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COMPARATIVE REGENERATION STATUS OF *PINUS GERARDIANA* IN TWO FOREST-USE TYPES OF SULAIMAN MOUNTAIN RANGE NEAR PAK-AFGHAN BORDER REGION: HISTORICAL, CURRENT AND FUTURE PERSPECTIVES

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Abstract

Pinus gerardiana Wall. ex D.Don is valuable commercial species with sparse distribution all around the world. In the Sulaiman mountain range of Pakistan, *P. gerardiana* faces many threats affecting its regeneration status and sustainable conservation. The aim of study was to evaluate the competing regeneration and expansion pattern of *P. gerardiana* in two different forest-use types (based on anthropogenic pressure) in Sulaiman mountain range. Seventy plots were randomly selected in each forest. Average regeneration density was significantly greater in the (low anthropogenic area) (85.76 ± 6.67 no ha^{-1}) than the (high anthropogenic area) (4.30 ± 0.98 no ha^{-1}). Determining the basal area (m^2 ha^{-1}), significantly higher value was recorded in low anthropogenic area (2.69 ± 0.14, $p<0.01$) in comparison to high anthropogenic area (1.43 ± 0.10, $p<0.01$). Average height of the trees was significantly higher in the high anthropogenic area. Shannon evenness and Simpson diversity indexes were determined based on the size of the dbh classes of the species. For low anthropogenic area, Shannon evenness and Simpson diversity index were recorded as 0.8355 ± 0.02 and 0.6109 ± 0.01 respectively while for high anthropogenic area the two indexes were recorded as 0.7429 ± 0.03 and 0.5109 ± 0.02 respectively. Overall the regeneration of *P. gerardiana* in the high anthropogenic area is in a critical state of condition. Hence, there is an urgent need to consider and take into account the alarming situation and to ensure the sustainability of these forests by enforcing strict laws through community involvement.

Key words: *Pinus gerardiana*; Sulaiman mountain range; Regeneration status; DBH

Introduction

Pinus gerardiana Wall. ex D.Don is a vital ecological and economical species, commonly known as "Chilgoza or neoza pine" in Pakistan. It has very sparse distribution and found in Indian Himalayas, remote valleys of Pakistan including Sulaiman mountain range, Kashmir and part of Afghanistan (Champion *et al.,* 1965). Research studies pertaining to its natural regeneration have revealed several factors both biotic and abiotic affecting the sustainable maintenance and better regeneration of the species in its natural habitat (Sharma & Minhas, 1993; Wahab *et al.,* 2008; Khan *et al.,* 2015; Akbar *et al.,* 2013; Kumar *et al.,* 2014; Kumar *et al.,* 2016). The poor natural regeneration had gone to the predominance of mature and over mature trees coupled with reduced number of younger trees in the forests (Sharma *et al.,* 2010). Among other factors being responsible for the poor regeneration and growth of *P. gerardiana*, the important one is collection of nuts by the indigenous communities due to its high price in the national and international markets (Peltier & Dauffy, 2009). This type of biotic intervention badly affecting the process of natural regeneration and stand development, which may result in the decline of forest resources and corresponding changes in the physico-chemical properties of soil with an ultimate effect on the succession pattern (Romme *et al.,* 1998). *P. gerardiana* is under critical condition and that is why IUCN has declared it an endangered species in the red list (Urooj & Jabeen, 2015).

In the Sulaiman mountain range of Pakistan, this species occurs in the zone with an altitude between 2700 m to 3400 m above sea level (Rafi, 1965). Anthropogenic disturbances during the last 100 years have been extended to this zone, which has brought drastic changes in the vegetation composition and regeneration pattern of *P. gerardiana* at higher altitudes (Moinuddin *et al.,* 1991). However, at lower elevations, this species has been almost entirely eliminated.. The ongoing anthropogenic practices may reduce the regeneration capacity of *P. gerardiana*, which can ultimately result its extinction from the entire region. In other words, the absence of effective management and conservation strategies, has put this ecologically and commercially valuable species into a great danger. Therefore, lack of data on the regeneration status of *P. gerardiana* in the Sulaiman mountain region is a scientific gap, which needs to be filled through a detailed study. Thus, the present study has been planned with the objectives to (i) compare the current natural regeneration status and other tree stand characteristics of *P. gerardiana* in two different forest-use types, and (ii) to evaluate the effect of various ecological and physiological conditions on the regeneration potential of *P. gerardiana* by investigating previous studies to device future conservation strategies in a relatively less explored area of Pak-Afghan border region. The results of this study would bring broader implication for the sustainable utilization of *P. gerardiana* in similar regions across the globe.

Materials and Methods

Study area and ethnic background of the local population: Sulaiman Mountain Range is an extension of the Hindu Kush Mountain Range mostly occurs in the Baluchistan province of Pakistan. The study area comes under dry temperate areas in the country, with a special importance from geological point of view, which forms a border line between the Plateau of Iran and Continent of Asia. Sulaiman Mountain Range is geographically consisting several Cretaceous folds having the highest peak of "Thakht-e-Sulaiman", locally called "Kaisay Ghar". Mainly, the study area is populated by three tribes; Harifal, Sherani and Oba Khel. Approximately, 1600 human population of Harifal and Sherani sub-tribes are residing in three villages namely Kamalzai, Darzai and Hasanzai located in the proximity of "Sheen Ghar" (Green mountain) Valley (High anthropogenic area). On the other hand, approximately 1200 population of Oba Khel sub-tribe is living in Ahmadi Dargah, Kasai, Lakai, Ghundi Kuna and Niazi Kot villages (less anthropogenic area), all of whom own about 112 km^2 of pure Chilgoza (neoza pine) and are the direct beneficiaries. The whole range support a pure stand of Chilgoza (*Pinus gerardiana*) forests stretched along 260 km^2 area and considered to be the world's largest pure stand of Chilgoza forest. The area, which has been selected for the assessment of regeneration of *P. gerardiana* is situated near "Thakht-e-Sulaiman", which administratively comes under the Sherani district and laying between 31°- 34' and 31°- 38' N latitude and 69°- 43' and 69°- 57' E longitude (Fig. 1), with elevation range between 500 m to 3350 m above the sea level. The rate of precipitation in the area is 200-500 mm annually (Raziq *et al.*, 2010).

Economically, the people in the study area are living below the poverty line having no proper source of income. Most of these people are herders and depend on forest products including unsustainable collection of pine nuts, cutting of pine trees and grazing in order to sustain their livelihood. The study area comes under the remote areas of Pakistan with a low literacy rate and lack of quality education. Moreover, the study area is lacking modern health facilities such as hospitals with no proper communication system in connecting the area to the urban areas.

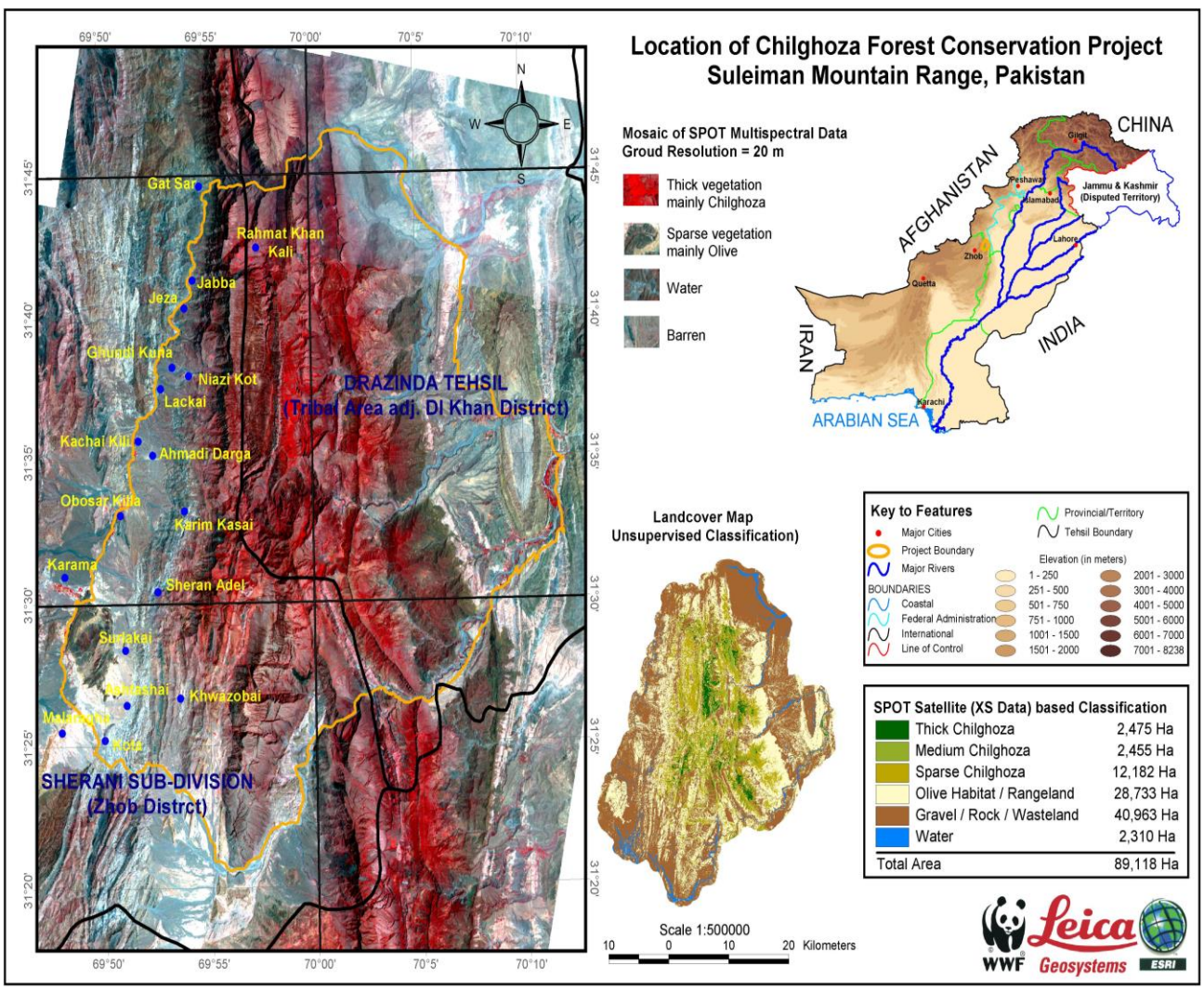

Fig. 1 (a). Map of the study areas (WWF-Pakistan)

Fig. 1. Map of the study area forest-use types and plot design: A showing high anthropogenic areas while B showing less anthropogenic areas.

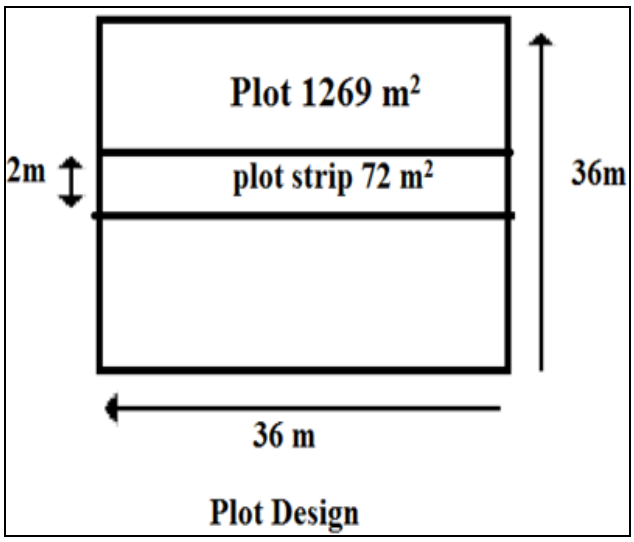

Fig 1 (b). Plot design.

Economic importance of *Pinus gerardiana*: *P. gerardiana* produces edible nut/seeds rich in many essential nutrients such as proteins, carbohydrates, fats, mineral matter and fibers (Thakur *et al.,* 2009). Chilgoza pine is an excellent source of fine turpentine resin. The seeds are used as anodyne and stimulant while the seed oil is used against wounds and ulcer. The fresh seeds contain sugars (4.07%), proteins (13.03%), oils (52.15%) and moisture (25.36%). The seeds have high demand in the local, national and international markets and fetch very good prices (Peltier & Dauffy, 2009). The price of pine nuts is ranging between 20-30 US$ in the open market**.** Out of the estimated 800 quintal (quintal is a historical unit of mass in many countries which is usually defined as 100 base units of either pounds or kilograms) nuts produced in Kinnaur India, about 750 quintal (worth 292242.31 US$) is exported to other parts of the country and abroad (Khan *et al.,* 2015; Akbar *et al.,* 2013). The larger proportion of nut production comes from Kinnaur alone while the remaining requirement is met through import from Afghanistan (Kumar *et al.,* 2014). Ecologically, the species is an excellent soil binder and prevent large scale soil erosion from the loose and fragile strata particularly in dry temperate and semi-arid regions. The natives in the study area have rights of seed collection from the natural forests growing in their jurisdiction. In general, the species has high potential for the socio-economic development of rural communities residing nearby Chilgoza forests.

Forest administration and classification of forest-use types: The indigenous people living in the proximity of Sulaiman Mountain Region are extremely dependent on these forests for their livelihoods, which results in uncontrollable grazing, trees cutting and seed collection posing a great threat to the sustainability of these forests. Therefore, forests occurring in the elevated zones are highly threatened due to continuous disturbance. The forests in the study area are owned by the local people while state has no involvement in the administration of these forests. World Wide Fund for Pakistan (WWF-P) is actively involved in the conservation of Chilgoza forests through community participation in the Sulaiman Mountain Range since 1992. Since then, WWF-P has developed rapport with the local community for the conservation of *P. gerardiana* in the study area. WWF-Pakistan worked with the local people and formed a Local Tribal agreement through "Jirga". The Jirga is a local committee of elder people for the implementation of law and order, and maintenance of the respective forests. The Jirga had imposed ban on the cutting of green *P. gerardiana* trees with the exception of only dry wood were allowed to be extracted. In case of any violation, the offenders were subjected to pay fine of US$ 100 per tree. Due to ban, the timber cutting has been reduced up to some extent, however, the WWF-P project came to an end and now there is no other government and private organization working for the conservation of this valuable forests resource (Anon., 2014).

Two forest-use types (high and low anthropogenic areas) making pure stands of *P. gerardiana* were selected in the study area. High anthropogenic area is the one situated near to the community is also known as Sheen Gher forest. On the other hand, low anthropogenic area is located away from the community and is called the Kaisay Gher forest in local language. The classification of both forest-use types is based on the local anthropogenic pressure including grazing, deforestation, local use of fuel wood, timber extraction, fodder collection, distance from the nearest community, human population size living in the proximity to these forest (Table 1). This classification is a modified form of classification adopted by Moktan *et al.* (2009) in his study carried on regeneration of mixed conifer forests in different forest-use types in western Bhutan Himalayas. Both forest-use types are situated in the same mountainous region, therefore, we assume the environmental variables, soil physicochemical properties and other abiotic factors similar in both forests.

A detailed literature survey was also conducted to collect all the data relating to various parameters of the *P. gerardiana.* The step was taken in order to present a comprehensive evaluation of the available data so as to make better recommendations based on the available literature. Data was gathered from indexed and non indexed journal by using online bibliographic data bases: PubMed, Scopus, Google, Google Scholar, Web of Science, ISI Web of Knowledge and Science Direct Navigator, as well as some library sources. Inside the data- bases, we used words like Regeneration status of Pines, effect of anthropogenic pressure on the regeneration capacity of *P. gerardiana,* ecological and physiological studies on *P. gerardiana,* etc. A very little proportion of literature was found in which further some physiological and ecological potential studies were reported.

Table 1. General attributes of the two forest-use types.

Particulars	Low anthropogenic area (Kaisay Gher Forest)	High anthropogenic area (Sheen Gher Forest)
Distance from the community (Km)	5-6	3-4
Administrative status	Private land	Private land
Anthropogenic activities	Grazing (2 months in a year) little deforestation	Grazing, deforestation, local use of fuel wood and timber, fodder collection around the year
Name of sites (no of plots)	Shamshadeen (25), Martanai (7), Torra Garra (4), Gardavo Narai (4), Tarrakai (4), Khrro Lakai (5), Zarra Punga (5), Naar (5), Maidan (3), Mammay Landa (8)	Ponga (39), FC Camp (20), Penakai (11)
Altitude (Meter above the sea level)	2381 to 2753	2473 to 2738
Latitude	31° 35' 48 N To 31° 38' 724 N	31° 34' 00.8 N To 31° 36' 28.2 N
Longitude	69° 56' 07 E To 69° 57' 33 E	69° 43' 00.6 E To 69° 44' 42.7 E
Population living around (Human population)	1200	1600
Slope (%)	42%	30%
Aspect	N=28 Plots S= 42 Plots	N=13 Plots S=5 Plots W=34 Plots E=16 Plots

Table 2. Tree Stand Characteristics. Mean ± standard deviation.

Variables	Low anthropogenic area	High anthropogenic area	Mann-Whitney U test
	Mean ± SE	Mean ± SE	
Regeneration (no ha^{-1})	85.76 ± 6.67	4.30 ± 0.98	$p<0.01$
Mature trees (no ha^{-1})	244.82 ± 16.04	68.45 ± 3.95	$p<0.01$
Height (m)	13.72 ± 0.62	19.57 ± 0.58	$p<0.01$
Average DBH (cm)	31.38 ± 1.19	42.11 ± 1.63	$p<0.01$
Basal area (m^2 ha^{-1})	2.69 ± 0.14	1.43 ± 0.10	$p<0.01$
Regeneration/ mature trees	0.39 ± 0.04	0.06 ± 0.02	$p<0.01$
Elevation (Feet)	8522.09 ± 37.83	8529 ± 23.15	Non significant
Shannon index tree ($H^{/}$)	1.0352 ± 0.02	0.7180 ± 0.04	$p<0.01$
Shannon evenness (E_H)	0.8355 ± 0.02	0.7429 ± 0.03	Non-significant
Simpson index	0.6109 ± 0.01	0.5109 ± 0.02	Non-significant

Sampling design, plots selection and field measurements: Survey was conducted during the month of November and December 2013. In both forest-use types, 70 inventory plots were selected for data collection on trees variables. First of all, GPS data were recorded, which resulted in an approximate map of the two areas (Fig. 1). For sampling and plot design Adnan & Hölscher, (2011) was followed. Afterwards, points (center of each plot) were randomly selected with the help of ILWIS software (version 3.4: ITC 2007). The software generated random values, in which one value for X axis and one value for Y-axis, with the point of intersection indicating the sample point. Plot design comprised of tree inventory plot of 36 m × 36 m (1269 m^2) square plot (Fig. 1) for data collection on tree stand structural variables (Table. 2). In each tree inventory plot, we measured diameter at breast height (dbh), tree height (measured through clinometer) of all living woody stems greater than 2 m high while on the plot level basal area and stem density were measured. Stems greater than 2 m height was counted as mature trees, while individuals with the length less than 2 m were considered regenerated. Furthermore, within each tree inventory plot, a rectangle plot strip of 36×2 m (72 m^2) was designed for measuring the regenerated trees density (Adnan & Hölscher 2010; 2012). Curtis & McIntosh (1950) protocol was followed in estimating individual plants density. Aspect orientation and slope were recorded for each plot. Shannon–Wiener diversity index H/, Shannon evenness and Simpson index per plot were also calculated (Magurran, 2004). The Shannon Index, Shannon evenness and Simpson diversity index were calculated based on the different classes of the tree relative to their dbh size.

Statistical analysis

All the numerical data was organized using Microsoft Excel. Mann–Whitney test was used to test statistical difference in the mean values of different variables among the two different forest-use types by using SPSS (Version 16.0) (SPSS Inc. 2007).

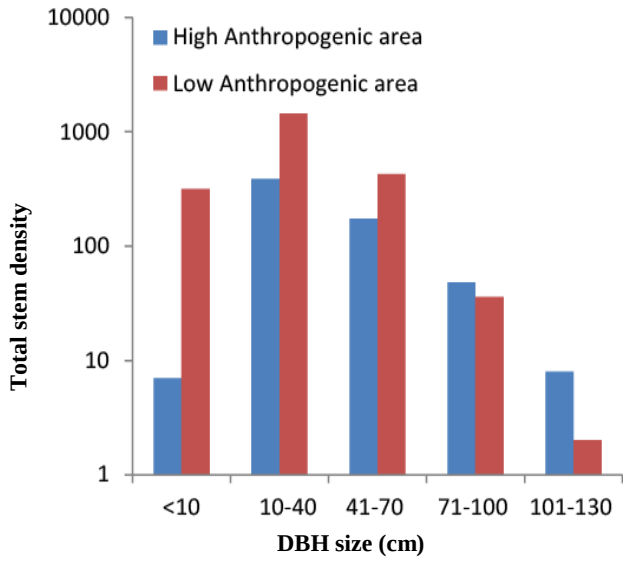

Fig. 2. Comparison of different dbh classes in the less and high anthropogenic areas.

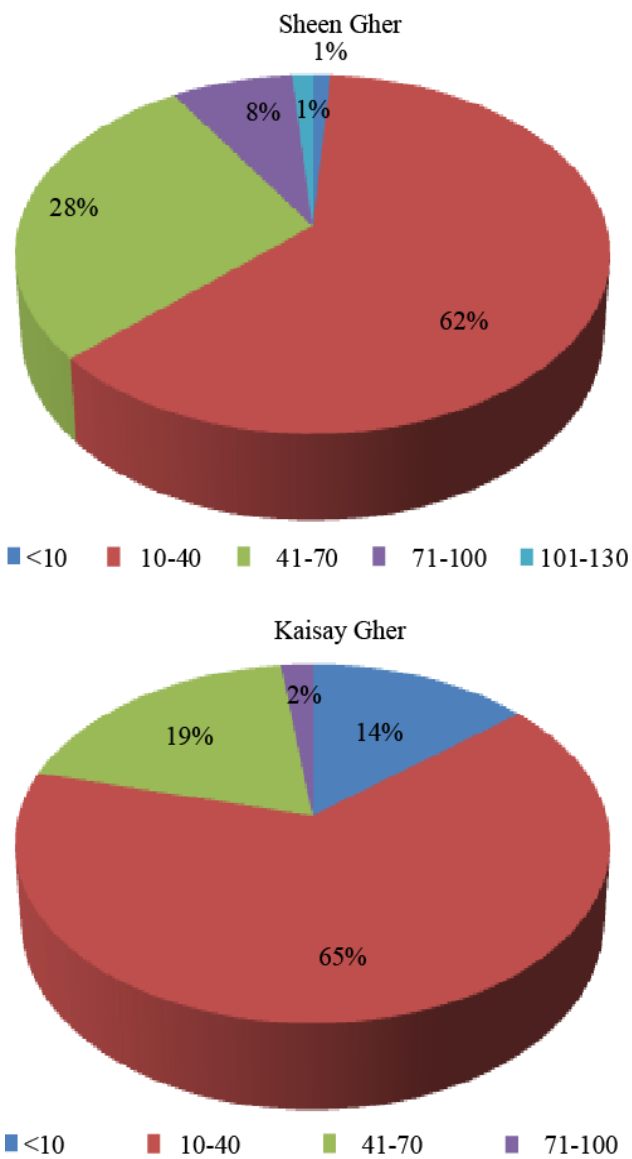

Fig. 3. Percentage of different dbh classes in both forest use-types

Results and Discussion

P. gerardiana is ecologically and economically valuable coniferous species with sparse distribution in different parts of the world including Pakistan. There are several biotic and abiotic factors being responsible for its exploitation and poor regeneration (Kumar *et al.*, 2015). This species has already been documented as in critical conditions in certain parts of the world such as Himalayan region (Malik *et al.*, 2012). In the Sulaiman mountain range, people are greatly dependent on the nuts obtained from this species, which is affecting the natural regeneration process to a great extent.

Comparative regeneration status of *P. gerardiana* in high and low anthropogenic areas: This study presents a comparative analysis of two forest-use types in terms of regeneration potential, based on anthropogenic pressure and other biotic factors such as grazing pressure. Forest regeneration is perhaps the single most important step, significantly highlighting the long term sustainability of growing forests (Saikia & Khan, 2013). Studies on the regeneration not only give a clear picture of the current status about a forest but also illuminate the future possible changes in forest composition (Malik & Bhatt, 2016). In the present study *P. gerardiana* showed significantly higher ($p<0.01$) regeneration density in Kaisay Gher forest (85.76 no ha^{-1}) as compared to Sheen Gher forest [4.30 no ha^{-1}] (Table 1). Table 1 show general attributes while Table 2 shows tree stand characteristic. The regeneration success of pine was extremely low in all the sampling plots of Sheen Gher forest (high anthropogenic area) as compared to the Kaisay Gher forest (low anthropogenic area), which may be due to the exposure of species to both biotic (seed harvesting and grazing) and abiotic factors (climatic and edephic factors). Rafi (1965) and Champion *et al.* (1965) reported lack of regeneration of the species in this forest. During the survey, some local people were of the point of view that almost all of the nuts are collected and harvested by the indigenous communities with the exception of trees on steep slopes and or far away from the reach of collectors. Similar results were obtained by Kumar *et al.* (2015), in Indian Himalaya, where he found a significant association between the regeneration of pine and the biotic factors like nut harvesting, lopping of branches and grazing of the domestic animals.

In this study, grazing of domestic animals was observed in the both forest types but the Sheen Gher forest was much exposed to this pressure as compared to the Kaisay Gher forest due to the fact the Kaisay Gher forest is situated at a considerable distance from the community as compared to the other one. Local people have also revealed that during the time of cone collection, indigenous communities migrate to the respective forests along with their domestic cattle and reside inside these forests for one or two months resulting in a heavy grazing pressure. Previous research studies have indicated that natural regeneration of the pine has been affected by the high frequency of grazing by sheep, goats, trampling and eating of the fallen nuts by birds and rodents (Singh *et al.*, 1973; Luna, 2008;

Malik & Shamet, 2008). In addition, the most important factor responsible for the poor regeneration is the harvesting process. This statement can be justified by the previous research reports (Peltier & Dauffy 2009; Sharma *et al.,* 2010) especially from Indian Himalaya (Malik & Bhatt, 2016; Kumar *et al.,* 2015). However, the poor regeneration status of *P. gerardiana* can not only be attributed to the seed harvesting and grazing. There are several other site factors such as climatic factors, physicochemical properties of soil (Singh *et al.,* 1973; Gaur *et al.,* 1995), low nitrogen level and aridity condition (Kumar *et al.,* 2016; Kaushal, 1993) can have significant contribution in the process of natural regeneration. It has been reported by Kumar *et al.* (2015) that drought, temperature fluctuations and desiccating wind have important role during the growth of seedlings of *P. gerardiana* in Indian Himalaya. There are several study reports mentioning the fact that pine regeneration is regulated by a complete interaction between the availability of seeds for regeneration and existence of micro sites for their germination, early growth and establishment (Bonnet *et al.,* 2005; Galipeau *et al.,* 1997). Similar results for pine have been documented previously by other researchers from different areas of Himalayan Range (Sharma *et al.,* 2010; Kumar *et al.,* 2015; Ahmed & Latif, 2007). In the current study, younger trees have less density than mature trees. The condition can be referred to the fact that previously the seeds of *P. gerardiana* were not completely removed, harvested and cleared from the forest floor by the communities, which enables the forest to regenerate at a sustainable rate.

In the Indian Himalaya, Kumar *et al.* (2015) recorded the regeneration success rate ranged between 8.44-15.93 % while Malik *et al.* (2012) recorded 18-22% regeneration success of *P. gerardiana*. Furthermore, due to poor regeneration potential of 15%, this species was declared as "Critically endangered" in the particular region (Malik *et al.,* 2012). Similar results about the regeneration of this species were also found by Singh *et al.* (1973) in Himachal Pradesh.

Population dynamics in both forest-use types: Considerable differences were found between the two forests stands when the population pattern was analyzed and different diameter size class distribution of *P. gerardiana* was investigated (Tables 1, 2). In the present study, *P. gerardiana* was found in pure stands with no other tree species except very few individual of *Pinus wallichiana* in both forest-use types. Kumar *et al.* (2015) in North-Western Indian Himalayan region found that *P. gerardiana* mostly occurred in pure stands with few exception of mixing with *Cedrus deodara*, *P. wallichiana* and *Qeurcus ilex*. Other studies have also reported similar kind of association of *P. gerardiana*-dominated forest in Pakistan (Ahmed & Latif, 2007) and in India (Peltier & Dauffy, 2009). In our study, the stems were classified into different categories on the basis of size of dbh i.e., < 10 cm (dbh), 10-40 cm (dbh), 41-70 cm (dbh), 71-100 cm (dbh) and 101-130 cm (dbh). The total numbers of individuals of different dbh size classes, which were recorded from the selected plots of Sheen Gher forest were 7, 387, 174, 48, 8, respectively while from Kaisay Gher forest were 318, 1447, 425, 36, 2, respectively (Fig. 2) A study conducted in Sulaiman Mountain Range by Moinuddin *et al.* (1991) described that in spite of variations in individual tree stand structure, generally small size classes (6.1-50 cm dbh) showed higher density (63%) of tree individuals as compared to large size classes. Therefore, higher number of young trees indicating the fact that *P. gerardiana* is a fair reproducer as concluded by Saxena & Singh (1984) reporting the parallel results from other forests. Similar results relative to dbh size class structure were also reported for other forests by West *et al.* (1981) and Ahmed *et al.* (1990). According to Knight (1975), such pattern of population structure indicates adequate recruitment. However, if we compare these previous studies with our study then both the studied forest-use types has insufficient regeneration. The size of dbh classes may be interrelated to the size of the trees in a particular area. It has been reported that lesser number of young trees and greater number of mature trees of *P. gerardiana* owes to the influence of biotic and abiotic factors (Kumar *et al.,* 2015). The presence of seedlings and younger trees of *P. gerardiana* was not observed in all the sample plots of sites in the region.

A considerable difference between the indexes of the two forests was observed. The Shannon index for the Sheen Gher forest is significantly lower (0.72 ± 0.04) than Kaisay Gher forest (1.04 ± 0.02). The percentage of individual trees density in the two areas having different dbh has been shown (Fig. 3). Percentage of the individuals trees having dbh 10-40 cm reported from Kaisay Gher forest was 65% while from Sheen Gher forest, 62% was reported. Percentage obtained for individual having dbh less then <10 as 14% for Kaisay Gher forest while for Sheen Gher forest the percentage was 1%). Similarly higher individual were observed in Sheen Gher forest (28%) with dbh ranged from 41-70 while the percentage for the Kaisay Gher forest was recorded as 19%. While comparing the percentage of individual having dbh 71-100, higher percentage was found for Sheen Gher forest as 8% while for the Kaisay Gher forest it was only 2%. It was also observed and recorded that the number of individual with dbh 101-130 were also present in Sheen Gher forest but almost negligible in Kaisay Gher forest (Fig. 3).

Calculating the average dbh value for tree of *P. gerardiana* in the two forests stands, significantly higher average dbh value was recorded from Sheen Gher (42.11 cm) then Kaisay Gher (31.38 cm). It means that the Sheen Gher forest having more aged trees then the other forest. This is just an estimation of the size of the dbh. In a study conducted by Champion *et al.* (1965), the systematic age of a *P. gerardiana* tree having 125 cm dbh was declared to be 150 years old. Study conducted by Moinuddin *et al.* (1991) illustrated that *Pinus* tree with 20 to 30 cm dbh was considered to be 60 years of age and further suggested that the dbh size has a strong positive relationship to the plant age. Moinuddin *et al.* (1991) reported that the individuals having 20 to 30 dbh of *P. gerardiana* had the capacity to grow more fast (6.8 ± 3.6

yr/cm) then the individual of *Juniperus excelsa* having the same dbh classess (10.3 ± 2.98 yr/cm).

Maximum average tree height in Sheen Gher forest was 19.57 m as compared to Kaisay Gher forest (13.72 m). Taking the value of basal area, significantly high value was recorded for Kaisay Gher forest (2.69 m^2 ha^{-1}) than Sheen Gher forest (1.43 m^2 ha^{-1}). In a study conducted about twenty six years ago by Moinuddin *et al.* (1991) in the Sulaiman Mountain Range, the recorded density of *P. gerardiana* was ranged from 24 trees ha^{-1} to 930 trees ha^{-1} with an average 266 individual trees ha^{-1} and with an average basal area of 25.5 m^2 ha^{-1}. A study conducted by Kumar *et al*. (2015) in Indian Himalaya, the recorded density and basal area of *P. gerardiana* was 118.25 ha^{-1} and 20.87 m^2 ha^{-1}, respectively. Similar growing stocks of the species have been found in other forest of the Himalayan Region (Ahmed *et al.,* 1991; Akbar *et al.,* 2014). Density of mature *P. gerardiana* trees was observed significantly highest in Kaisay Gher forest (245 no ha^{-1}) than in Sheen Gher forest (68 no ha^{-1}). Similarly, regeneration/mature trees ratio was also significantly higher in Kaisay Gher (low anthropogenic area) (0.39) than Sheen Gher (high anthropogenic area) (0.06).

Comparing the results of the present study with the previous literature, the basal area of the *P. gerardiana* in the Sulaiman Mountain Range is at alarmingly lowest level. This crucial and drastic change in the growing stock can be attributed to the high anthropogenic pressure due to manmade activities in these forests. The community representatives highlighted that the local people cut down the forest trees for monitory purposes mostly in marriages, construction of houses, and starting new businesses etc. Hence, there is a dire need to conserve this valuable species from further exploitation.

Previous reports: a way forward to improve regeneration of *P. gerardiana*: Most literature pertaining to *P. gerardiana* has been published on physiological, biochemical and ecological parameters in different parts of the world especially Pakistan and India. Some studies have indicated the availability of information on biochemical attributes of seeds, storage condition, propagation and nursery development (Singh & Chaudhary, 1993; Singh *et al.,* 1992; Malik *et al.,* 2008; Malik & Shamet, 2008; Malik *et al.,* 2009). The worldwide reduction in pine nuts supply highlights the economic and ecological significance of pine forests production in horticultural, agroforestry, and other forestry related areas (Sharashkin & Gold, 2004). This is because, chilgoza pine mostly occurs in natural forest and not cultivated due to its slow growth and takes longer time to produce commercial nuts. However, the dependency of local people on nuts has classified *P. gerardiana* under social forestry system in spite of being a conifer species (Seghal & Khosla, 1986). Nuts producing pines could be a suitable agroforestry species, only if certain varieties are developed that are i) well adapted to the local ecological conditions, b) fast growing, c) are precocious (i.e., start producing nut crops at an early age), d) reliably produce heavy crops biennially, and e) serve as multipurpose species that can produce valuable products other than pine nuts (e.g. timber) (Sharashkin & Gold, 2004). There is an immense scope to domesticate *P. gerardiana* and further improve this crop through the establishment of clonal seed orchard and control breeding for increase in nut production both quality and quantity (Singh, 1992). This may be due to fact that *P. gerardiana* exhibit wide variation in most characters with high heritability and genetic gain, which indicates that these characters could be improved by selection (Kant *et al.,* 2006).

Preliminary studies conducted by inoculating the seedlings with mycorrhiza show great promise in the establishment and performance of the seedlings. The seedlings of *P. gerardiana* inoculated with mycorrhizal symbiont showed a 67.6% increase in mycorrhizal development (Lakhanpal & Kumar, 1995). Kumar *et al.* (2014) found that the application of gibberellic acid at 75 ppm, seed soaking for 24 hour at 15^{o}C incubation temperature can be the best treatment to enhance germination in *P. gerardiana*. Seeds of this species show moderate germination but cannot retain better germinability under normal ambient storage (Malik *et al.,* 2008; Bhardwaj & Gupta, 1998). Studies have indicated that larger seed size could increase germination and other seedling growth parameters like plant height, collar diameter, root length and total biomass seedling performance of *P. gerardiana* (Griffin, 1972; Dumroesa & Wenny, 1987). Seed storage is an important aspect of any sound management program, especially in conifers species where seed supply is often limited due to low production and long seed years (Robbins, 1984). Chilgoza pine has been reported to have both physiological and morphological dormancy and slow seedlings growth. Stratification is a method employed to break dormancy of seeds, ensure uniform and quick germination of seeds, and vigorous tree growth in many forest species (Malik, 2007; Barton, 1954). Moreover, a convenient growing media (e.g. vemicompost) and control conditions (e.g. nursery) should not only supply physical, chemical and biological characteristics required by a plant species but also provide conditions for plant production (e.g. easy to supply, suitable cost, easy processing, lightness and homogenous plant production, disease suppression) (Malik, 2007; Sahin & Anapali, 2006).

Various environmental factors are responsible for the poor regeneration of pine. Kumar *et al.* (2015) reported that the abiotic factor affecting the regeneration potential of pine include drought, soil erosion, sandy soil, low nitrogen level in soil, rockiness of terrain, steepness of slop, grazing, seed dormancy, erratic seed year, heat of sun, desiccating wind. Consequently it has been concluded that not only the biotic factors are responsible for poor regeneration but abiotic factors have great contribution in the maintenance of natural regeneration in its natural zone.

Conclusions and recommendations: *P. gerardiana* is an economically and ecologically valuable species with narrow distribution all over the world. In the Sulaiman Mountain Range, regeneration status of this species

was assessed in two different forest-use types including low anthropogenic area (Kaisay Gher) and high anthropogenic area (Sheen Gher). In general, poor regeneration potential of this species may be referred to both biotic and abiotic factors. It is evident from the previous research studies that various physiological and ecological factors are significantly affecting the growth parameters of *P. gerardiana*. However in most cases, such factors are directly and indirectly affected by various anthropogenic factors. Hence, it is concluded that the regeneration potential of *P. gerardiana* is on a decrease in abovementioned mountain range due to high anthropogenic pressures. The main local problems to this mountain range are unlawful tree cutting, unsustainable nuts collection, and unrestricted grazing. These problems are affecting the eco-physiological factors pertaining to this species, which in turn can be responsible for the reducing regeneration rate of *P. gerardiana*.

Based on the facts and findings of this study, suitable management strategies are required for the sustainable utilization of *P. gerardiana* in the entire region. These strategies could for example:

- Joint forest management of the government forest department and local community. Considering limited distribution, failure of natural regeneration, endangered status, and socio-economic and ecological significance of this species, there is an urgent need to undertake artificial regeneration of this species under *in situ* and *ex situ* conditions. As an example, developing vigorous seedlings in nurseries and their plantation in suitable habitats (natural / other similar regions) have been viewed one of the viable options for its conservation and effective management.
- Germinability parameters of chilgoza seeds can be significantly influenced by different soaking periods. Therefore, various tools and techniques should be followed in the nurseries as well directly in the field in order to overcome the low germinability of the seedlings. Different types of pre-treatments should be examined to increase the chances of survival of the species.
- Genetic aspects should also be taken into considerations for producing multipurpose fast growing varieties of this species. This is vital from the *ex situ* view point and could serve in uplifting the socio-economic conditions of local people.
- Special awareness campaign should be launched for the sustainable conservation of the plant species.
- Further ecological studies are required on the regeneration of *P. gerardiana* from biotic and abiotic perspectives, which would serve as guideline for the successful management and conservation of this species in its natural conditions.
- To reduce impact of biotic factors, fencing of the area for some period to augment *P. gerardiana* regeneration is also suggested.
- Studies which are possible in the area

If no proper attention has been made towards the conservation of *P. gerardiana*, then the probability is higher in the near future that this valuable Pine forest would disappear or remain further in small pockets. This condition would have further broader implications both for the ecosystem and livelihood of the local people.

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