs such as *Artemisia* spp., *Carduuse delbergii, Saussurea* spp., *Impatiens* spp., etc. in both the sites were among the typical Trans-Himalayan floral elements. Similarly, Adhikari et al. (2016) recorded 495 species belonging to 267 genera and 73 families of vascular plants through systematic collection in cold arid region of Nanda Devi Biosphere Reserve, Western Himalaya, India. Due to the local (within stand) and landscape level variations and the production of spatial heterogeneity, the variation in floristic composition among the altitudes of the present study may be attributed to the prevailing climate, topography, anthropogenic disturbances. The salient features of phytosociological study showed *F. xanthoxyloides* is one of the dominant species in its habitat. In Uttarakhand, maximum mean IVI value was recorded in Malari (170.26), whereas in Himachal Pradesh, maximum IVI value 161.71 of *F. xanthoxyloides* was recorded in Ribba. Total tree density of the afghan ash in Uttarakhand varied from 460.66 to 344.44 per hectare, while, total basal area varied from 28.95 m^2 to 19.00 m^2 per hectare. In Himachal Pradesh, Ribba and Jhangi site of Moorang Forest Range, the maximum share to total basal area 35.65 to 18.77 m2 per hectare of the trees was contributed by *F. xanthoxyloides*, while minimum was recorded for *Alnus nitida* (4.46), *Quercus ilex* (0.29), respectively. The results obtained are attributed due to variation in biogeography, habitat, soil and biotic-abiotic disturbances along the altitudinal gradients. The tree diversity varies place to place mainly due to change in biogeography, habitat, soil and disturbances. In the present investigation on *F. xanthoxyloides* forest in a cold desert ecosystem, the average number of seedlings, saplings and trees recorded in Uttarakhand were 374.68 N ha^{-1}, 286.88 N ha^{-1} and 78.63 N ha^{-1}, respectively, whereas in Himachal Pradesh 774.74 N ha^{-1}, 337.25 N ha^{-1}, 136.46 N ha^{-1} were recorded, respectively. Successful regeneration is always indicated by an adequate quantity of seedlings, saplings, and trees in any given population. The highest number of individuals in the seedling stage and a significant decline in both higher tree classes and sapling classes, which results in hill-shaped curves, show that the rate of conversion from sapling to tree is not proportionate (Negi et al. 2018). In present study *F. xanthoxyloides* showed reduced number of seedlings that grew into saplings. Less number of seedlings that grew into saplings might be due to climatic and non-climatic factors which immensely influence the functioning of the forests and make the forest vulnerable (Pandey et al. 2022). Natural regeneration is the fundamental requirement for the sustainability of forests (Dey 2014). In this process, aged trees perish and are perpetually replaced by young ones. In a forest, older trees act as a seed bank, which produces young trees, continuing the cycle over time and space (Lindenmayer et al. 2014). The study of population structure gives a general picture of the distribution of individuals within each species, their state of

regeneration, and the population's viability. Similarly, Rajwar et al. (1999) suggested the climatic and biotic stress influence the regeneration potential of species and pointed out that the proportionate conversion of seedlings into sapling stage affected by biotic disturbances and competition for space and nutrients. Furthermore, Kumar et al. (2022b) revealed that the *Juniperus macropoda* tree's growth and development qualities, such as crown height, crown breadth, crown length, and stand characteristics, were highest at lower elevation ranges and considerably decreased along the gradient of elevation. *Fraxinus xanthoxyloides*, as an excellent source of fuelwood, timber, and fodder, another potential explanation for the reduced conversion rate of seedlings into saplings could be the trampling and grazing by both domesticated and wild animals. In present study the composite forest structure of different sites showed maximum density of individuals in small diameter class of trees viz, 10-20.1 cm and 20.1 to 30 cm, which was decreased as increasing diameter classes. In general, the reverse J-shaped curve was observed in all the CBH classes in all the sites which signify regeneration status at the stand level was good. Borogayary et al. (2018) stated that, Reverse -J type distribution of overall population is an indication of stable population structure or good regeneration status. The density-diameter distribution of stems has been used repeatedly to represent the population structure of the forests (UNESCO/UNEP/FAO, 1978). Recently, Pandey et al. (2022) conducted a study in Western Himalayan region (Uttarakhand and Himachal Pradesh) to estimate the vulnerability of various temperate forests due to climate change. Results revealed that the Neoza Pine; Moist Deodar; Ban Oak and Dry Broadleaved and Coniferous forest were the most vulnerable forests in the Himalayan temperate forests due to climate change. Overall population structure of the study areas are based on the number of tree seedlings, saplings and adults displayed a greater proportion of seedlings followed by saplings and adults. So, proper care to naturally regenerating seedlings and saplings is required to survive and restocking of adult individuals in future.

Conclusion

The present paper highlights the present status of Afghan ash tree species in different temperate forests of Uttarakhand and Himachal Pradesh, India based on field measurements on the composition and distribution of species in the selected sites/ranges. The analysis confirms that the status of the species in temperate forests varies with respect to the climatic condition of the sites and variations in status remain similar across the altitude and exposure level.

Declarations

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Consent for Publication: The participant has consented to the submission of the Manuscript to the journal.

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Authors' Contributions: Conceptualization of research work and designing of experiments (MT, AK); Execution of field/lab experiments and data collection (AK, GCR, RS); Analysis of data and interpretation (AK, NK); Preparation of manuscript (AK, MT)

References

1. Adhikari B., Kumar A., Mitra, M. and Rawat G. (2016). Flora of Niti valley: a cold arid region of Nanda Devi Biosphere reserve, Western Himalaya, India, *Check list*, 12(1): 1-16.
2. Anon (1956). The Wealth of India, Raw Materials, Vol, IV: F-G. Publication and Information Directorate, (CSIR), New Delhi pp. 61-63.
3. Bodh M., Samant S. S., Tewari L.M. and Kumar V. (2018). Diversity, distribution, indigenous uses and conservation of medicinal plants in Shikari Devi Wildlife Sanctuary of Himachal Pradesh, India. *The Journal of Ethnobiology and Traditional Medicine*. *Photon*, 129: 1399-1425.
4. Borogayary B., Das A. K. and Nath, A. J. (2018). Tree species composition and population structure of a secondary tropical evergreen forest in Cachar district, Assam. *Journal of Environmental Biology*, 39(1): 67-71.
5. Champion H. G. and Seth S. K. (1968). A revised survey of the forest types of India. Manager of publications.
6. Chauhan A., Jishtu V., Thakur L. and Dolma T. (2020). Medicinal plants of the Trans-Himalayan Cold Desert of Ladakh-a review. *International Journal of Science, Environment,* 9(2): 239-253.
7. Chawla A., Parkash O., Sharma V., Rajkumar S., Lal B., Singh R. D. and Thukral A. K. (2012). Vascular plants, Kinnaur, Himachal Pradesh, India. *Check list*, 8(3): 321-348.
8. Chopra R.N., Nayar S.L. and Chopra I. C. (1956). Glossary of Indian Medicinal Plants. CSIR, New Delhi.pp. 330.
9. Curtis J. T. and Mcintosh R. P. (1950). The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, 31(3): 434-455.
10. Dey D. C. (2014). Sustaining oak forests in eastern North America: regeneration and recruitment, the pillars of sustainability. *Forest Science*, 60(5): 926-942.
11. Farhadi P., Soosani J., Alijani V. and Adeli K. (2013). Comparison of the *Quercus brantii* and *Pyrus glabra* Boiss Species Structure in Zagros Forests (Case Study: Ghalehgol Forest, Khoramabad City, Iran). *Int. J. Biol. Sci.*, 3:210–217.
12. Hooker J. D. (1904). A Sketch of the Flora of British India. London: Kessinger Publishing.
13. Jain S.K. (1968). Medicinal plants. National Book Trust, India. pp 216.
14. Knight D.H. (1963). A distance method for constructing forest profile diagrams and obtaining structural data. *Tropical Ecology*, 4: 89-94.
15. Kukreti A, Thapliyal M, Kurmanchali N, Rawat L, Ramola G.C. and Singh R. (2022). Ethnomedicinal uses of *Fraxinus xanthoxyloides* (Afghan Ash): A review. *Indian Forester*. 148(1): 101-103.
16. Kumar A., Srivastav M., Adhikari B.S. and Rawat G.S. (2019). Plant studies in the first Himalayan Biosphere Reserve: a review. *Journal of Mountain Science.* 16(2): 351-363. https://doi.org/10.1007/s11629-018-5105-0
17. Kumar A., Adhikari B. S. and Rawat G. S. (2022a). A hierarchy of landscape-habitat-plant physiognomic classes in the Indian Trans-Himalaya. *Trees, Forests and People*, 7:100172.
18. Kumar D., Bhardwaj D. R., Sharma P., Sankhyan N., Al-Ansari N. and Linh N. T. T. (2022b). Population Dynamics of *Juniperus macropoda* Bossier Forest Ecosystem in Relation to Soil Physico-Chemical Characteristics in the Cold Desert of North-Western Himalaya. *Forests*, 13(10): 1624.

19. Lindenmayer D. B., Laurance W. F., Franklin J. F., Likens G. E., Banks S. C., Blanchard W., Stein, J. A. et al. (2014). New policies for old trees: averting a global crisis in a keystone ecological structure. *Conservation Letters*, 7(1): 61-69.
20. Mandal G. and Joshi S. P.(2014). Analysis of vegetation dynamics and phytodiversity from three dry deciduous forests of Doon Valley, Western Himalaya, *India. J. Asia-Pac. Biodiver*, 7: 292– 304.
21. Mishra B.P., Tripathi R.S., Tripathi O.P. and Pandey H.N. (2003). Effects of disturbance on the regeneration of four dominant and economically important woody species in a broad-leaved subtropical humid forest of Meghalaya, north east India. *Current Science*. 84(11):1449-1453.
22. Misra R. (1968). Ecology Work Book. Oxford and IBH Publishing co. Calcutta, 244pp
23. Negi P. S. and Sharma S. (2015). Effect of time of fruit collection on the seed germination of *Fraxinus xanthoxyloides* (Wall. Ex G. Don) DC. *Indian Forester*, 141(4):379-383.
24. Negi S.S. (1995). Cold Deserts of India. Indus Publishing Company, New Delhi. pp 240.
25. Negi V. S., Giri L. and Sekar K. C. (2018). Floristic diversity, community composition and structure in Nanda Devi National Park after prohibition of human activities, Western Himalaya, India. *Current Science*, 115(6): 1056-1064.
26. Odum E. P.(1971). Fundamentals of Ecology, Philadelphia, PA, W.B. Saunders and Co, 3rd edn.
27. Pandey R., Sharma J., Singh R., Rawat M., Saklani H., Tomar P. K.,... and Semeraro, T. (2022). Vegetation Characteristics Based Climate Change Vulnerability Assessment of Temperate Forests of Western Himalaya. *Forests*. 13(6): 848.
28. Rajwar G. S., Dhaulakhandi M. and Kumar P. (1999). Regeneration status of an Oak forest of Garhwal Himalaya. *Indian Forester,* 125:623-630.
29. Rawat B., Gairola S., Sekar K. C. and Rawal R. S. (2014). Community structure, regeneration potential and future dynamics of natural forest site in part of Nanda Devi Biosphere Reserve, Uttarakhand, India. *Afr. J. Plant Sci*, 8(7): 380-391.
30. Rawat B., Negi V. S., Mishra J. and Tewari L. M. (2013). The potential contribution of wildlife sanctuary to forest conservation: a case study from Binsar Wildlife Sanctuary. *J. Mot. Sci.* 10(5): 854–865.
31. Rawat P. (2022). Ex situ conservation of *Schleichera oleosa* (Lou.) Oken. through seeds. Ph.D. Thesis. Forest Research Institute, Dehradun.pp-1-145.
32. Sagar R., Raghubanshi A. S. and Singh J. S. (2003). Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest ecology and Management*, 186(1-3): 61-71.
33. Samant S.S. and Dhar U. (1997). Diversity, endemism and economic potential of wild edible plants of Indian Himalaya. *Int J Sust Devel World Ecol*. 4:179–191.
34. Samant S.S., Dhar U and Palni L.M.S. (1998). Medicinal plants of Indian Himalaya: Diversity, distribution, potential values. Gyanodaya Prakashan, Nainital
35. Shankar U. (2001). A case study of high tree diversity in a sa1 (*Shorea robusta*)- Dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Current Sci*ence, 81:776-786.
36. Sharma P. K., Sethi G. S., Sharma S. K. and Sharma T. K. (2006). Ethnomedicinal observations among the inhabitants of cold desert area of Himachal Pradesh. *Indian Journal of Traditional Knowledge.* 5(3):358-361.
37. Sheldon J.W., Balick M. and Laird S. (1998). Is using medicinal plants compatible with conservation? *Plant Talk*, 98: 29-31.
38. Singh J.S. and Singh S.P. (1987). Forest vegetation of the Himalaya. *Botanical Review*, 53 (1):80-192.
39. Uma Shankar R. (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: 776-786.

40. UNESCO/UNEP/FAO. (1978). Tropical Forest Ecosystems: A State of Knowledge Report. UNESCO, Paris, France.
41. Uniyal S.K., Awasthi A, Rawat G.S. (2002). Current status and distribution of commercially exploited medicinal and aromatic plants in upper Gori Valley, Kumaon Himalaya, Uttaranchal. *Current Science*. 82: 1246-1252.
42. Qanbari V. and Jamali A. A. (2015). The relationship between elevation, soil properties and vegetation cover in the Shorb-Ol-Ain watershed of Yazd. *J Biodivers Environ Sci*, 6(5):49-56
43. Vidyarthi S., Samant S.S. and Sharma P. 2013. Traditional and indigenous uses of medicinal plants by local residents in Himachal Pradesh, North Western Himalaya, India. *Int. J. Biodivers. Sci. Ecosystem Services and Management*, 9(3): 185-200.

Figures

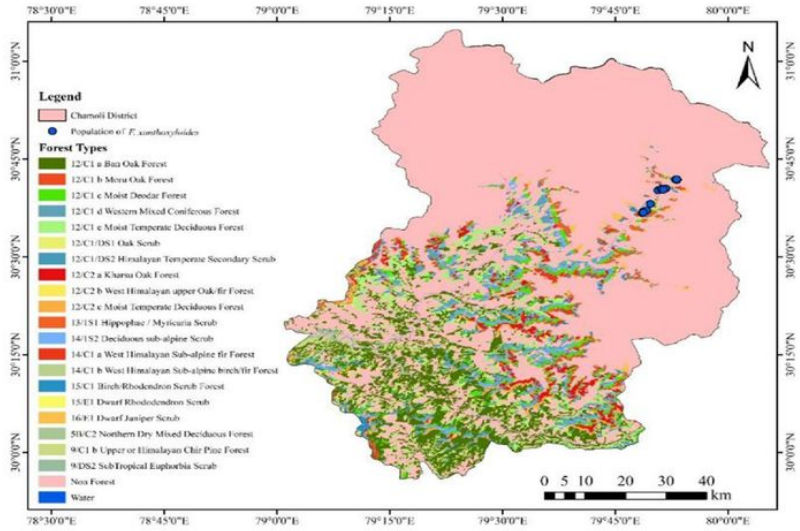


Fig. 1a:

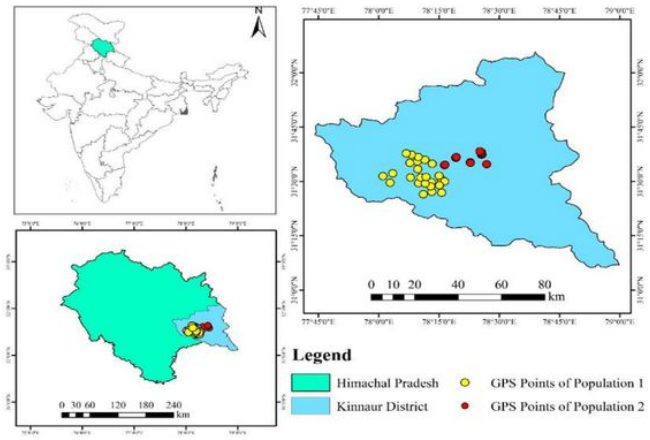


Fig. 1b:

Figure 1

a: Geographic location of Uttarakhand populations of *Fraxinus xanthoxyloides*

b: Geographic location of Himachal Pradesh populations of *Fraxinus xanthoxyloides*

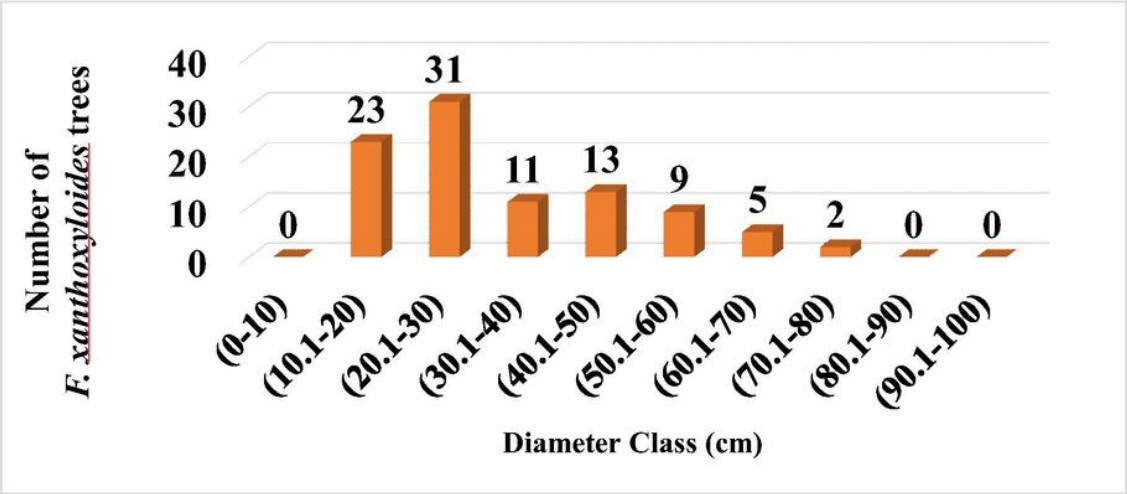


Figure 2

Population structure of *Fraxinus xanthoxyloides*in Jhelum site, Nanda Devi National Park, Joshimath Forest Range, Uttarakhand

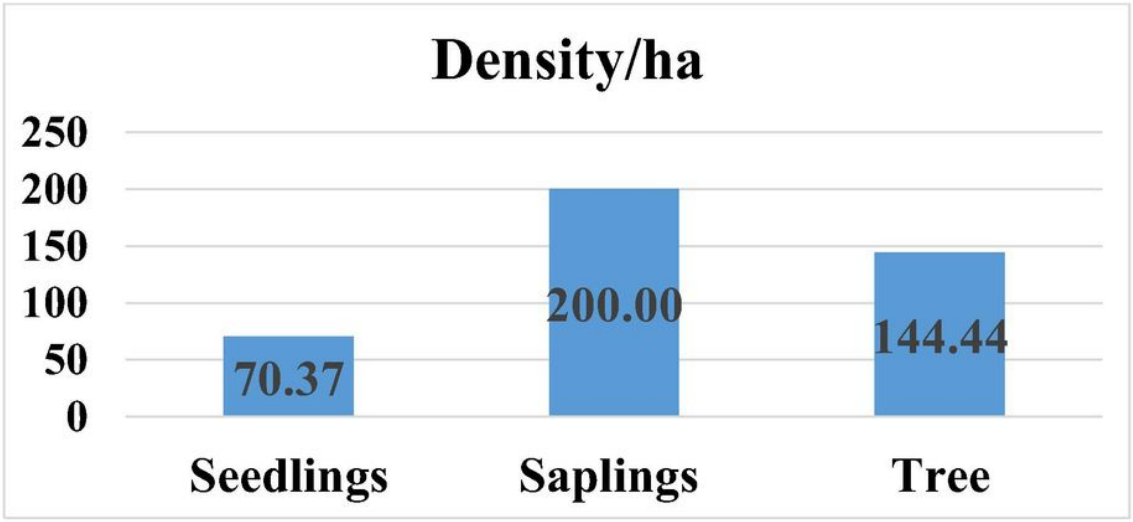


Figure 3

Seedling, Sapling and tree density of *Fraxinus xanthoxyloides* in Jhelum site, Nanda Devi National Park, Joshimath Forest Range Uttarakhand

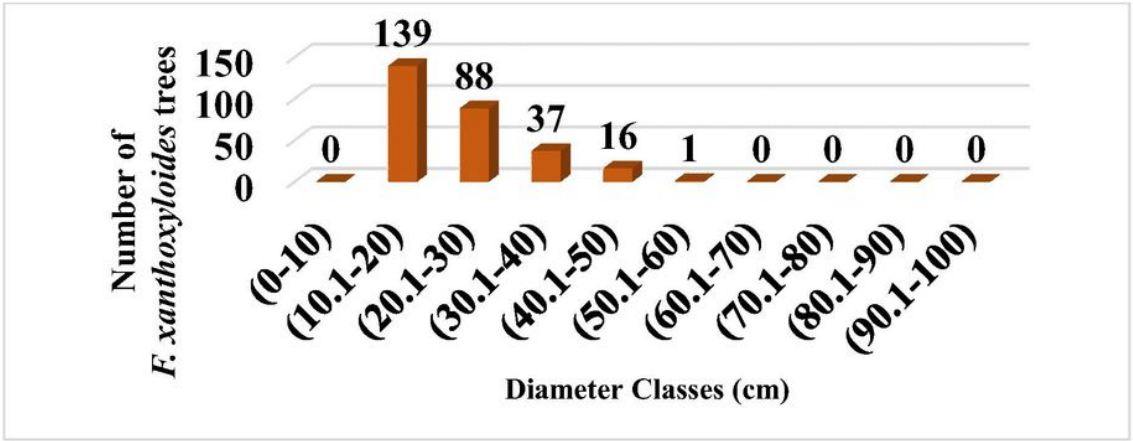


Figure 4

Population structure of *Fraxinus xanthoxyloides* in Malari site, Nanda Devi National Park, Joshimath Forest Range, Uttarakhand

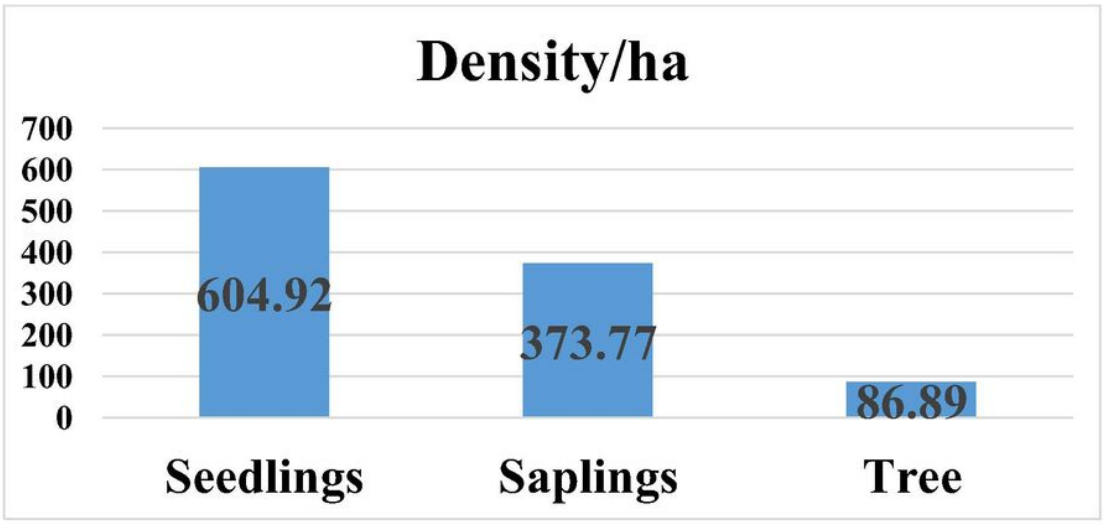


Figure 5

Seedling, Sapling and tree density of *Fraxinus xanthoxyloides* in Malari site, Nanda Devi National Park, Joshimath Forest Range, Uttarakhand

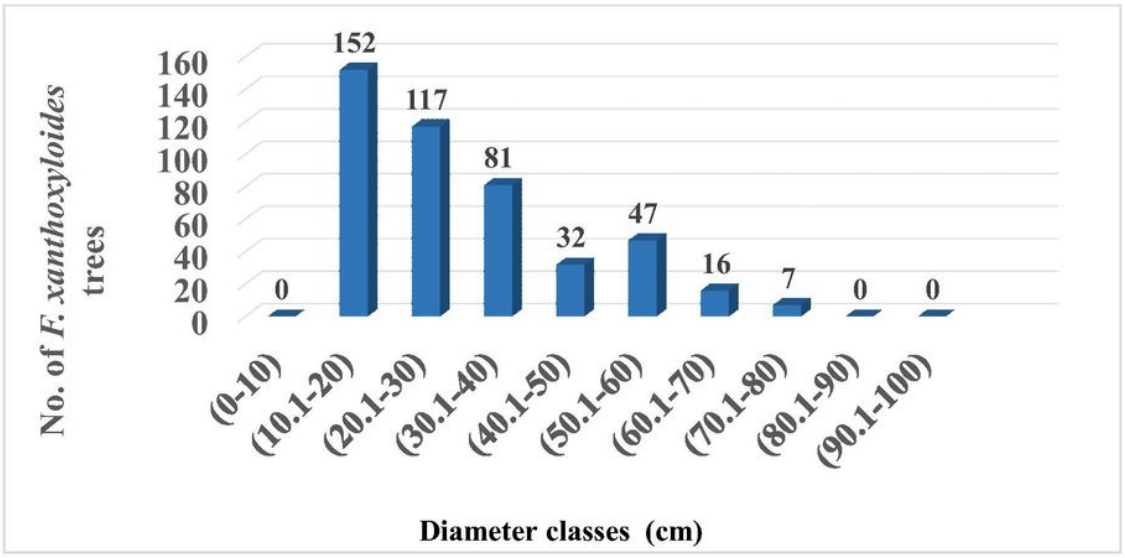


Figure 6

Population structure of *Fraxinus xanthoxyloides* in Ribba site, Kinnaur Forest Division, Moorang Forest Range, Himachal Pradesh

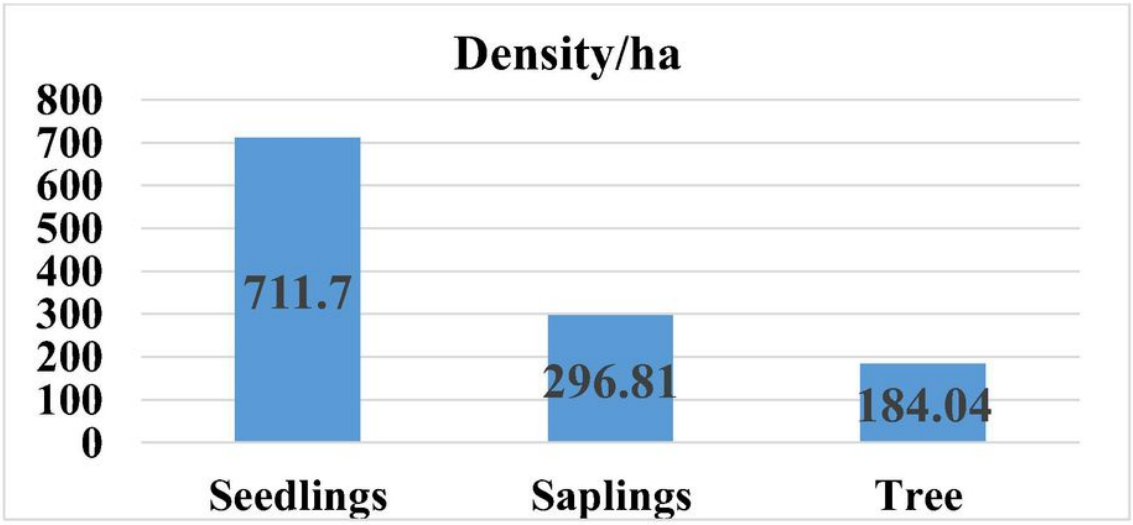


Figure 7

Seedling, Sapling and tree density of *Fraxinus xanthoxyloides* in Ribba site, Kinnaur Forest Division, Moorang Forest Range, Himachal Pradesh

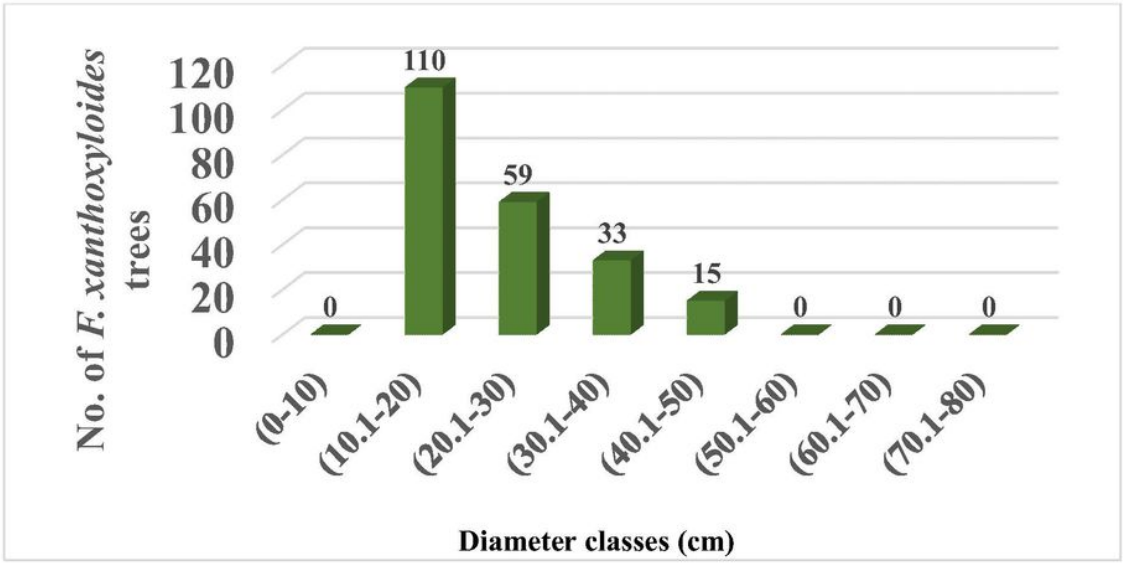


Figure 8

Population structure of *Fraxinus xanthoxyloides* in Jangi site, of Kinnaur Forest Division, Moorang Forest Range, Himachal Pradesh

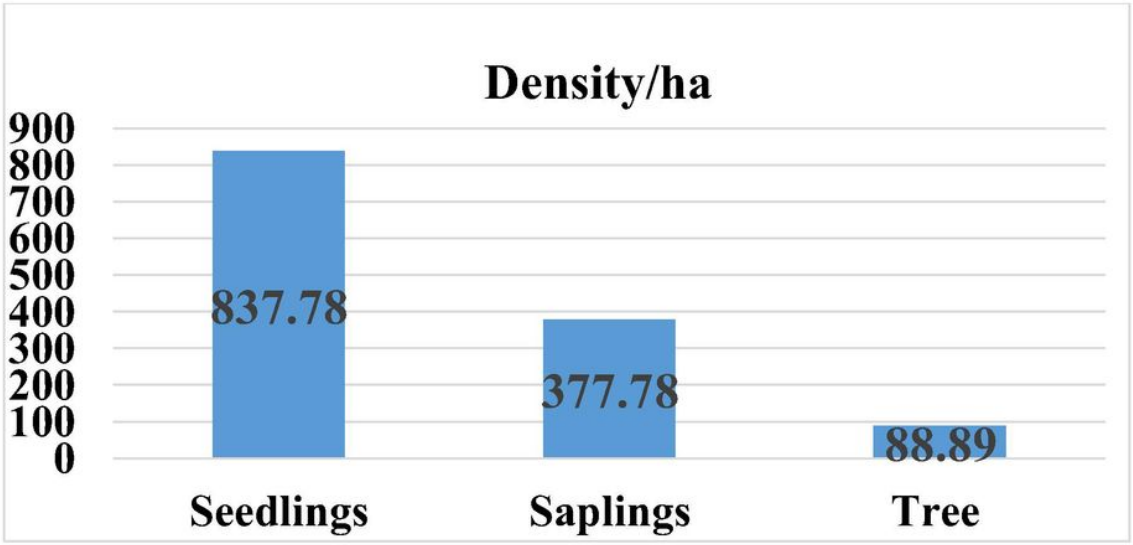


Figure 9

Seedling, sapling and tree density of *Fraxinus xanthoxyloides* in Jangi site, at Kinnaur Forest Division, Moorang Forest Range, Himachal Pradesh