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Natural regeneration status of Indian Hazelnut (*Corylus jacquemontii* - Decne.) in Western Himalaya of Himachal Pradesh

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Abstract
The Indian hazelnut (*Corylus jacquemontii* Decne.) belonging to family betulaceae is considered synonym of Turkish hazelnut (*C. colurna* L.). Indian hazelnut is sparsely distributed in small scattered group, varies from 10-15 ft bush form to 70 to 80 ft medium sized tree distributed in North-western temperate Himalayas form Kashmir to Kumaon between 1800-3300 m amsl. It is found associated with oak, fir, spruce, deodar, betula, maple and walnut in natural zone. In India, the species is little known except in high Himalayan regions where it is used mainly by the locals, grazier and the tribes (Pangwal and Bhot) as food. No literature/systematic work has been undertaken regard its distribution pattern, growth and regeneration potential, both natural as well as artificial till date in India. Beside valuable nuts, the species is extensively lopped for fodder and fuel along with maple (*Acer spp*.) and kharsu oak (*Quercus semecarpifolia*) in its natural zone. To access is natural regeneration status in wild the study was carried out in Hazel bearing forests of and of Himachal Pradesh. The manuscript describes the natural regeneration status of Indian hazelnut and associated species in selected hazelnut bearing sites in Sach (Pangi Forest Division) and Kotkhai Forest Range (Theog Forest Division) in district Chamba and Shimla of Himachal Pradesh. In all, eleven tree species were recorded form Pattidhank and Sali forest, while seven and ten species appeared in Gajta and Mindal forests, respectively. Natural regeneration was highest in Gajta (29.07%), followed by Sali (26.25%) forests distributed across two Forest Ranges i.e. Kotkhai (Shimla Circle) and Sach Range (Chamba Circle), respectively. Thus, proper silvicultural measures, along with in-situ conservation and large scale afforestation of this species with the participation of local communities is the need of the hour.

Keywords: Hazelnut, regeneration, species, density, Himalayas

Introduction
The rich floral wealth of the Himalayas has been closely associated with traditional, cultural and socio-economical status of the hill peoples in the Indian Himalayan Region. About 8000 plant species of which 30% are endemics, 10.2% trees, 8.44% wild edibles and over 15% medicinal herbs found in Indian Himalayan Region (Samant and Dhar, 1997) [16]. The dependency of hill people on this rich plant diversity is known since time immemorial. Indian hazelnut (*Corylus jacquemontii* Decne Syn. *C. colurna* L.) is one such wild edible nut belonging to the family betulaceae, growing in temperate forests between 1800-3300m a.m.s.l. in North Western Himalayas (Brandis, 1971) [2]. The species provide not only fuel, fodder and timber but also yield edible nuts for human as well as wildlife consumption (Gupta *et al*. 2017) [8]. The kernels are a rich source of proteins, carbohydrates, vitamins, poly-unsaturated fatty acids and other minerals iron, calcium and potassium, etc. The research shows that hazelnuts exert strong protective influence against coronary heart problems, some types of cancer and other diseases (Richardsons, 1997). Indian hazelnut is self-incompatible tree species found in scattered groups in natural habitat. The species is facing changes in its structure, density and composition in recent years due to global warming, climate change, and anthropogenic pressure (Gupta and Sharma, 2016).

Scientific knowledge of growth, distribution, population dynamics and genetic diversity of wild hazelnut species and cultivation of the hazel nut cultivars is still in the primitive stage in India. The manuscript, therefore assume significance for its conservation and management of wild *Corylus* spp. in the Himalayan forestry programme.

Materials and Methods

Study site

The present investigation was conducted in the hazelnut bearing sites of Pattidhank and Gajta forests in Kotkhai Range of Theog Forest Division (North Latitude 30^0- $56^{'}$ and 31^0- $17^{'}$ and East Longitude 77^0-$16^{'}$ and 77^0- $37^{'}$) and Sali and Mindal forests in Sach Range of Pangi Forest Division (North Latitude $32^048^{'}$ and $33^013^{'}$ and East Longitude $76^015^{'}$ and $76^047^{'}$) in Himachal Pradesh. The study was carried out to understand forest association, distribution pattern and hazelnut community natural regeneration status of woody perennials in widely separated forests in Shimla and Chamba forest circle of the state.

Regeneration survey

The goal of the regeneration survey is to assess the impacts of past management practices that prescribes the stocking, density and composition of present or future stand for an area and *sine qua non* for the forest management. The regeneration survey was carried out in all the main sample plots (25m x 20m) in which forty sub quadrates of size 2m x 2m were laid. The regeneration data for Indian hazelnut and associated species was collected on the basis of number of individuals occurring in recruit, (current year seedling < 10cm), unestablished (10 to < 200 cm) and established stage (≥ 200 to 600cm) in each quadrate. The height of unestablished plants was also measured for the assessment of regeneration (Champion, 1935) as four unestablished plants were taken equivalent to one established plant. The data thus collected was analyzed using the standard procedures/ formulae given by Chacko (1965).

Regeneration assessment

The data thus collected was analyzed using the formulae given by Chacko (1965) [3] as follows:

$$\text{Recruits (r) /ha} = 2500 \sum_{i=1}^{n} r\,i / m$$

$$\text{Unestablished regeneration (u)/ha} = 2500 \sum_{i=1}^{n} u\,i / m$$

$$\text{Established regeneration (e)/ha} = 2500 \sum_{i=1}^{n} e\,i / m$$

Where, n – Number of sampling units; m – Total number of recording units in survey; ri – Total number of recruits in each sampling unit; ui – Total number of unestablished plants in each sampling unit; ei – Total number of established plants in each sampling unit.

$$\text{Weighted average height (m)} = \frac{\text{Total height of unestablished regeneration} + (\text{Number of established plants x establishment height})}{\text{Total unestablished plants} + \text{total established plants}}$$

On the basis of above estimates, following indices were calculated:

$$\text{Establishment index } (I_1) = \frac{\text{Weighted average height}}{\text{Establishment height}}$$

$$\text{Stocking index } (I_2) = 1/2500 \text{ X } \frac{\text{Unestablished regeneration/ha}}{4} + \text{Established regeneration/ ha}$$

Established stocking percent = 100 (I_1 x I_2)
Regeneration success (%) = Stocking index (I_2) X 100

Results and Discussion

The data pertaining to the natural regeneration parameters are presented in the table 1 & 2 and fig. 1 & 2. In all eight tree species regenerated in hazelnut bearing forests of Gajta and Pattidhank forests of Kotkhai Forest Range. On the other hand, only seven tree species were found to regenerate in Sali and Mindal bearing forests of Sach Forest Range. It is quite evident that across all the sites of hazelnut bearing forests, maximum number of recruits and unestablished plants per hectare was recoded in Gajta forest (2250 ha^{-1}; 1657 ha^{-1}), followed by Sali (876 ha^{-1}; 624 ha^{-1}), Pattidhank (689 ha^{-1}; 500 ha^{-1}) and Mindal (94 ha^{-1}; 281 ha^{-1}) forests. However the highest number of established plants was recorded for Sali forest (501 ha^{-1}) and the lowest for Mindal (93 ha^{-1}) forests. Gupta (2015) while studying the regeneration potential of fir and spruce reported higher number of recruits in Kotgarh (4250 ha^{-1}) followed by Rajgarh (3667 ha^{-1}) and Kullu (3168 ha^{-1}) Forest Division owing to adequate number of seed bearers. The sufficiency of regeneration is often judged on the basis of number of established plants in a unit area. According to Chacko (1965) [3], the desired number of established plants is 2500 per hectare and the quadrat is considered fully stocked when it contained at least one established plant.

Table 1: Regeneration status of hazelnut bearing forest in Kotkhai and Sach Forest Range

Sites/Species	Recruits No./ha	Unestablished No./ha	Established No./ha	Per-cent Regeneration
Kotkhai Range				
Pattidhank Forest				
Abies pindrow Spach.(Royle)	281.00	-	-	-
Picea smithiana (Wall.) Boiss	219.00	31.00	-	0.31
Pinus wallichiana A.B. Jacks	63.00	250.00	63.00	5.00
Quercus dilatata Royle	63.00	188.00	-	1.88
Populus ciliate Wall. ex Royle	-	31.00	-	0.31
C. jacquemontii Decne.	63.00	00	31.00	1.25
Total	689.00	500.00	94.00	8.75
Gajta Forest				
Picea smithiana (Wall.) Boiss	219.00	313.00	188.00	10.63

Pinus wallichiana A.B. Jacks	750.00	719.00	125.00	12.19
Taxus wallichiana Zucc.	31.00	94.00	-	0.94
Quercus dilatata Royle	1250.00	500.00	-	5.00
Ilex dipyrena Wall.	-	31.00	-	0.31
Total	2250.00	1657.00	313.00	29.07
Sach Range				
Sali Forest				
Abies pindrow Spach.(Royle)	94.00	-	-	-
Picea smithiana (Wall.) Boiss	406.00	187.00	63.00	4.38
Pinus wallichiana A.B. Jacks	313.00	437.00	63.00	6.88
Acer caesium Wall. ex Brandis	-	-	63.00	2.50
Betula utilis D.Don	-	-	31.00	1.25
C. jacquemontii Decne.	63.00	-	281.00	11.25
Total	876.00	624.00	501.00	26.25
Mindal Forest				
Picea smithiana (Wall.) Boiss	-	-	31.00	1.25
Cedrus deodara (Rox burgh) D. Don	94.00	250.00	31.00	3.75
Acer caesium Wall. ex Brandis	-	31.00	31.00	1.56
Total	94.00	281.00	93.00	6.56

Table 2: Regeneration establishment and stocking data for different tree species in hazelnut bearing forests in Kotkhai and Sach Forest Range

Sites/Species	Weighted average height (cm)	Establishment index (I_1)	Stocking index (I_2)	Established stocking percent ($I_1 \times I_2 \times 100$)
Kotkhai Range				
Pattidhank Forest				
Abies pindrow Spach.(Royle)	-	-	-	-
Picea smithiana (Wall.) Boiss	20.00	0.10	0.00	0.03
Pinus wallichiana A.B. Jacks	18.81	0.09	0.05	0.47
Quercus dilatata Royle	18.13	0.09	0.02	0.17
Populus ciliate Wall. ex Royle	70.00	0.35	0.00	0.11
C. jacquemontii Decne.	50.00	0.25	0.01	0.31
Total	176.94	0.88	0.08	1.09
Gajta Forest				
Picea smithiana (Wall.) Boiss	139.00	0.70	0.11	7.38
Pinus wallichiana A.B. Jacks	70.96	0.35	0.12	4.32
Taxus wallichiana Zucc.	3.88	0.02	0.01	0.02
Quercus dilatata Royle	9.13	0.05	0.05	0.23
Ilex dipyrena Wall.	1.39	0.01	0.00	0.00
Total	224.35	1.13	0.29	11.95
Sach Range				
Sali Forest				
Abies pindrow Spach.(Royle)	0.00	0.00	0.00	0.00
Picea smithiana (Wall.) Boiss	106.75	0.53	0.04	2.34
Pinus wallichiana A.B. Jacks	77.69	0.39	0.07	2.67
Acer caesium Wall. ex Brandis	50.00	0.25	0.03	0.63
Betula utilis D. Don	50.00	0.25	0.01	0.31
C. jacquemontii Decne.	200.00	1.00	0.11	11.25
Total	484.44	2.42	0.26	17.20
Mindal Forest				
Picea smithiana (Wall.) Boiss	50.00	0.25	0.01	0.31
Cedrus deodara (Rox burgh) D. Don	52.45	0.26	0.04	0.98
Acer caesium Wall. ex Brandis	35.00	0.18	0.02	0.27
Total	137.45	0.69	0.07	1.56

As far as natural regeneration of *C. jacquemontii* is concerned, it is clear from the data in table 1 that proportion of current year seedlings of hazelnut was low (63 ha^{-1}) in Pattidhank and Sali forest, while it was complete absent in Gajta and Mindal forest. More over unestablished plants of hazelnut were also absent in all the selected sites of two Forest Ranges. However, the maximum number established plants were recorded in Sali (281 ha^{-1}) forest contributing overall 11.25 per cent regeneration success. The lowest number of established plants (31 ha^{-1}) were reported in Pattidhank forest of Kotkhai Forest Range. On the other hand, Katoch (2014) [9] studying *Rhododendron* community found no recruit and established plant of hazelnut but only 139 unestablished plant per hectare in Jalori forest of Banjar Forest Division of Kullu Circle. Regeneration potential of a species simply expressed as its ability to complete the life cycle. But the absence of recruits, unestablished plants and poor conversion of unestablished plants to established regeneration will adversely affect the stocking and community structure of hazelnut bearing forests in future scenario. Rajwar *et al*., (1999) [14] has observed that the climatic factors and biotic stress would influence the regeneration potential of species comprising the stand of vegetation. They further pointed out that the proportionate conversion of seedlings into sapling stage is affected by biotic disturbances and competition for space and nutrients.

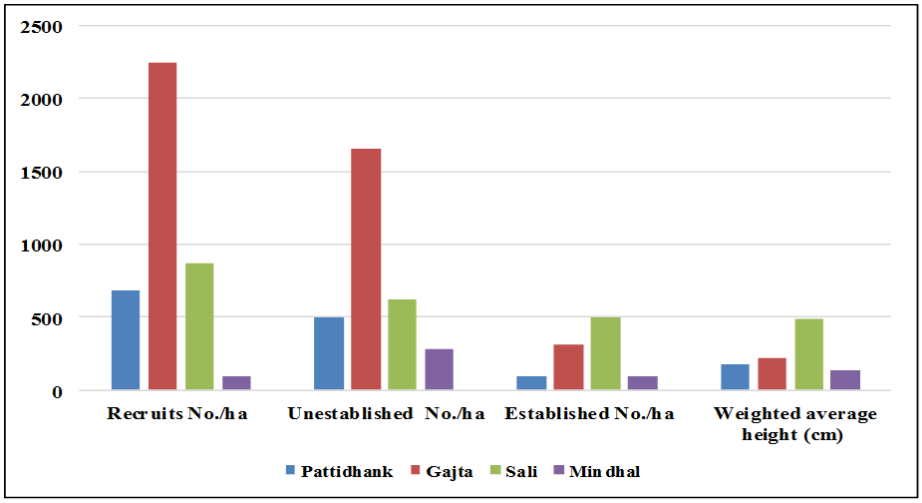

Fig 1: Natural Regeneration parameters of *C. jacquemontii* in hazel bearing forests of Kotkhai and Sach Range

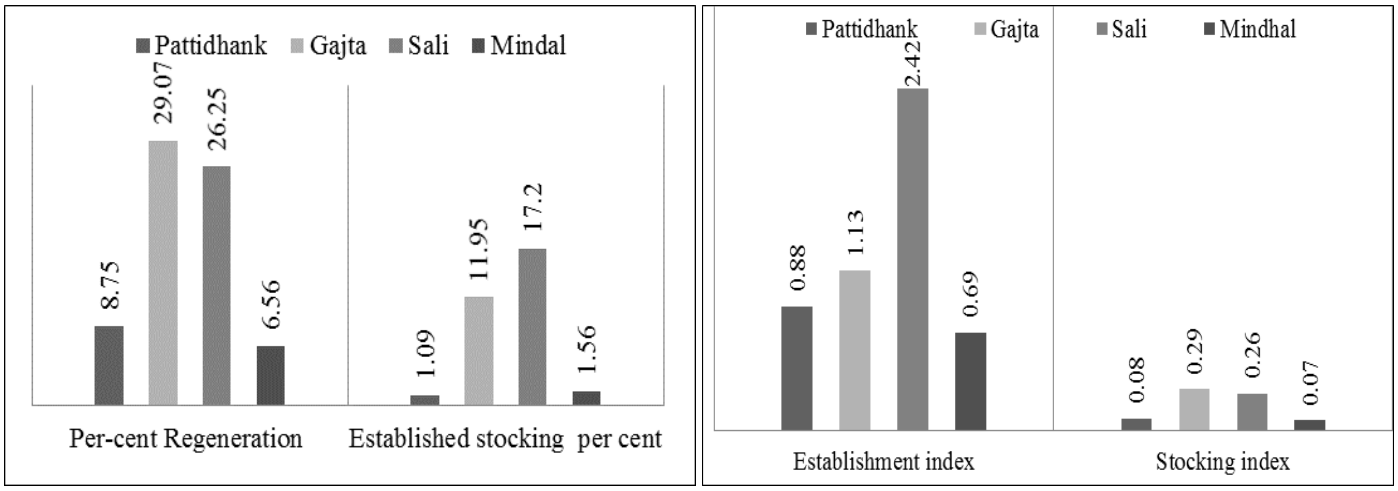

Fig 2: Natural Regeneration parameters of *C. jacquemontii* in hazel bearing forests of Kotkhai and Sach Range

The poor hazelnut regeneration may be attributed to considerable weight of the nut seeds that prevent its spread over grater distances. After falling to the ground they are willingly eaten by small rodents like pica, flying squirrel, rats and even by Himalayan brown bear as reported by Vaidya (2003) [19] in the working plan of Pangi Forest Division. More over the nuts are frequently collected by the locals for self-consumption or/and sold in local market as they fetches very high price. Therefore, only scarcely seeds grow into seedlings in the vicinity of maternal plants where they suffer form other problems like trampling and grazing by animals both by wild as well as domesticated animals like goat, sheep, cow etc. Therefore the evaluation of wild populations of hazelnut species is more important in view of the fact that only few nuts germinates and their proportionate conversion to saplings is decreasing continuously due to habitat degradation, overexploitation and many other factors. Ahmed and latif (2007) [1], Malik (2007) [12], Kumar (2012) [11] and Kumar *et al* (2016) [10] and has also indicated high biotic interference like grazing, trampling by sheep and goats, eating by birds and rodents and collection of nuts by locals as the main cause for the poor natural regeneration status of *Pinus gerardiana* in Kinnaur Forest Division. Anthropogenic interferences, such as, lopping for fuel and fodder, collection of litter, minor forest products in addition to grazing, trampling and browsing can substantially alter habitats and species composition (Sapkota *et al.* 2009) [17]. Thus, the overall regeneration of hazelnut is poor due to less availability of seed for the natural regeneration. In broad leaved forest the disturbances gives an opportunity for invasion by conifers and if the disturbances is prolonged, the oak and other broad leaved forests get slowly replaced by pine forests in the lower fringes (Rawat, 2001; Dhaulkhandi *et al*., 2008; Pananjay *et al*., 2012) [15, 5, 13].

It is evident from the fig. 2 that the regeneration success was highest in Gajta (29.07%), Sali (26.25%) forest followed by Pattidhank (8.75%) and Mindal (6.56%) forest in descending order. Among the conifer species, natural regeneration was better for *Pinus wallichiana* at Pattidhank, Gajta and Sali forest with regeneration success of 5.0, 12.19 and 6.88 per cent respectively. While among the broad leaved species *Quercus dilatata* has the highest regeneration per cent at Pattidhank (1.88%), Gajta (5.0%) in Kotkhai Forest Range (Table 1). Incase of Sali forest *C. jacquemontii* showed the highest regeneration success of 11.25 per cent and while *Cedrus deodara* in Mindal forest with 3.75 per cent. Katoch (2014) [9] while accessing the natural regeneration potential of pink rhododendron bearing forest found the highest regeneration per cent for *Rhododendron campanulatum* in Rhala and Jalori pass bearing forest, while minimum for *C. jacquemontii* in the forest adjoining Jaolri pass in Banjar Forest Division.

The figure 2 indicate the maximum established index was in Sali (2.42), followed by Gajta (1.13), Patttidhank (0.88) and Mindal (0.69) forest. The data tabulated in table 2 reveals that

the maximum established index among the conifer species was for *Picea smithiana* (0.70) in Gajta forest, whereas, it was maximum for *C. jacquemontii* (1.0) in Sali forest among the broad leaved species. Similarly *C. jacquemontii* recorded the maximum value (0.11) of stocking index in Sali forest of Sach Forest Range. The maximum value of established stocking per cent was found in Sali (17.20) and Gajta (11.95) in Sach and Kotkhai Forest Range respectively. Among the conifer species highest stocking per cent was recorded for *Picea smithiana* (7.38) in Gajta forest, while it was maximum for *C. jacquemontii* (11.25) in Sali forest among the broad leaved species in hazelnut bearing forest. Srivastava *et al*. (2005) [18] concluded that several factors as poor seed crop, poor water supply during summer when seed germinate, consumption by birds, rodents, monkeys, bears and lopping of trees etc. contribute to poor regeneration in oak.

Conclusion

The investigation carried on the natural regeneration status of hazelnut bearing forest in two forest range of Himachal Pradesh, India, so it is concluded that the hazelnut population is highly heterogeneous and found closely associated mainly with oak, fir, spruce, deodar, blue pine, maple and walnut in the western Himalaya. It can be concluded that low values of per cent regeneration of *C. jacquemontii* in Pattidhank forest, while complete absence of regeneration in Gajta and Mindal forest indicate the poor natural regeneration status of the ecologically and economically important species of the Himalayan region having potential value for the wildlife. The high biotic pressure in the hazelnut bearing forest will alter the plant community structure, density and affect the survival rate of tree seedlings in future. In the light of the above findings there is urgent need to conservation this species with suitable conservation measures and large scale afforestation involving local communities under social forestry prgrames.

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