Regeneration of *Quercus semecarpifolia* Sm. in Shivapuri Hill, Nepal

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Population structure of *Quercus semecarpifolia* Sm. (khasru) was studied in mature forest of Shivapuri Hill (Shivapuri National Park, Kathmandu), Central Nepal from November 2002 to February 2003. A total of 16 quadrats (20m x 20m) for trees and 58 (5m x 5m) for seedling and sapling were laid from 2200m to 2500m on southern face of the hill. The study site had mature forest with comparatively low tree density (203 ha^{-1}) but high basal area (50 m^2 ha^{-1}). The forest had abundant number of small seedlings (density 3807 ha^{-1}) but sapling was very rare (density 62 ha^{-1}). Survival of large seedling and sapling appear to limit the regeneration of khasru forest. Size class diagram of khasru resembled bell shape with higher density of medium sized trees. So there is lack of continuous regeneration of khasru under its own canopy. Partial canopy opening by thinning of old trees may induce regeneration in old growth and mature khasru forest but long term monitoring of seedling and sapling survival in permanent plot is essential to reach any conclusion.

Key words: *Quercus semecarpifolia*, khasru, regeneration, Shivapuri National Park

Quercus semecarpifolia Sm. (Fam. Fagaceae; local name khasru) is one of the dominant trees of upper temperate and sub alpine forest of Himalaya. Khasru is closely linked with subsistence hill agriculture as a source of timber, wood fuel, dry season fodder and litter. So it becomes one of the most over exploited trees species in Himalayas. Due to over-exploitation and an inherently slow growth rate, kharsu oak forest is failing to regenerate and shrinking in Nepal and the adjoining Himalayan region (Metz 1997, Shrestha and Paudel 1996, Singh and Singh 1992). Annual lopping, acorn herbivory, seedling and sapling browsing, litter collection and forest fire are important factors preventing regeneration of kharsu in disturbed forests. In a nearly undisturbed forest of central Nepal (Langtang National Park), the regeneration of khasru is continuous (Vetaas 2000) but the preliminary observation (Siluwal *et al.* 2001) of the other forest in the same region (Shivapuri National Park, central Nepal) revealed that the regeneration was not continuous in the protected forest too.

Seedling/sapling count (e.g. Koirala 2004) and analysis of size class diagram (Shrestha 2003, Vetaas 2000) are two common methods used for regeneration study. However the later can give better indication of long terms regeneration status than the seedling count. Combination of these two measurements may give actual situation of reproduction (i.e. production of viable seed) and regeneration pattern.

In the present work, population structure and regeneration pattern of kharsu in Shivapuri National Park (central Nepal) were studied.

Study site

The study area (85° 23" E, 27° 47" N to 27° 48" N and alt. 2200m to 2500m) lies on southern slope of Shivapuri Hill (alt. 2732m) in Shivapuri National Park (alt. 1360m to 2732m, area 144 sq. km). It belongs to temperate mountain oak forest type (TISC 2002). Soil is sandy loam and acidic with pH 4.2 – 5.2 (Shrestha (Tamot) et al. 2000). The climate is hot–humid during monsoon (June–September), cool-dry during winter (October-January) and hot–dry during summer (February-May). In some winter days temperature falls below freezing point and it is maximum (about 23°C) during August. Annual rainfall ranges from 1800mm to 3200mm with 80%

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rainfall during monsoon (Chaudhary 1998). The study site represents the lower elevational range of khasru distribution in this forest. The area has been protected since 1975, first as watershed and wildlife reserve and as national park since 2002. People continue to collect woodfuel and bring their domestic animals for grazing.

Materials and method

Khasru is a high altitude oak of Himalaya with distribution from southwest China to Afghanistan, at elevation of 2100m to 3800m. It occurs in moist temperate and sub alpine region with heavy snowfall and moderate rainfall, and is absent from the dry regions of inner Himalayas (Negi and Naithani 1994). Khasru is a gregarious species, growing upto 35m tall in natural forest (Jackson 1994). Mature fruits fall during next July and seeds germinate immediately.

At lower elevational range (between 2200m and 2500m) of the khasru forest randomly selected 16 square quadtrats (20m x 20m) were studied from November 2002 to February 2003. Number of tree, diameter at breast height (dbh) and tree height (using clinometer) were measured. Associated tree species were recorded. Nomenclature follows DPR (2001). Density (ha^{-1}) and basal area ($m^2\ ha^{-1}$) of tree were calculated. From density of different diameter classes (dbh class: 10-20cm, 20-30cm, 30-40cm, etc.), the size class diagram was developed to analyze regeneration pattern.

Each plot was divided into four equal parts and a sub plot (5m x 5m) was laid in each part for seedling (dbh = 0, height <137cm) and sapling (dbh<10cm, height>137cm). In four plots seedling and sapling were absent, and in each of them, sub plot was not studied. Outside the plot, additional ten sub plots were with seemingly high seedling density were also measured for seedling and sapling. So, total quadrats were 58 for seedling and sapling. Seedling height, leaf number, number of die back and sapling height were measured. In each plot litter thickness was measured and canopy cover was visually estimated.

Result

Khasru was dominant tree species within the range of study area. The important associated tree species were *Rhododendron arboreum* Smith., *Cinnamomum sp, Symplocos ramosissima* Wall., *Myrsine semiserrata* Wall., *Eurya acuminata* DC., *Ilex dipyrena* Wall., *Lyonia ovalifolia* (Wall.) Drude., *Viburnum mullah* Buch.-Ham. ex. D.Don., *Persea* sp., *Quercus lamellosa* Sm. and *Q. lanata* Sm. The density of kharsu tree was 203 ha^{-1} (Table 1). Maximum density recorded at a plot was 725 ha^{-1} (29 trees in 20m x 20m) but the tree size was small (average dbh 16cm and height 6m). It also had the highest number (21 species) of associated tree species. The number of associated species was decreasing with increasing elevation, and it was absent at the quadrat lying at the highest altitude. Average height of the tree was 13m (max. 27m) and dbh 48cm (max. 142cm). Basal area of kharsu was $50m^2\ ha^{-1}$ (0.5%).

Distribution of seedling and sapling was not uniform. Seedling was absent from 26% of sub plots and sapling from 90%. Seedling density was 3807 ha^{-1} with maximum of 29,200 ha^{-1} in a sub plot. The sub plot with maximum seedling density had thin litter (i. e. soil surface was visible) and low canopy cover (tree canopy 10% and shrub canopy 45%). Die back was observed in 38% of seedlings. Sapling density was 62 ha^{-1} with maximum of 1200 ha^{-1} in a sub plot.

Table 1. Density of seedling (dbh = 0, height <137cm), sapling (dbh<10cm, height>137cm) and tree (dbh≥10cm) of khasru

Plant size	Density (ha^{-1})	Max. density (ha^{-1}) in a plot
Seedling	3907	29,200
Sapling	62	1200
Tree	203	725

Size class diagram (fig. 1) showed highest density of smallest diameter class (dbh 10cm– 20cm). However, remaining part (between 20cm–150cm) of the curve assumed the bell shape with maximum density of medium sized tree (dbh class 50cm–60cm).

Discussion

The forest is dominated by khasru with tree density 203 ha^{-1} and basal area $50m^2\ ha^{-1}$. At least 28 other tree species were present in the forest and their combined density was 402 ha^{-1}. However upper canopy was mainly formed by khasru, and other species formed sub canopy and lower canopy. Present value closely agrees with previous report from the same forest (217 ha^{-1} by Siluwal et al. (2001) and 200 ha^{-1} by Subedi and Shakya (1988)). Kharsu density in Langtang National Park (north central

Nepal) was 400 ha^{-1} (Vetaas 2000) and in Kumaun (central Indian Himalayas) it was 872 ha^{-1} (Singh and Singh 1992). Basal area (48.4m^2 ha^{-1}) in Kumaun forest is similar to the present value. Tree biomass (i.e. 462.1 ton ha^{-1}) of khasru forest was among the highest value for this kind of forest. Low density and high basal area is the nature of mature and old growth forest.

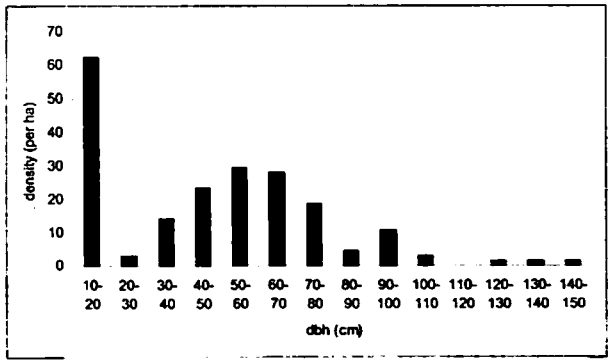

Fig. 1 Density diameter curve of khasru showing distribution of population in different diameter class

Seedling was abundantly present (3807 ha^{-1}). Kharsu forest elsewhere in central Nepal also has well representation of seedling (Vetaas 2000, Metz 1997) but in some forest of Kumaun Himalaya (India) seedling was absent (Singh and Singh 1992). In Shivapuri, maximum seedling density (29,200 ha^{-1}) was found in a plot at 2397m elevation, which had thin litter and open tree canopy (about 10%). It was near the pastureland and trampling where cow dung was frequent. So it appears that grazing was not a limit to seedling growth, as reported by Metz (1997) in disturbed stand.

Sapling density was too low (62 ha^{-1}). Sapling was found only below 2300m elevation and in 10% of total sample plots. At this elevation the number of associated species was high and khasru tree was smaller (av. dbh 29cm) with few larger trees (dbh upto 99cm). So khasru forest at lower limit of distribution in Shivapuri was not mature and had few sampling. But at upper elevation, which had mature forest, sapling was absent though there was well representation of seedling. Remarkably seedling size ranged from 4-28cm in height with die back in 38%. Even the larger seedling was absent from this mature forest. So it was evident that khasru seedling did not survive beyond this stage under its own canopy.

Size class diagram clearly revealed the lack of sustainable regeneration. Except smallest dbh class (10-20cm) the diagram resembles a typical bell shape, a characteristic of non regenerating forest. In a regenerating forest (which has reverse J shaped size class diagram), the density increases with increasing dbh class but in present case density was decreasing from 50-60cm to smaller dbh class except the smallest one. So the population of younger individuals was continuously decreasing, at least in the mature khasru forest. High density of smallest dbh class was due to the representation of smaller individuals from young kharsu forest from lower elevation (<2300m). For example, at this elevation 27 out of 40 individuals of this class were present in a single plot.

Population structure of khasru from seedling to mature tree revealed that the regeneration was hampered even if the trees were producing abundant number of viable seeds, as evident from seedling density. The major problem appeared to be the survival of large seedling and sapling. A wide range of biotic and abiotic factors have been proposed to be responsible for large scales death of seedling, sapling and recruit, and thus the poor regeneration of khasru. Vetaas (2000) suggested that fire prevents recruit from reaching the canopy phase and some external factors (e.g. radiation) rather than soil may be responsible for lower representation of sapling. Metz (1997) hypothesized that khasru can not regenerate under its own canopy and needs severe disturbance (e.g. intense ground fire, landslide) for successful regeneration. Upreti *et al.* (1985) attributed poor regeneration of khasru to climate change at its lower limit of elevational range of distribution in Kumaun Himalayas. Negi and Naithani (1995) reported that the dense growth of herbs (e.g. *Pteracanthus alatus* (Wallich ex Nees) Bremek and *P. urticifolius* (Kuntze) Bremek) inhibited the survival of seedling and sapling. Similarly adverse effect of herbaceous cover on seedling emergence, survival and growth was reported by Tripathi and Khan (1990) in *Quercus dealbata* L. and *Q. griffithii* Hk. f. & Th. In disturbed forest lopping reduced seed production, and litter collection damaged the seedling and sapling (Shrestha and Poudel 1996).

Poor regeneration of khasru is not the result of single factor. Perhaps a set of biotic and abiotic factors, combined with inherent slow growth rate of khasru is responsible for it. Relative role of different factors may depend on disturbance intensity, source of disturbance, maturity of forest stand and site specific variation in herbaceous cover and litter thickness. In

less disturbed forest of our type, lopping and litter collection were not important factors. Since highest seedling density was found in a plot with high trampling near the pastureland, grazing may not prevent the survival of small seedling. It is possible that frequent grazing prevented the dense growth of herbaceous cover and removed the possible adverse effect. But we were unable to observe herbaceous growth during monsoon. We have no information on the survival of large seedling and sapling. It requires long term monitoring of seedling/ sapling growth in permanent plot. This type of study is still lacking particularly in the Nepal's Himalaya.

Some of the fragmented information have shown that natural regeneration can be induced in khasru by appropriate management practice (Shrestha 2003b). Though plantation of nursery raised seedling was not successful (Stewart 1984), direct sowing of seed has promising result in India (Negi and Naithani 1995). In disturbed forest lopping in the interval of at least three years and complete protection of few mother trees increased seed production and regeneration potential (Shrestha and Poudel 1996). Similarly, Vetaas (2000) has reported higher sapling density in a plot with higher tree canopy in otherwise disturbed forest. So, opening of canopy by limited lopping may facilitate sapling establishment. Manual thinning of old trees has also promising result (Negi and Naithani 1995). In Shivapuri, canopy gap was formed by death of old trees in some sites. The plots with less than 50% tree canopy generally had higher number of seedling (e.g. the plot with the highest seedling density had 10% tree canopy). It appears that natural regeneration of khasru can be induced by sustainable lopping in human disturbed forest, and thinning of old tree in mature forest.

Conclusion

Shivapuri hill has mature and old growth khasru forest with comparatively low tree density (203 ha^{-1}) but high basal area cover (50m^2 ha^{-1}). The forest had well representation of khasru seedling (density 3807 ha^{-1}) but sapling was very rare (62 ha^{-1}) and present at lower elevation which had young forest stand. Sapling was absent from mature forest stands. Survival of khasru beyond the seedling stage seemed to be the most important constraint of khasru regeneration. Grazing, lopping and litter collection were not important limiting factors for regeneration. Size class diagram resembles bell shape with high density of medium sized trees; it indicates the lack of sustainable regeneration. A set of biotic and abiotic factors may be responsible for poor regeneration of khasru, but their relative importance varies with disturbance regime, maturity and management of forest. In old growth mature khasru forest, partial canopy opening by thinning of old trees may induce regeneration but long term monitoring of seedling and sapling survival in permanent plot is essential to reach any conclusion.

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