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Plant Population Structure and Species Diversity Status at Two Disturbance Regimes Within Mixed Forests and Sal Forests of Gorakhpur, India

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ABSTRACT

This study of plant population structure and regeneration strategy of various woody species of mixed forests and sal forests compares the effect of disturbance on the status of species population especially with reference to ramet vs. genet. The less disturbed forests were more dominated by sprouters and ramet producing species as compared to highly disturbed ones. Analysis of variance among the number of species falling under different regeneration categories, i.e., OS (Regenerating only through seeds), FS (Facultative sprouters), OR (Obligate sprouter), RP (Ramet producers) and SR (Storage roots) showed significant differences ($F_{4,3} = 5.31$) at $p < 0.01$.

A total of 166 species was recorded in less disturbed mixed forest and only 48 species in highly disturbed sal forest stand. At low disturbance, the trees like *Mallotus philippensis, Holarrhena antidysenterica, Ficus glomerulata, Careya arborea* and *Pongamia pinnata* showed quite stable population structure. On the other hand, trees like *Flacourtia indica, Carissa spinarum, Casearia tomentosa, Putranjiva roxburghii, Antidesma ghaesembilla* and *Cassia fistula,* at high disturbance, were quite frequent as sprouts in mixed forests as compared to sal stands. In presence of recurrent disturbance, the common undertrees and lianas readily acquired shrubby habit. Most of the obligate sprouter and ramet producers formed several sub-populations or meta-populations (patronized by a single genet).

Population structure for tree species was stable in less disturbed forest stands having large number of individuals of lower girth classes. Except for sal, most of the tree species showed reverse J-shaped population structure. The ramet and genet density, along the age series, was positively correlated in sal forests and negatively correlated in mixed forests. Proportion of obligate sprouters was quite similar for less disturbed sal and mixed forests when the whole complex of a single genet was treated as only one individual. The diversity index (H) was always greater when a genet complex was treated as single individual than in case when each ramet, distinct at soil surface, were treated as separate individuals irrespective of the forest type and degree of disturbance. Further, this index was always greater for forest communities facing low disturbance. The similarity index values ranged between 0.46 to 0.84 for any two forest stands. The information on the impact of disturbance and heat stress of different degrees on the regeneration strategy and population structure of woody plants may be helpful for adapting conservation and diversity maintenance strategy within the regional tropical forest ecosystem.

Key Words: Regeneration Strategy; Ramet- and Genet; Population Status; Metapopulation; Disturbance; Sal and Mixed Forests.

INTRODUCTION

Population is a specific set of individuals of a species which occur within defined geographical area. The species are generally organized into local populations in the form of discrete patches or groups. Population status of component species in a community can be evaluated by its distribution in different girth classes which, in turn, determine the reproductive status of the species, indicating the future course of stability of forest communities (Odum 1971). Natural regeneration is a central component of tropical forest ecosystem dynamics and is essential for preservation and maintenance of bio-diversity (Grubb1977). As floristic and structural composition changes, the competitive relationship of species may change with corresponding changes in pattern of regeneration (Barker and Kirkpatrick 1994). The species composition of forests depends on the regeneration pattern and population structure of compositing species the forest in space and time. The disturbance types affect the dominance and composition of seedlings in the forest understorey (Benitez-Malvido 1998). For the proper management of mixed plantations, uneven-aged stands and natural forests has given rise to the need to understand the regenerative process that ensure maintenance of the community structure and ecosystem stability (Moravie et al. 1997). Disturbance often leads to habitat fragmentation which results into the clumped distribution of species. It has been observed that recurrent fire and other disturbances may alter the size or status of a species population by influencing its structure and mode of regeneration (Bond and Midgely 2001). Successful regeneration of a tree species can be predicted by the structure of their overall population as well as sufficient numbers of seedlings, saplings, and adults (Pandey 2000). Forest trees have been observed to show considerable diversity in sprouting behavior; Many species may sprout as juveniles and lose the ability to sprout as adults (Bellingham and Sparrow 2000). In response to sustained perturbations, several species may effectively compensate their heavy seedling loss through regeneration by non-seed methods (Saha and Howe 2003). The capacity for horizontal spread of ramets is likely to affect the spatial distribution of the species at the genet level (Keely et al. 2001).

Various disturbances determine the forest structure and tree diversity at the local and regional scales and the species composition of forests depends on the regeneration of species in space and time (Rocabado et al. 2012). An increasing interest in the development and management of mixed plantations and natural forests has given rise to the need to understand the regenerative process that ensure maintenance of the community structure and ecosystem stability (Philips and Gentry 1994). The main challenges, faced in the recovery of degraded forest ecosystems, lie in finding the plant species that may grow under inhospitable conditions of degraded landscape. This is especially important for degraded forests and soils that have lost their upper horizons due to repeated cutting, fire and rains.

Various authors have documented the vegetation structure and composition of *Terai* forest of the region. Champion and Seth (1968) compared various communities associated with sal forests along the moisture gradients. The study on comparison of *terai* flora with regional grassland was conducted by Panigrahi et al. (1969). Pandey and Shukla (2003) assessed the species composition, regeneration pattern and conservation status of managed forest at Sohagibarwa Wildlife Sanctuary, Gorakhpur. Some information on population status, community structure and the diversity patterns of sal forests are available (Pandey and Shukla 2005, Majumdar et al. 2012, Kushwaha and Nandy 2012, Gautam et al. 2014) but the overall diversity and population structure of trees and shrubs of sal forest at different disturbance level is still little explored. The information on the effect of disturbance on regeneration and population status of plants is necessary to understand the wealth of forest community. It is important to compare the differences in population structure and regeneration pattern of associated plants in plantations and mixed forests. Further, the information on the status of plant population, regeneration potential and diversity attributes are of primary importance in the planning of conservation measures.

STUDY AREA

The study was conducted in *Terai* forest of north- eastern Uttar Pradesh under Gorakhpur Forest Division which is located between 27º 05′and 27º 40′ N latitude and 83º 30′ and 84º 10′E longitude and at 95 m altitude (Figure 1). The climate is seasonal and sub-tropical. The total average annual rainfall is about 1814 mm, 87% of which occurs during the wet summer or monsoon season. During the relatively dry period of about 8 months, i.e. January– June and November–December the monthly rainfall is less than 100 mm. The soil is old Gangetic alluvium. The texture is sandy loam and the soil reaction is circum-neutral. The major part of the landscape is covered by Sohagibarwa Wildlife sanctuary. The diversity of regional forest is of prime importance because of its interesting flora and fauna.The regional forest of north-eastern UP is of subtropical semi-evergreen type with a number of deciduous elements. Of the total 428.2 km^2 forested area of the sanctuary, 2.32% is still under the natural, semi-evergreen forest vegetation. The deciduous plantations of Gorakhpur Forest Division consist mostly of sal (*Shorea robusta* Gaertn),

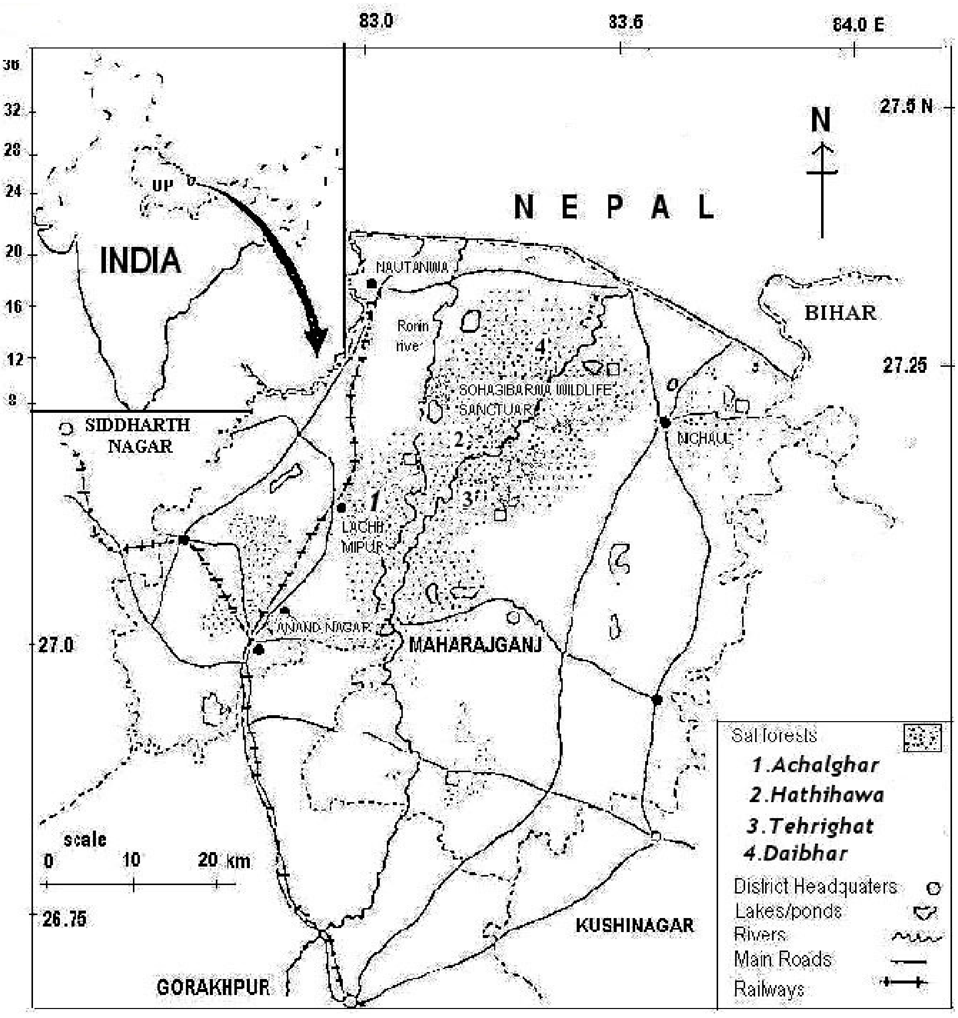

Figure 1. Location of four study areas at forest vegetation of Gorakhpur Division.

planted mainly through *taungya* system. In this system, the clear-cutting of natural-growth forests follows the operations like ground-clearing by landless farmers (also called *taungya*), who plough the site and use the land for taungya cultivation. Freshly-collected sal seeds are sown in lines at intervals of about 10 feet between any two lines and the inter-line spaces are used to cultivate cereals, pulses and vegetables for 2–3 consecutive years. Once the sal saplings get established, their rows cast shade, rendering the site unsuitable for supporting any more agricultural crops. Now the site is abandoned, the sal saplings are left to grow naturally and ecological succession sets in. As the sal ages, the associated vegetation also develops naturally and gains considerable species diversity. Of these, several over- and understorey trees, a number of shrubs and some perennial herbs may grow as sal associates. The resultant plant community, developing in association with sal plantation, fairly mimics the composition of natural growth forests of the region. In the sanctuary, 75% of the area covered by sal is either natural or planted forest (Manikant 1994). Mixed forests are sal forests with number of deciduous species situated in the core zone of the sanctuary.

METHODS

Two stands each of sal plantation forests and natural growth forests were identified within in regional forests facing low disturbance and high disturbance. The age of the stands was 50 ± 5 yr and they represented average conditions of their respective disturbance regime, species content and vegetation pattern. The disturbance level was measured through disturbance index or DI (Pandey and Shukla 1999). A DI of >60 denoted high disturbance and that of < 30 as low disturbance. In each of the above four stands, one-hectare (100 m x 100 m) plots were marked on the basis of average ground vegetation. Each plot was sub-divided into 4 quarters and 10 random quadrats, each of 10 m. x 10 m. were laid in each quarter. Trees were counted in all the 25 quadrats of each quarter. For accounting the individuals of <30 cm gbh (girth at breast height), only 10 random quadrats per quarter, i.e. 40 quadrats (0.40 hectare) per hectare plot were observed. The data on the number of trees, genets and sprouts/ramets were suitably multiplicated to represent them on per hectare basis. Both the leguminous and non-leguminous species were identified and the number of their trees (> 30 cm. gbh.), other genets and sprouts/ramets were counted and the basal diameter was measured. The individuals with separate identity at the

Table 1. Characteristics of study sites: types of stress and disturbance, disturbance index (DI) with common trees and shrubs.

Attributes	Study Sites			
	Sal Forests		Mixed Forests	
Name of Place	Achalgharh	Hathihawa	Tehrighat	Daibhar
Intensity of burning	Burning of dry leaves and woody, litter and undershrubs recurrent; Flames >1 m	Occasional burning of dry leaves; flames	Burning of leaf and woody litter and small plants, flames ~1 m	Rare burn
Degree of clipping/ cutting	Common	Less common	Common	Less common
Frequency of cattle grazing, browsing and trampling	Quite frequent	Less frequent	Frequent	Very rare
Disturbance Index (DI)	>60	< 30	> 60	< 30
Disturbance level	High (HD)	Low (LD)	High (HD)	Low (LD)
Common tree associates	*Aegle marmelos* *Eugenia heyneana,* *Mallotus philippensis,* *Shorea robusta,*	*Adina cardifolia,* *Careya arborea,* *Cassia fistula,* *E. heyneana,* *Ficus glomerata ,* *Holarrhena antidysenterica,* *M. philippensis,* *Mitragyna parviflora,* *S. robusta*	*Dillenia indica* *M. philippensis,* *Miliusa tomentosa* *Pongamia pinnata,* *Schleichera oleosa,* *S. robusta,* *Tectona grandis,* *Terminalia tomentosa,* *Woodfordia fruitcosa,*	*Alstonia scholaris,* *Bauhinia perpurea,* *Colebrookia oppositifolia* *Diospyros tomentosa,* *F. glomerata,* *M. philippensis,* *Morus indica,* *Phyllenthus officinalis,* *S. robusta,* *Semecarpus anacardium,* *Stereospermum suaveolens,* *Streblus asper,* *W. fruitcosa*
Common woody shrubs	*Desmodium pulchellum,* *Flacourtia indica,* *Moghania bracteata* *Moghania lineata,* *Zizyphus mauritiana*	*Carissa spinarum,* *Clerodendrum infortunatum* *Desmodium gangeticum,* *L. alata* *M. liniata,* *Moghania chappar*	*Antidesma ghaesembilla,* *C. infortunatum* *C. oblongifolius* *Casearia tomentosa* *Cassia nodosa,* *D. gangeticum,* *Putranjiva roxburghii*	*A. ghaesembilla* *Asparagus racemosus* *B. stipularis,* *Bauhinia vahlii,* *C. infortunatum* *C. spinarum* *C. tomentosa,* *D. triangulare,* *M. chappar,* *Piper sp,* *Smilax macrophylla*

soil surface were treated as genet. The plants arising from suckers on subterranean root-stock of the genet, were treated as ramets. A ramet is vegetatively produced, potentially independent individual initially having organic connection with the mother plant or genet. A brief description of study sites is given in Table 1. The requisite size of the sample plot for adequate sampling of forest vegetation was found to be 10,000 ± 1000 m^2 (Pandey and Shukla, unpublished data).

Further, individuals with ≥30 cm girth at breast height (1.37 m) were treated as trees, and those having < 30 cm gbh were treated as non trees. The density and basal area of each species were determined in different girth classes according to Mueller- Dombois and Ellenberg (1974). The dominance was determined as Simpson's index ($Cd = \sum \ln pi^2$) and diversity as Shannon's index ($H' = -\sum \ln pi \ln pi$), where, pi represents the proportional abundance of i^{th} species in the community. The calculation of dominance and species diversity was made on two counts – first by treating the whole population of ramets along with their genet (genet-complex) as a single individual and second by taking each superficially distinct shoot as a separate individual.

Population Status and Age Structure

Population structure is expressed in terms of number of individuals present in each of the definite girth class distribution of tree species while in case of shrubs it is based on percent individuals in different age group. The percent number of individuals falling under girth-class (in case of trees) or age classes (in case of woody species) were arranged in the form of horizontal bars to show the age-structure of the species populations (Rabotnov 1969). The tree individuals were grouped into five girth classes (31-60 cm; 61-90 cm; 91-120 cm; 121-150 cm and >150 cm). The non-tree individuals (<30 cm gbh) were arranged according to their age from 1 yr to 5 yr. The age of woody shrubs was ascertained on the basis of growth-features (Halle et al. 1978, Shukla and Ramakrishnan 1986) and the number and vigour of sprouts. The basal diameter and shoot growth of the individuals were tallied with those of already excavated and measured individuals for approximation of the age of the individuals of a population.

Modes of Regeneration

Species were categorised into different regenerating groups as noted below:

Plants regenerating through seeds only are classified as OS, if they are fire/ disturbance killed, and were regenerated from seeds, indicated by the presence of seedlings in the forests. All the species other than OS sprouters are further grouped under-

Facultative sprouters (FS)- Those species which had been observed sprouting as well as regenerating as seed, as indicated by presence of seedlings. Some of these species that are FS were observed in some sites as regenerate through seed only or obligate sprouting, but overall in the study area were recorded as expressing both responses.

Obligate sprouters (OR)- Obligate sprouters were those species that exhibited sprouting but had not been recorded as regenerating from seed in any highly disturbed sites.

Ramet producers (RP)- All species which can produce ramets are grouped under ramet producers and Storage roots (SR) - Plant has considerable underground storage roots are grouped under storage roots.

RESULTS

A comparison of species habit, density and basal area were made in sal forests and mixed natural forests facing different level of disturbances. There was minimum 48 species in sal forest under high disturbance while 113 in sal forest facing low disturbance. Less disturbed mixed forest had 166 species while 76 only in high disturbed mixed forests. The trees species (> 30 cm gbh) richness and the number of shrubs were much greater in less disturbed mixed natural forest while herbs are more in highly disturbed stands. The less disturbed sal forests also showed appreciable shrubs and trees species richness. The less disturbed mix forest had highest tree density (587± 37.3 plants ha^{-1}) while sal forest facing high disturbance (366± 16.5 plants ha^{-1}) had the least. Less disturbed sal forest and highly disturbed mixed forest were quite comparable in terms of tree density. Density of genet individuals (<30 gbh) was high for low disturbed mixed forests followed by sal forests in same level of disturbance. Ramet followed the same pattern as genet. Least density for ramet and genet was recorded in sal forests facing high disturbances. The difference between basal areas was quite high in mixed forests facing different level of disturbances as compared to sal forests. Low disturbed mixed forest has maximum basal area for trees (Table 2). The t-test showed that ramet density, genet density and basal area between low and

Table 2. Characteristics of the sal and mixed forest stand: species richness under different habit categories and the density of genet vs. ramets at two disturbance levels.

Attributes	Study Sites			
	Sal Forests		**Mixed Forests**	
	HD	LD	HD	LD
Plant Habit:				
Trees	3	47	26	68
Shrubs	27	40	33	67
Liana	2	14	9	22
Herbs	16	12	11	9
Total species	**48**	**113**	**76**	**166**
Density per ha				
Trees (>30 cm gbh)	366± 16.5	426± 13.1	422± 15.0	587± 37.3
Genets (<30 gbh cm)	22,948± 152	31,421± 333	28,046± 244	43,489± 964
Ramets (<30 gbh cm)	54,644±566	1,06,035± 4250	65,599± 704	1,12,360± 1485
Total basal area (m^2 ha^{-1})	12.2 ± 0.36	23.06 ± 1.04	18.07 ± 0.60	44.07 ± 2.30

high disturbances differ significantly in both the forest types ($p < 0.05$).

Population Status and Age Structure

A comparison of sal trees, non-leguminous trees and leguminous trees was made in sal forests and mixed natural growth forests. The total number of trees (>30 cm gbh) and the number of seedling and sapling were much greater in less disturbed mixed natural growth forest. Further, the number of leguminous trees was also markedly greater in these forests. The less disturbed sal forests also showed appreciable number of sprouts/ ramets of leguminous trees and shrubs (Figure 2). In general, forest stands facing low disturbances has stable age structure. Here sum of proportions of 30- 60cm and 61-90 cm gbh girth classes was more as compared to higher girth classes. Tree density across the girth classes in all forest types generally decreased from smaller to larger girth classes except mixed forest under high disturbance which has considerable proportion of individuals under higher girth classes. In sal forests, under high disturbances, tree density in lower girth class (61-120 cm) was higher than in any other forest type (Figure 3). The density of ten common trees of regional forest with different level of disturbances in sal and mixed forest is shown in Figure 4a,b. *Shorea robusta, Careya arborea, Ficus glomerata, Woodfordia fruticosa* and *Schleichera oleosa* trees had reverse J- shaped girth class distribution with high number of individuals of higher girth classes in all forests except sal under high

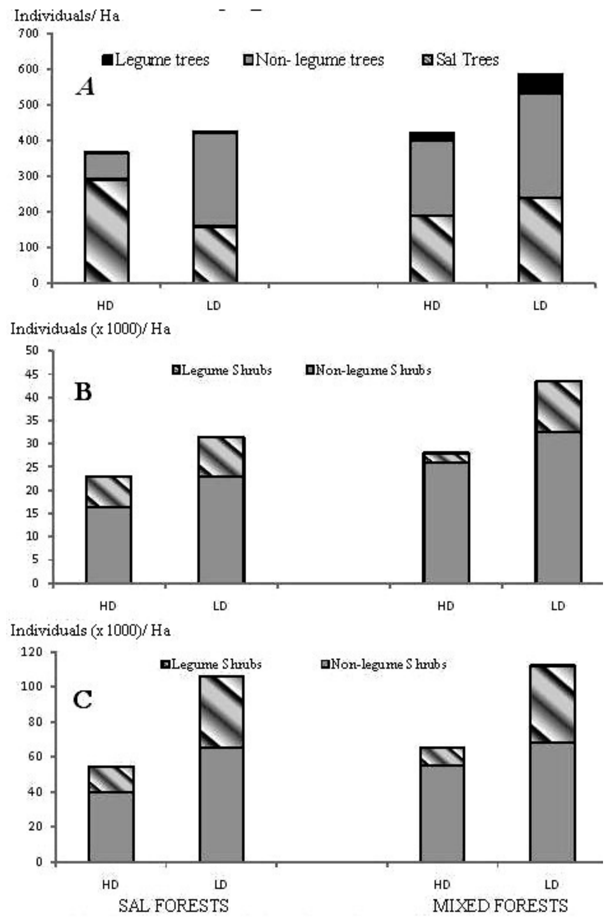

Figure 2. Total number of individuals per hectare in sal forests and natural growth forests facing high/low disturbance (HD/LD). A. Trees; B. Genets of shrubs and woody climbers and C. Sprouts/ramets.

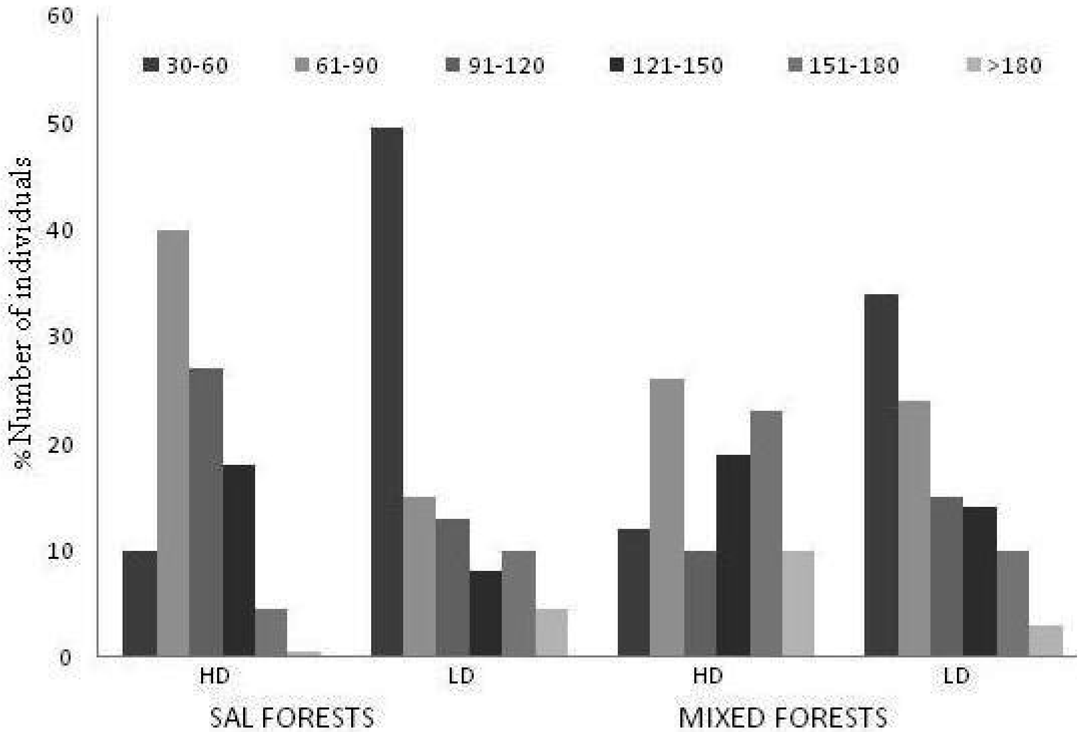

Figure 3. Age structure of trees (≥30 cm gbh) in different forests.

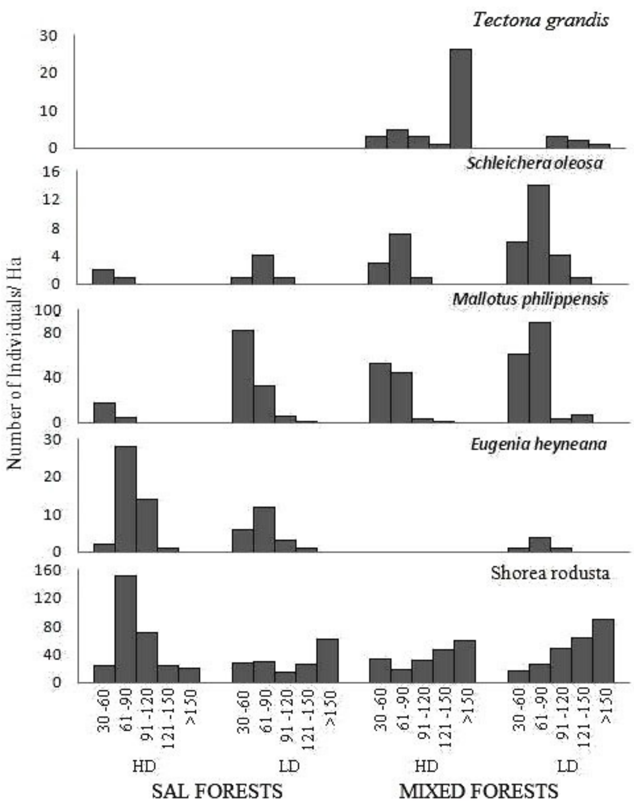

Figure 4a. Population structure of five common tree species in different forests.

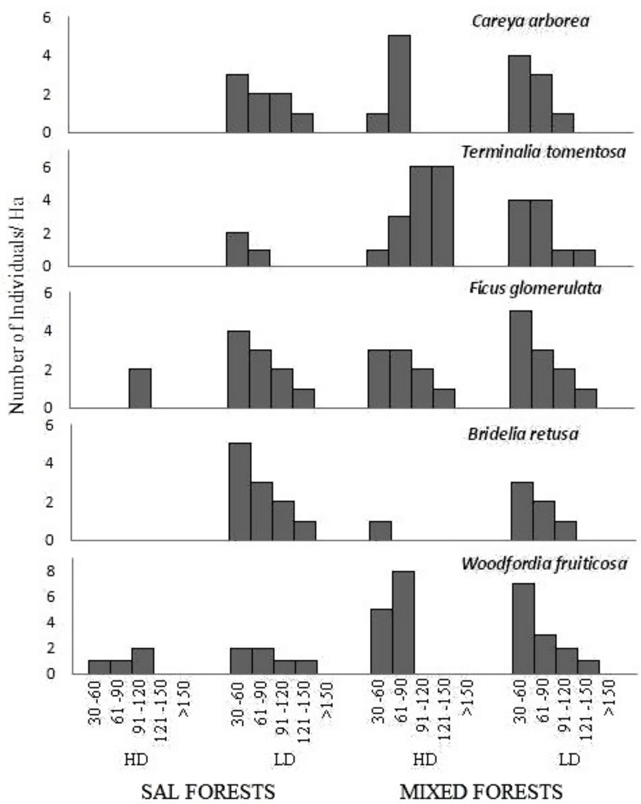

Figure 4b. Population structure of five less common tree species in different forests.

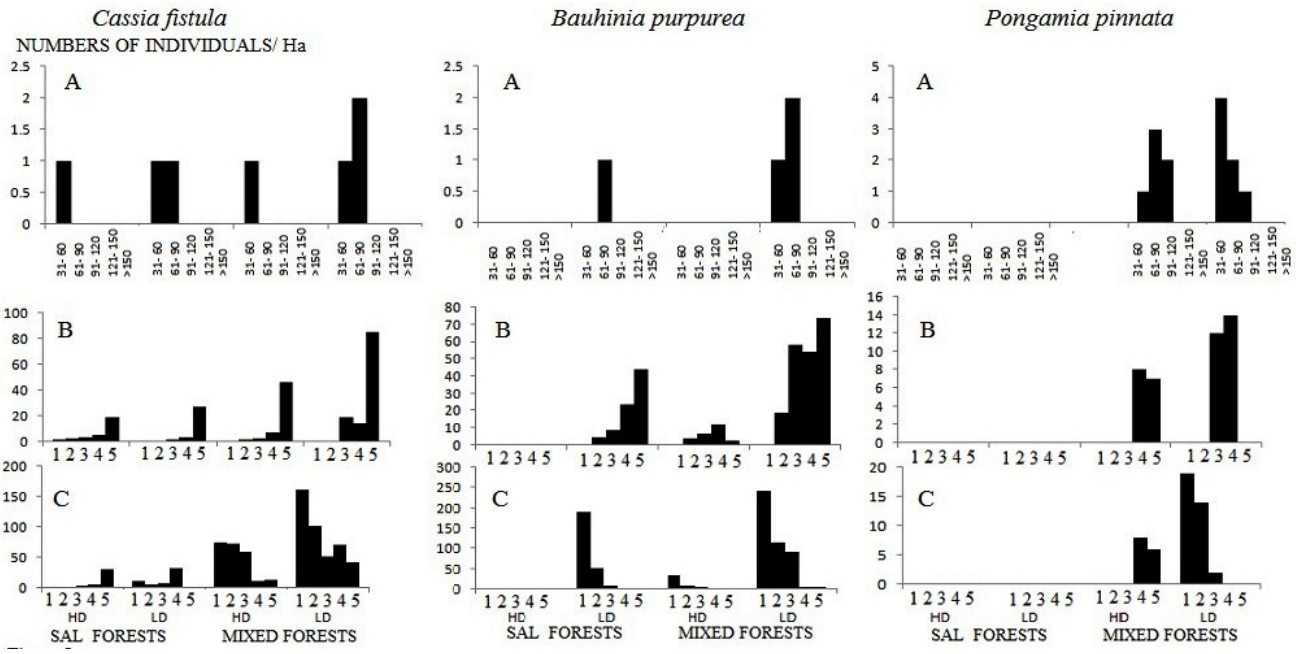

Figure 5a. Distribution of tree individuals (A) among different girth classes (cm) and that of young plants or genet (B) and sprouts/ ramets (C) among different age classes (year) for 3 legume trees within sal plantation forests and natural growth forests facing high and low disturbances (HD/LD)

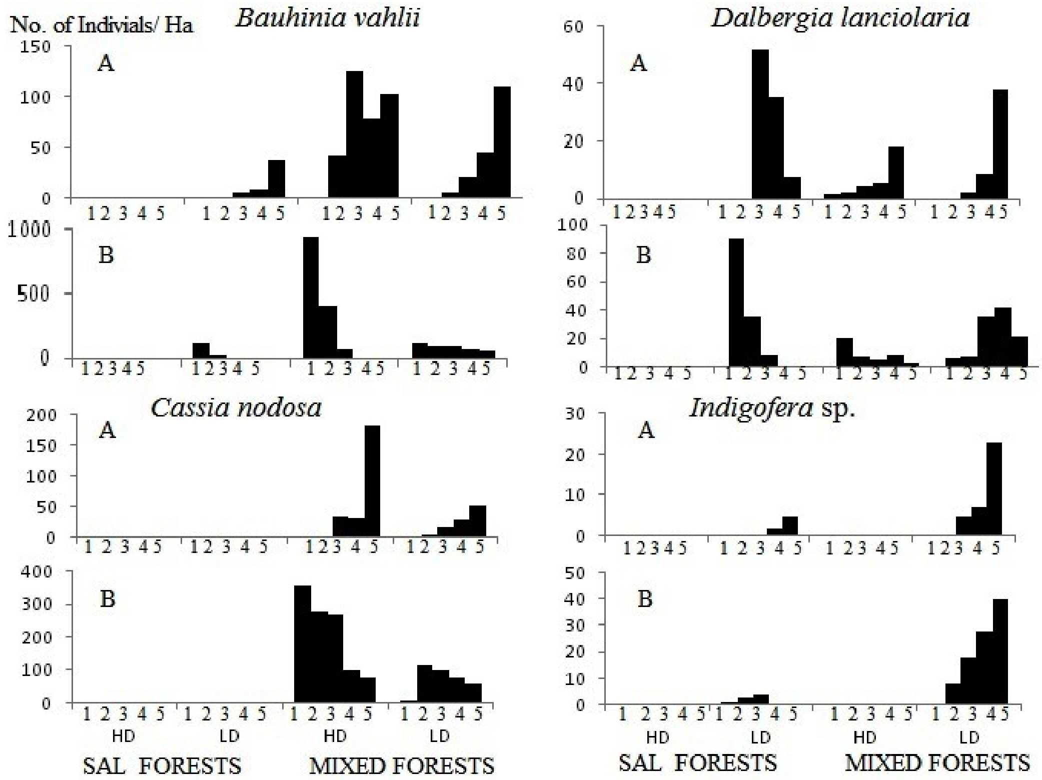

Figure 5b. Distribution of young plants or genet (A) and of sprouts/ ramets (B) among different age classes (year) for legume species within sal forests and mixed forests under high/ low disturbances (HD/LD).

disturbance. In this case, *Shorea* trees had very high density of 61cm to 120 cm gbh size class distribution. *Eugenia heyneana* has quite stable population density in sal forests, while *Tectona grandis* trees altogether absent from the same. In low disturbed forest, four tree species, *M. philip-pensis, F. glomerulata, C. arborea* and *B. retusa* were regenerating well with greater density of lower girth class individuals. After *M. philippensis* trees, mixed forests was dominated by trees of *T. tomentosa* and *W. fruticosa*. Trees like *Lagerostromia paruiflora, Toona ciliate, Stereospermum suaveolens* and *Phyllanthus officinalis* were restricted to mixed forests facing less disturbances. Population density of *C. arborea, F. glomerata* and *W. fruticosa* was quite stable in low disturbed sal forests. Tree density for *Bridelia retusa*, *C. arborea* and *Terminalia tomentosa* were altogether nil in highly disturbed forests.

The trees like *Bauhinia purpurea* and *Pongamia pinnata* were rarely encountered in highly disturbed sal stands but the sprouts of species were quite frequent in mixed forest. The trees of *Cassia fistula* were rare but young plants of 3-5 year age were available in different stands. The number of young sprouts of *C. fistula* was generally more common in mixed forests as compared to sal stands. *B. purpurea,* an undertree, however, occurred in less disturbed stands only. Though the trees (>30 cm gbh) were rare but the young plants (~5 yr age) and young sprouts (< 3 year) were considerably greater in number at low disturbance. High number of *Pongamia* individuals was noticed in sal forest. The species was exclusive but was quite infrequent in mixed forest too (Figure 5a). In presence of even slight but recurrent disturbance, the legume undertrees and liana frequently acquired shrubby habit. *Bauhinia vahlii,* an woody climber, was encountered in all the stands of sal and mixed forests but the number was considerable only in mixed forest and less disturbed sal forests. The individuals of 3-5 year age were quite high in number. The sprouts, however, were young but in greater number. *Dalbergia* was represented in different age groups but the number of individuals of 3-5 yr age was considerable only in mixed forests. Sprouts /ramets were of younger age (<3 year) in all the stands except in less disturbed mixed forest. *Cassia nodosa* was virtually absent in sal stands. At high disturbance, young genets were mostly absent in mixed forest but the number of ≥ 5 year old genets was quite considerable irrespective of disturbance level. The latter species were present in good number in all the mixed forest stands and more so in highly disturbed stands. *Indigofera* was encountered only at low disturbance especially in mixed forest in which the number of sprouts of 2 to ≥5 year age was also quite high as compared to sal stands (Figure 5b).

A comparison of the number of genet and sprouts was made assuming the species of *Moghania* and *Desmodium.* In general, the number of genet of *D. gangeticum* and *D. heterocarpon* was much higher in less disturbed sal forests as compared to less disturbed mixed forests. *D. pulchellum* was noticeable only in highly disturbed sal forests. The genets were well distributed among 1- ≥5 yr age but the sprouts surviving were mostly of younger age (1-2 yr.). *D. triangulare* population was sizable only in less disturbed mixed forest and most of genets and sprouts belonged to higher age group (Figure 6).

The age structure of genets as well as sprouts of *M. prostrata* showed a general decline from 1 to > 5 yr. age in all the stands. The number was high as well as the population was better represented in different age group at low disturbance in both the sal and mixed forest. The number of genets as well as sprouts of *prostrata* was, however, quite mearge in any of the stands. *M. lineata* was exclusively present in sal forests and was better at high disturbance. Only a few individuals could be found in mixed forest. On the other hand, the population of *M. bracteata* was sizable only in mixed forests facing low disturbance and the individuals were well distributed among age classes (1- ≥5 yr.). A few young genets and sprouts of the species were also encountered in some safe pockets of highly disturbed sal forests. *M. chappar* commonly occurred at low to moderate disturbance and the population was well distributed among different age classes. At high disturbance, only a few genets and sprouts could survive (Figure 7).

In sal forests the gap between ramet and genet density was quite high in 1 or 2yr while in older age the trend was sharp decrease. While the density of genet/ha in mixed forest was greater after 2 yr individuals in high disturbed and on the other hand in low disturbed forest after four year age. The ramet and genet density, along the age series, was positively correlated in sal stands facing high disturbances (r= 0.92) as well as low disturbances (r= 0.51). While in case of mixed forests ramet and genet density along the age series was negatively correlated (Figure 8).

Regeneration Strategy

Only 3 to 5 species were obligate sprouters in different forests while ramet producers varied from 13 to 23. The

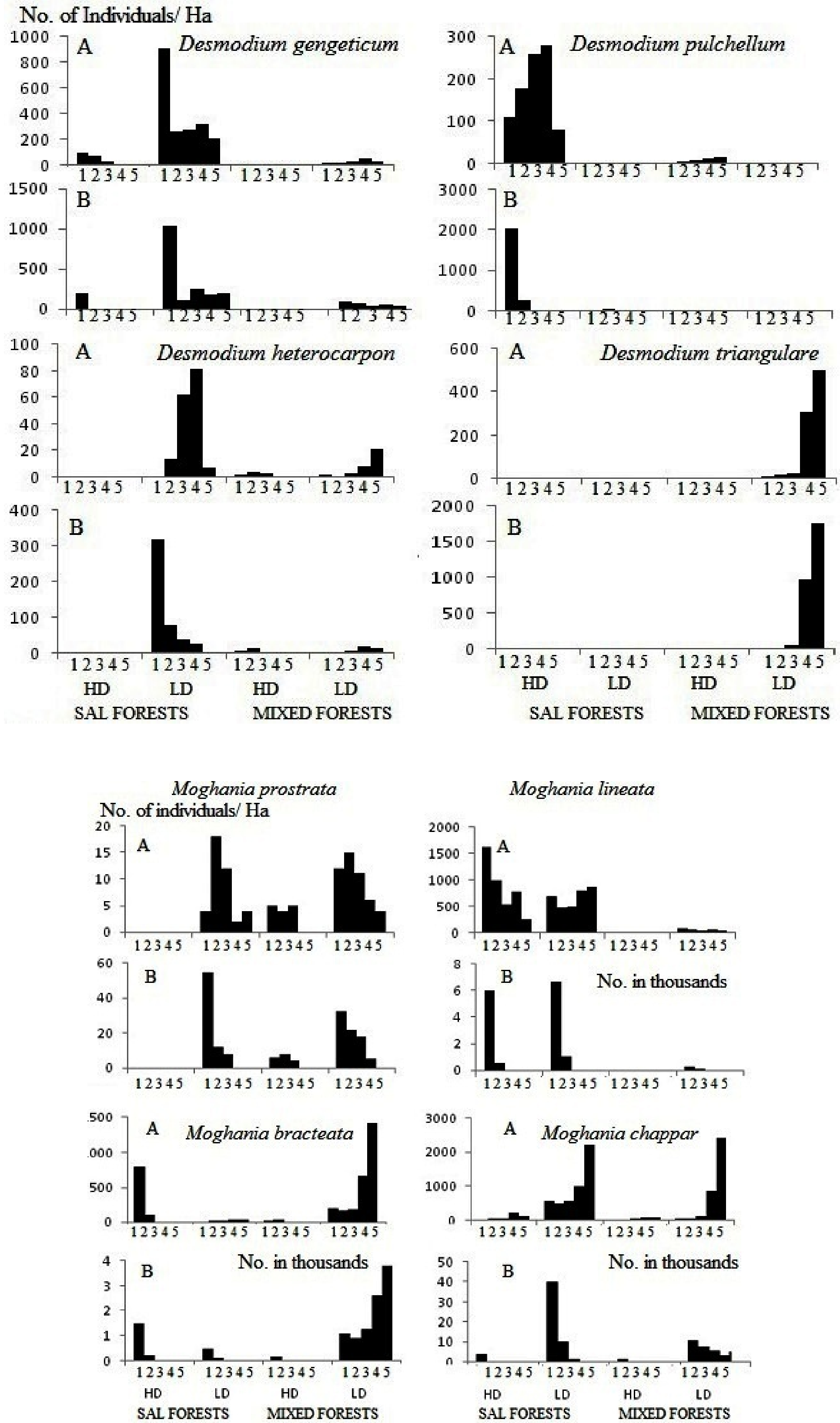

Figure 6. Distribution of young plants or genet (A) and of sprouts/ ramets (B) among different age classes (year) for the 4 congeneric species of *Desmodium* within sal forests and mixed forests under high/ low disturbances (HD/LD).

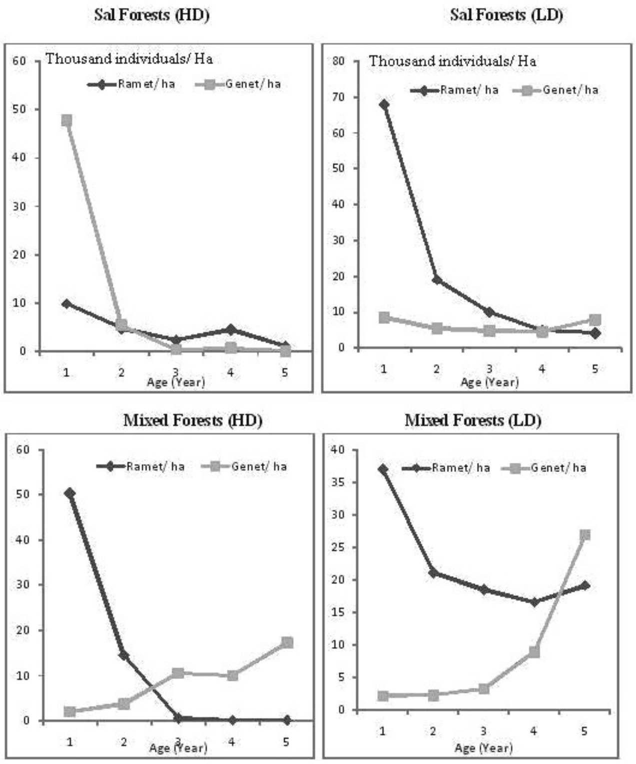

Figure 7. Distribution of young plants or genet (A) and of sprouts/ ramets (B) among different age classes (year) for the 4 congeneric species of *Moghania* within sal forests and mixed forests under high/ low disturbances (HD/LD).

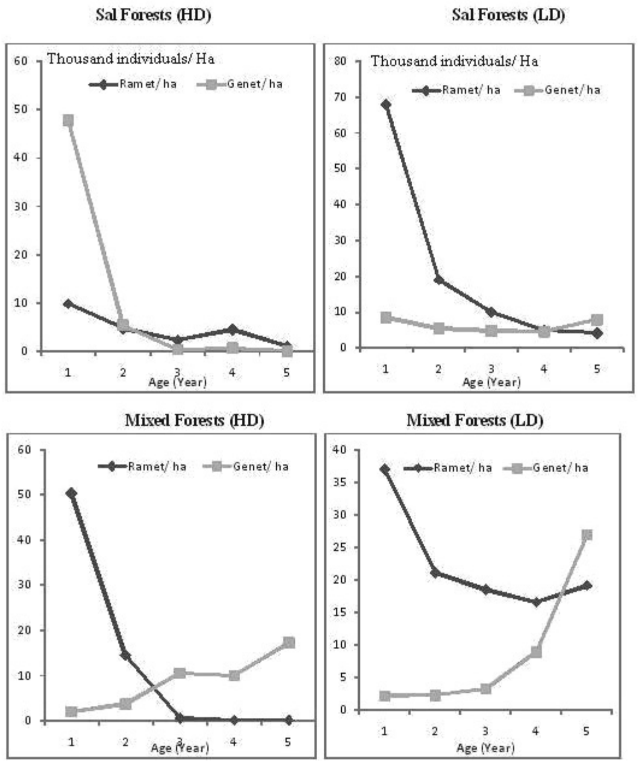

Figure 8. Number of genet and ramet individuals/ Ha along the age series in sal and mixed forests facing high and low disturbances.

facultative sprouters and obligate sprouters were very high in forests facing low disturbances. Root storage species were more in number in high disturbed forests. Values of χ^2 were highly significant among different regenerating species category in each forest stands (Table 3). Values of analysis of variance between regeneration categories among different forest stands were very close to significant value, while variance among number of species falling under different regeneration categories showed significant difference ($F_{4,3} = 5.31$) at $p < 0.01$ (Table 4). Proportion of OR was maximum in sal as well as mixed forests when ramet and genet individuals were treated as separate individuals while FS was comparable high in mixed forest than the sal forests in above case. Low disturbed forests have very high proportion of ramet producers followed species propagated by storage roots and FS. OR and OS were lease in the case. In case of genet complex as an individual low disturbed sal and mixed forest have very much similar proportion of regenerating groups. Forests under high disturbance, the OR was very high in sal and mixed forests when genet complex as an individual, while FS was very high mixed forest than sal forests (Figure 9). In general Raunkiaer's frequency class distribution is directly affected by disturbances not by the type of forests. Distribution of species among different frequency class showed that plants of frequency class A and B increases in proportion from high to low disturbed sal and mixed forests. In contrast, the frequency class C, D and E showed progressively decreased from high to low disturbed stands (Figure 10).

Irrespective of the level of disturbance and type of forests, the value of *H* was always greater whenever a genet complex was treated as an individual than in case when each ramet was treated as a separate individual. The trend was reverse for dominance index. Values of diversity indices varied between 2.52 to 3.36. In case of genet as an individual, H is 3.36 in sal stands and 3.29 in mixed forest facing low disturbances. In the case of superficially distinct individuals as ramet the H is 2.52 in high disturbed sal forest while it is 2.97 in low disturbed mix forest (Table 5). Simpson's index is always high at high disturbance provided that each superficially distinct shoot is considered as an individual.

Table 3. Number of species in different regeneration category in sal and mixed forests facing high/ low disturbance.

Forest Types (Monto carlo)	Regeneration strategy OR	FS	OS	RP	SR	Total	χ2 -statistics χ2 - value	df	P
Sal Forest									
HD	3	12	10	13	10	48	4.36*	4	0.3676
LD	5	52	28	20	8	113	33.07*	4	0.0001
Mixed Forest									
HD	4	27	13	17	11	76	10.72*	4	0.031
LD	5	79	49	23	10	166	60.01*	4	0.0001

*Values are significant

Table 4. Two factor without replication ANOVA statistic of regeneration categories of different species at two different disturbances level in sal and mixed forests.

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1602.55	3	534.1833	3.194399	0.062547	3.490295
Columns	3549.7	4	887.425	5.306772*	0.010724	3.259167
Error	2006.7	12	167.225			
Total	7158.95	19				

* significant

Table 5. Values of diversity index (*H*) and dominance index (*D*) for Mixed forests and sal stands, based on the whole genet complex as a single individual and each superficially distinct shoot, irrespective of being genet or ramet, as separate individuals at two different levels of disturbance (HD/LD).

Disturbance Level	Genets complex treated as single individual		Each genet and ramet as separate individuals	
	H	D	H	D
Mixed Forests				
HD	3.08	0.061	2.61	0.102
LD	3.29	0.053	2.97	0.086
Sal Forests				
HD	2.72	0.089	2.52	0.109
LD	3.36	0.050	2.91	0.075

The value of similarity index was 0.84 in low disturbed sal and mixed forests while it is 0.77 in high disturbed forests stands. Mixed forest facing low disturbance and high disturbed sal forests has 0.46 similarity index (Table 6).

Table 6. Similarity indices based on sorenson's method between sal and mixed forests facing low and high disturbances (LD/ HD).

`	Sal Forests HD	LD	Mixed Forests HD	LD
Sal Forests				
HD	x	0.60	0.77	0.46
LD	x	x	0.64	0.84
Mixed Forests				
HD	x	x	x	0.69
LD	x	x	x	x

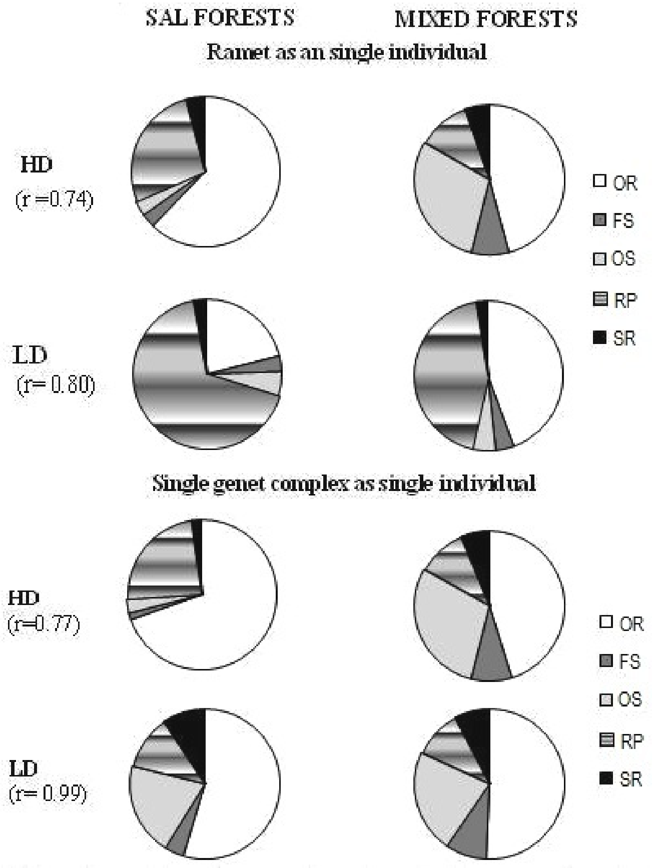

Figure 9. Proportion of different regeneration categories OS =regenerating only through seeds; FS =Facultative sprouters; OR =Obligate sprouter; RP =Ramet producers and SR=Storage roots] of species in different forests facing low/ high disturbances (HD/LD).

DISCUSSION

The present study indicated that sal as well as mixed forests facing low disturbance are fairly rich in species richness under different habit. Less disturbed regional forested landscape of north eastern U. P. is characterized by number of legume trees and shrubs. Comparison of woody species richness between the two forest types shows that over all low disturbed mixed forest are richer than sal forest facing same level of disturbances. In general total number of shrubs and herbs are more in highly disturbed stands while trees are greater in low disturbed stands. In both forest types trees and liana species richness declined with increase in disturbance level because species richness in a forest depends on climatic, edaphic and biotic factors (Ayyappan and Parthasarathy 1999). It is argued that each individual species depend some set of other species for its continued existence. The loss of natural associations may be the probable reason for supporting low species richness at high disturbances (Walker 1992).

Plant population structure may change due to changes in recruitment of individuals at low diameter size classes or exploitation of individual at high size classes or throughout the class size structure. The population structural change is directly related with the regeneration pattern of individuals within the community (Cunningham 2001). The low disturbed mixed forest community was more mature than the rest other communities and represents all gbh classes. Absence of

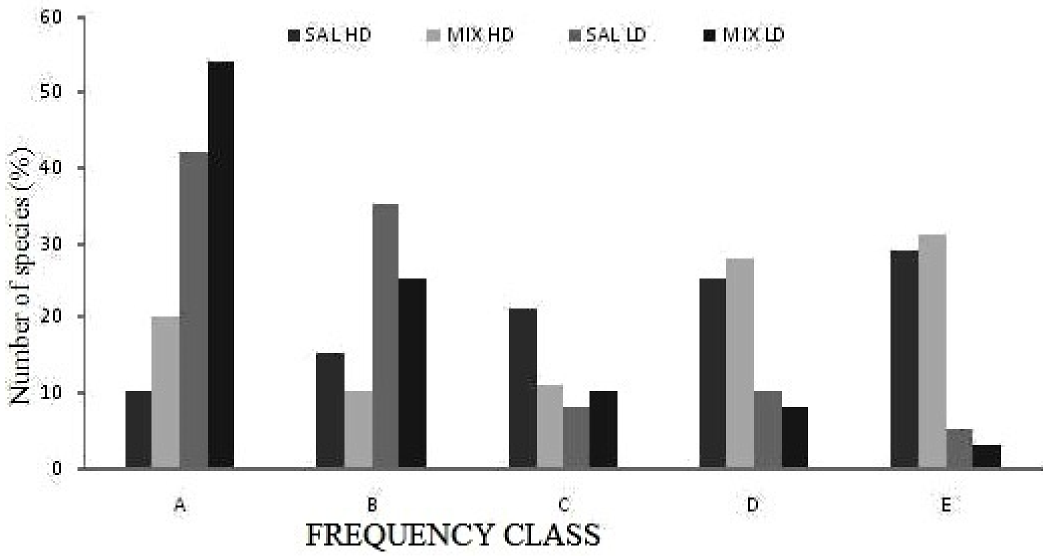

Figure 10. Raunkiaer's frequency class distribution in sal and mixed forests under high and low disturbances.

higher girth classes in disturbed community suggested enough disturbances. When a tree is cut over, gaps might not be filled by seedlings but by shoots sprouting and ramet-producers from the base of the tree. Legumes like *M. chappar*, *D. gangeticum* and ramet producing species (*A. ghasembill, B. retusa, C. tomentosa, C. infortunatum, C. oblongifolius, F.indica , H. antidysenterica, M. philippensis*) are very good in number in stands facing low disturbances to fill these spaces because the sprouts grow much faster than seedlings and can quickly reoccupy their own gaps (Bond and Midgley 2001). In our study, sal forest showed low species density and diversity as compared to the natural forest. *Shorea* is dominated in the regional forested landscape so in each forest age structure is strongly influenced by it. The sal planted forest is still in the evolving stage with several common associates of younger girth classes were common in it. Some of the naturally growing species such as *M. philippensis, Miliusa tomentosa, C. arborea S. cumini,Casearia tomentosa, A. ghaesembilla, F. indica, Carissa spinarum, Putranjiva roxburghii* and *C. fistula* were regenerating in the planted forests as well. Similar findings were also reported by other workers indicating that natural species have regenerated automatically under the plantations (Shah 1994). Therefore, the resultant sal forest community under low disturbance mimics the natural growth mixed forests of the region.

For most of the legume species age class composition of genet at high disturbance, resembled the reverse J-shaped distribution (number increased with increasing age), which indicate the future decline in their population. The canopy gaps created by disturbance provide good regeneration sites for these species. It is reported that the species occupying canopy gaps and those tolerant of water-logging can maintain their population even at high disturbance level (Chadrasekhara and Ramakrishnan 1994). Even within a gap, differences in light, moisture and temperature regimes and spatial heterogeneity caused by root, bole and crown zones, create a number of potential regeneration niches. Such heterogeneities are of fundamental importance in maintenance and promotion of high tree diversity in tropical forest communities (Barik et al. 1992). It is also suggestive that such species are probably the more recent arrivals to the site. Further, species like *P. pinnata, C. nodosa* and *D. triangulare* could not be encountered in sal forest, whereas *M. prostrata, D. heterocarpon* and *Indigofera* sp. were present exclusively in the least disturbed stands irrespective of overstorey dominance. At high disturbance, the sprouts were mostly very young and genets were quite old. *M. chappar* exhibited considerable adaptability in terms of sprouting and was present in good number at any degree of disturbance. Its investment into the subterranean shoot-stock was considerable. Mallik and Gimingham (1983) reported that several Ericaceae are able to resprout quickly after cutting or burning because they invest shoot-stock photosynthates in their shoot growth. In stochastic environment, the metapopulations a collection of cohorts shows a hierarchial structure which consists of the distribution of genets of different age and each genet consists of a distribution of ramets of different size (Alexander et al. 2012). *M. chappar* at moderate disturbance, had stable population structure with maximum number of young individual i.e. upright pyramid with considerable number of old ramets. On the other hand, at high disturbance, most of the sprouts, produced annually, got lost at the end of active growth season. The population of sprouts, therefore, remained always young. At low disturbance, however, most of the individuals were of middle age. In this complex of multistemmed structure, competition occurred at both levels, among genets and among ramets of a genet (de Kroom et al. 1992). Different levels and types of disturbance have differential impacts on forest communities and have been considered an important factor for structuring forest communities (Vesk and Westoby 2004).

The distribution of dominant trees in different girth class (reverse J shaped curve) suggests that the less disturbed forest is quite stable. High tree density in lower girth class could be attributed to rapid colonisation and turnover of gaps in the forest (Whitmore 1993). This also suppressed growth of young plants due to dense overhead canopy as reported by Rao et al. (1997) may be one of the reasons for the presence of a large population of young plants. Except sal forests facing high disturbance population structure of *Shorea* with high population of younger girth classes showed the good regenerating status of regional forests. However, many widespread species tend to be locally abundant in certain areas and relatively rare in others (Hubbell and Foster 1983). The occurrences of other single tree species at low disturbance may have been due to their low regeneration capacity. The density girth distribution of tree species in the present study confirmed the reverse J-shaped distribution. Girth class distribution structure of the population also confirms that the forest is under regenerating stage. Juvenile sprouting ability can be considered part of the recruitment strategy of a species.

All the sprouters are not clone producers. Degree of sprouting and clonality depends on level of disturbance. However, although clonal plants generally sprout but only a small fraction of woody sprouters are clonal and capable of vegetative spread (Pandey and Shukla 2001). Plant sprouting ability is highly affected by disturbances at high than at low intensity levels. Basal sprouting from root crowns is a widespread persistence strategy among tree species that experience disturbance (Bond and Midgely 2001). A smaller subset of tree species produce sprouts from roots or rhizomes. This is also often a reparative response, but it is additionally an evolutionary adaptation for occupying new ground with clonal growth (Cornelissen et al. 2014). A better sprouting ability is related to the ability to survive frequent disturbances, in juveniles, which are characteristics of both forest understorey and frequent fire or drought. To retain sprouting ability until grown seems to be an adaptation to survive infrequent large disturbances (Shibata et al. 2014).

Disturbances are ubiquitous in both natural and managed ecosystems. Many plant communities and species are dependent on disturbance, especially for regeneration. The anthropogenic disturbances greatly affect the biodiversity and structural characteristics of a community (Tripathi and Umashankar 2014). It is one of the challenging tasks before the ecologist, to understand the relationship between the biodiversity and functioning of ecosystems (Tilman et al. 2014). Growth of ramet producers and facultative sprouters colonized rapidly within the low disturbed forest community, can cope up the regional forest and also supports the local need. Plantation practices must include the legume shrubs and trees which not only make the heterogeneous understorey but also fulfil the nitrogen needs of the forest. Mixed forest facing low disturbances potentially ensures considerable plant diversity and vegetation cover at the forest floor even under continual pressure of fuel-wood extraction and other severe perturbations. These observations are of considerable significance with respect to regeneration of plants and maintenance of their population in forest stands of north-eastern U.P. Besides information on the present status, the results also provide clues for the management option in these forests and for the maintenance of species diversity in such stochastic environment.

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