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Population structure and biomass partitioning in four congeneric species of *Moghania* under different disturbance regime in sal forests of Gorakhpur, India

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Abstract
The woody perennials of four species of genus *Moghania* (*M. chappar*) (Benth.) Kuntze, *M. bracteata* (Roxb.) L., *M. lineata* (L.) Ktze. and *M. prostrata* Roxb.) contribute significantly to the understorey vegetation cover of sal dominated forests of Gorakhpur division. The main objectives were to determine the effects of disturbance on different *Moghania* spp. with reference to its *genet* and *sprout/* ramet population and its biomass allocation pattern into different compartments. *Genet* density of *Moghania* spp. decreases with increasing the level of disturbances, while ramets were highest at moderate disturbance. *M. chappar* was the most dominant in all the sal forests. *M. lineata* showed better growth at high disturbance while *M. chappar* and *M. bracteata* commonly occurred at low to moderate disturbance. *M. prostrata* was very sensitive to disturbance and occurred at stands facing low disturbance. At moderate disturbance, the population structure of different *Moghania* species showed the dominance of young plants but the age pyramid showed normal or stable population structure. The total as well as above ground biomass showed significant difference ($P<0.01$) among the species and disturbance level as evident from F- test. At high disturbance, the mean biomass allocation towards different compartments of *Moghania* spp. was significantly different and the total biomass was positively correlated to canopy cover at low as well as moderate disturbance. The ratio of shoot and root biomass ranged from 1.67 to 2.80 for *M. chappar*, *M. bracteata* and *M. lineata* at moderate disturbance. Irrespective of disturbance level, this ratio for *M. prostrata* remained close to 1. There was significant positive correlation (< 0.01) between number of shoots with shoot biomass and with root biomass for *M. chappar* at three disturbance level. The species of *Moghania*, especially *M. chappar* have considerable high potential of the production of non- timber wood in stochastic environment and can cope-up well with moderate disturbance. They can provide good understorey cover even in presence of considerable disturbance and thus can add to the maintenance of ecosystem attributes of the disturbed forests.

Keywords: Ramet and *genet*, population status, age structure, sal forest, disturbance, biomass allocation

1. 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 small patches or groups. Disturbance often leads to habitat fragmentation which results into the clumped distribution of species. Further, some species may show aggregation at suitable habitat sites and may form discrete patches of natural population constituting genet as well as all the ramets of the species (Harper 1967) [12]. One striking feature of clonal plants is hierarchical organization, in which each genetic individual (genet), i.e. the developmental product of a single zygote, consists of genetically identical and semi-autonomous construction units (ramets; Eriksson and Jerling, 1990). Due to over increasing population in tropics, the disturbances are unpredictable events that reduce plant biomass. Disturbance regimes play an important role in biomass allocation pattern. They are a crucial factor affecting plant strategies, population status and architecture pattern of terrestrial plants worldwide (Midgley 1996) [19]. Seed germination and vegetative propagation are the two major means of regeneration in many perennials but the species of harsh environment are known to regenerate by non- seed methods (Calaghan 1988) [5]. The disturbance may play an important role in populations where recruitment occurs primarily via vegetative reproduction rather than by seed and it cause significant changes in the size or structure of a plant population by influencing the structure and regeneration of adult plants (Hartnett and Richardson 1989) [14]. Several studies on the biomass and allocation pattern of perennial are available (Baruah and Ramakrishnan 1989) [2] and few studies have also examined the influence of disturbance regimes on the demographic and life history traits of individual species (Bellingham and Sparrow 2000) [3]. However, study carried out by Clarke *et al* (2005) [8] demonstrated that under disturbance resprouters were favoured because of their ability to persist in more competitive environment.

Legumes are an important component of plant community which controls nutrient cycling and soil development process on nitrogen- poor soil because of their ability to fix atmospheric nitrogen (Virginia 1986) [32]. Thus abundance and diversity of legumes within the managed plant communities can be an important factor in determining plant succession and ecosystem functioning (Chapin *et al* 1986) [7]. The four congeneric species of *Moghania* contribute significantly to the understorey vegetation cover of sal dominated forests of Gorakhpur division. *M. chappar* and *M. bracteata* may readily assume the posture of an under-tree in absence of disturbance while *M. lineata* and *M. prostrata* are shrubs within sal forests across the forested landscape of north-eastern U.P. The unbranched woody shoots of *M. chappar* provide cheap and easily available forest produce which is regularly harvested for various uses. *Moghania* genus contributed about 15% of the total IVI for whole forest community (Pandey and Shukla 2003) [24]. *M. chappar and M. lineata,* however, did not spread its ramets much and its growth and dominance was evidently favoured by moderate disturbance. At low to moderate disturbance, the *M. bracteata* sprouted well, while the *M. prostrate* did not sprout well even at low disturbance (Pandey 2000) [3]. The knowledge of the effects of disturbance on the biomass partitioning and population size of common leguminous species is necessary to understand the status of these vital resources, community- related phenomena and the disturbance-induced changes in the overall communities of forest vegetation. The present article, therefore, deals with the population status and biomass allocation into different components of different *Moghania* genus in disturbed forest environment of Gorakhpur Division.

2. Methods

On the basis of level of disturbances three sal forests stands were identified. Forest stands of 50 ±5 yr were marked within each of three zones of the Sanctuary to identify 1-ha plots within stands after low, moderate or high level of disturbances. The disturbance level was measured through disturbance index or DI (Pandey and Shukla 1999) [23]. Each of the marked plots showed almost average condition for a given level of disturbance. For sampling of the population of *Moghania,* each plot of 1-ha area was divided into 4 quarters and each quarter was sub-divided into 25 grids. Each grid was equivalent to a quadrat of 10mx10m size. 10 random quadrats marked as per 5x5 latin square design were observed; thus a total of 40 quadrats per plot were considered for observation on the age structure of genet and ramet populations. The data was suitably multiplied to represent them on per hectare basis. The individuals with separate identity at the soil surface were treated as genet. Basal sprouts arising from root-stock or those having subterranean organic connections with genet were treated as ramets, the potentially independent individuals, vegetatively produced from a genet. The percent number of individuals falling under different age classes was arranged in the form of horizontal bars to show the age- structure of species populations. The individuals were arranged according to their age from 1 yr to 5 yr. The age of *Moghania* sp. was ascertained on the basis of growth feature (Shukla and Ramakrishnan 1986) and 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.

The standing biomass was measured on per individual basis at the end of the active growth phase. A set of 5- replicates of different species of *Moghania* which represented different age series (from 1 to 6 year) and sequence of maturity status were excavated with their root intact. The excavated individuals were carefully washed with fine jet of water. The biomass of the harvested individuals was sorted out into their root, stem, leaf and inflorescences. The sampled individuals were dried at 80º± 2º C to constant weight. The dry weight of respective component was obtained and summed to get above ground, belowground and total biomass. The leaves and branches senescing and falling during growth, were also accounted for estimating aboveground and belowground biomass production. Some inaccuracies were involved in the estimation of belowground production due to difficulties in the estimation of death, decay and consumption of fine roots. The above set of biomass estimation was made in stands facing high, moderate and low level of disturbances. The regression analysis was made to relate and compare the above ground with belowground biomass under three level of disturbance regimes using an equation, $y= a+ bx$, where a and b are constants, and y is intercept.

3. Results

3.1 Population structure

The intensity of disturbances affected population size as well as the proportion of seedlings and mature individuals. Low to moderately disturbed sal forests showed appreciable number of sprouts of *Moghania* sp. An observation on the proportion of genet and basal sprouts/ramats and the total number of potential shoots per hectare for four different species of *Moghania* compared it within different disturbance regimes. Except for *M. prostrata* all other species were quite abundant at low to moderate disturbance. The two species, *M. chappar* and *M. bracteata*, had sufficient number of sprouts at low to moderate disturbances, while the *M. lineate* had greater sprouting at moderate to high disturbance. The *M. prostrata* was very rare at highly disturbed forests while *M. lineate* avoided shading and was present in gaps created by disturbance (Figure 2). The population structure of mature genets of *Moghania* sp. varied with the degree of disturbances. In general, at moderate disturbance the number of individuals of sprout or ramet origin per population was highest. Conversely, the highly disturbed stands showed lowest proportion of genets as well as share of mature plants mostly of sprout origin along the age series. Except for *M. chappar*, the number of genet individuals from young to old age classes steadily decreased at lower disturbance. This trend was, however, reversed for sprouts/ramats in stands facing moderate disturbance, where the age pyramid showed retrogressive population with very rare young plants. However, sprouts were good in number from 1 to 3 yr at low to moderate disturbances. At moderate disturbance, the population structure of genets showed the dominance of young ones and the age pyramid showed normal or stable population structure. In general, the ratio or number of ramet per genet was maximum at moderate disturbances and minimum at high disturbances. Genet as well as ramet individuals of *M. chappar* commonly occurred at low to moderate disturbance and the population was well distributed among different age classes. A high disturbance, only a few genets and ramets could survive. 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 except at highly disturbed one. The number of genets as well as sprouts of *M. prostrata* was, however, quite mearge at highly disturbed sal forests. The individuals of *M. bracteata* were high as well as the population was better represented in different age group at low and moderate disturbance while *M. lineate* was good in number at high disturbance. Only a few individuals could be found at least disturbance. A few young genets and sprouts of the species were also encountered in some safe pockets of highly disturbed sal forests of the region (Figure 2).

3.2 Resource allocation

The changes in standing biomass of different compartment of the four woody species of *Moghania* at three disturbance levels with increase age of individuals was observed for biomass allocation pattern. Total biomass of these legumes showed 10 to 15 times increase from 1st year to 6th year of plant age. Aboveground biomass was highest at moderate level of disturbance for species other than *M. prostrata* which showed its maximum only at low disturbance. The pattern of biomass allocation changed markedly at three disturbance level for the species, *M. chappar* and *M. bracteata*. The standing aboveground biomass of the two species was quite similar. The per cent biomass allocation to underground parts was generally much higher. The tendency of greater allocation to underground parts was evident both at low and high disturbance level. At moderate disturbance level, however biomass of *M. chappar* was greater than that of *M. bracteata* of similar age. The allocation to belowground biomass showed a general increase with increase in plant age. *M. chappar* had similar aboveground biomass at low or high disturbance up to 4 year plant age (Figure 4). *M. lineata* and *M. bracteata* showed marked differences in aboveground biomass production between the low and high level of disturbance. In general, the aboveground biomass production increased up to 4 year irrespective of disturbance level. Belowground biomass production showed no clear- cut pattern with respect to degree of disturbance, but for *M. chappar* and lineate, it was better at moderate disturbance. The biomass allocation pattern of *M. lineata* followed the trend of *M. chappar* with respect to plantage or degree of disturbance. *M. bracteata* and *M. prostrata* showed greater total belowground at low disturbance. High disturbance caused much lower belowground production in all the species except *M. bracteata*, for which it was better at low disturbance. *M. prostrata*, however, showed maximum proportion of biomass allocation towards underground parts at any age or level of disturbance (Figure 5). In general, the shoot biomass in these species was always greater at moderate or low level of disturbance. The total as well as aboveground biomass showed significant difference (P<0.01) among species and disturbance level as evident from F- test (Table 1, 2). Table 3 shows the changes in ratio of shoot and root biomass of the four species at three disturbance level. In general, the aboveground biomass of (shoot: root ratio = ~ 1) at high as well as low disturbance level. At moderate disturbance, however, this ratio ranged from 1.67 to 2.8. Irrespective of disturbance level, this ratio for *M. prostrata* remained close to 1. The regression in figure 6 shows the pattern of relationship of the number of shoots with shoot biomass and with the root biomass for *M. chappar* at three disturbance level. The lines of relationship between these two variables were less sloppy in case of moderate disturbance level. The correlation coefficient, however, was positively significant (p<0.01) in each case.

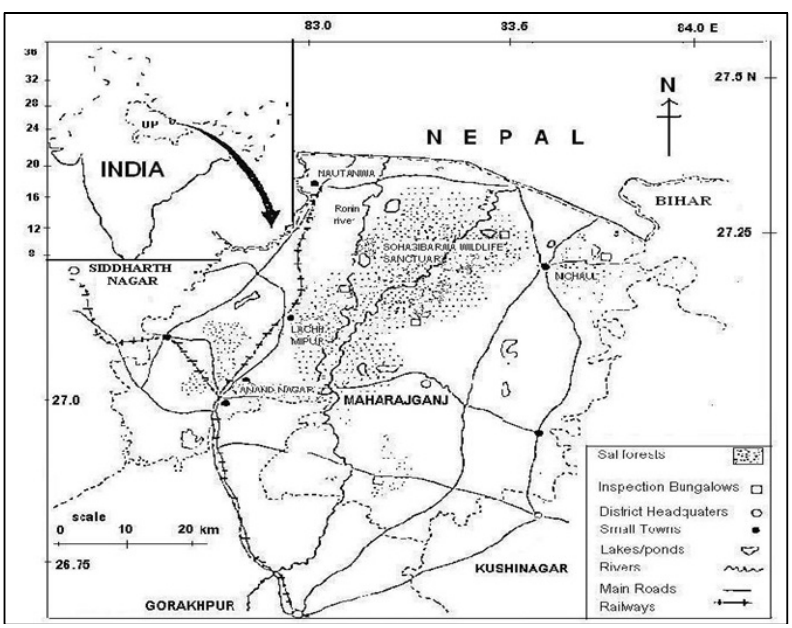

Fig 1: study site shown within the Sohagi Barwa wildlife sanctuary in the Gorakhpur forest division, India

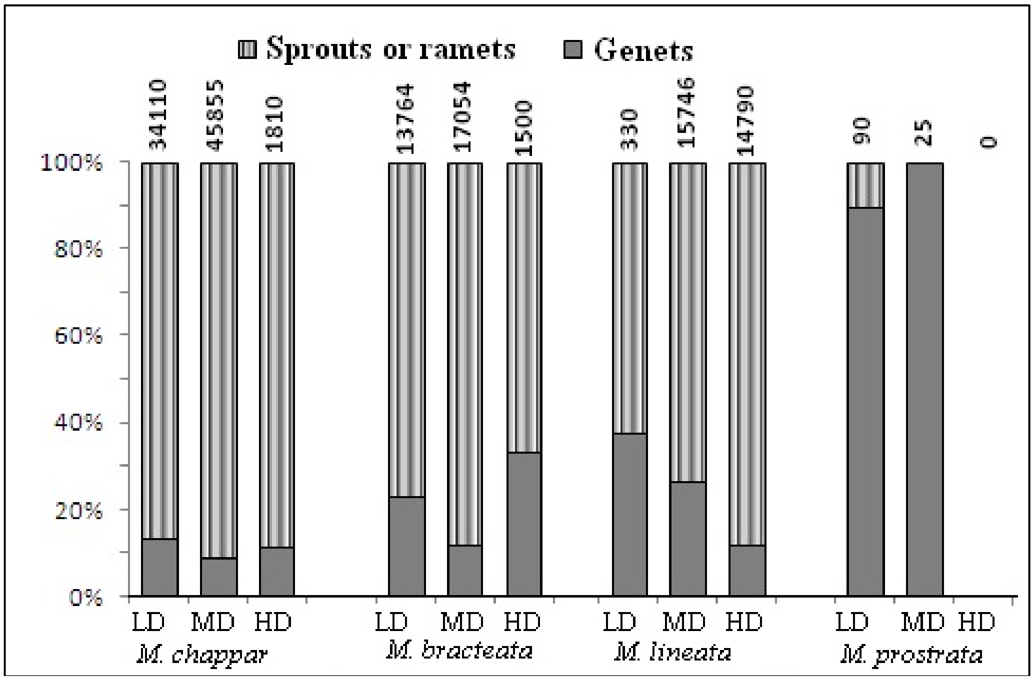

Fig 2: The percent number of genets and sprouts/ramets for different Moghania Species in sal forest low (LD), moderate (MD) or high disturbance (HD). (Total number of potential shoots/Ha is shown on top of each bar)

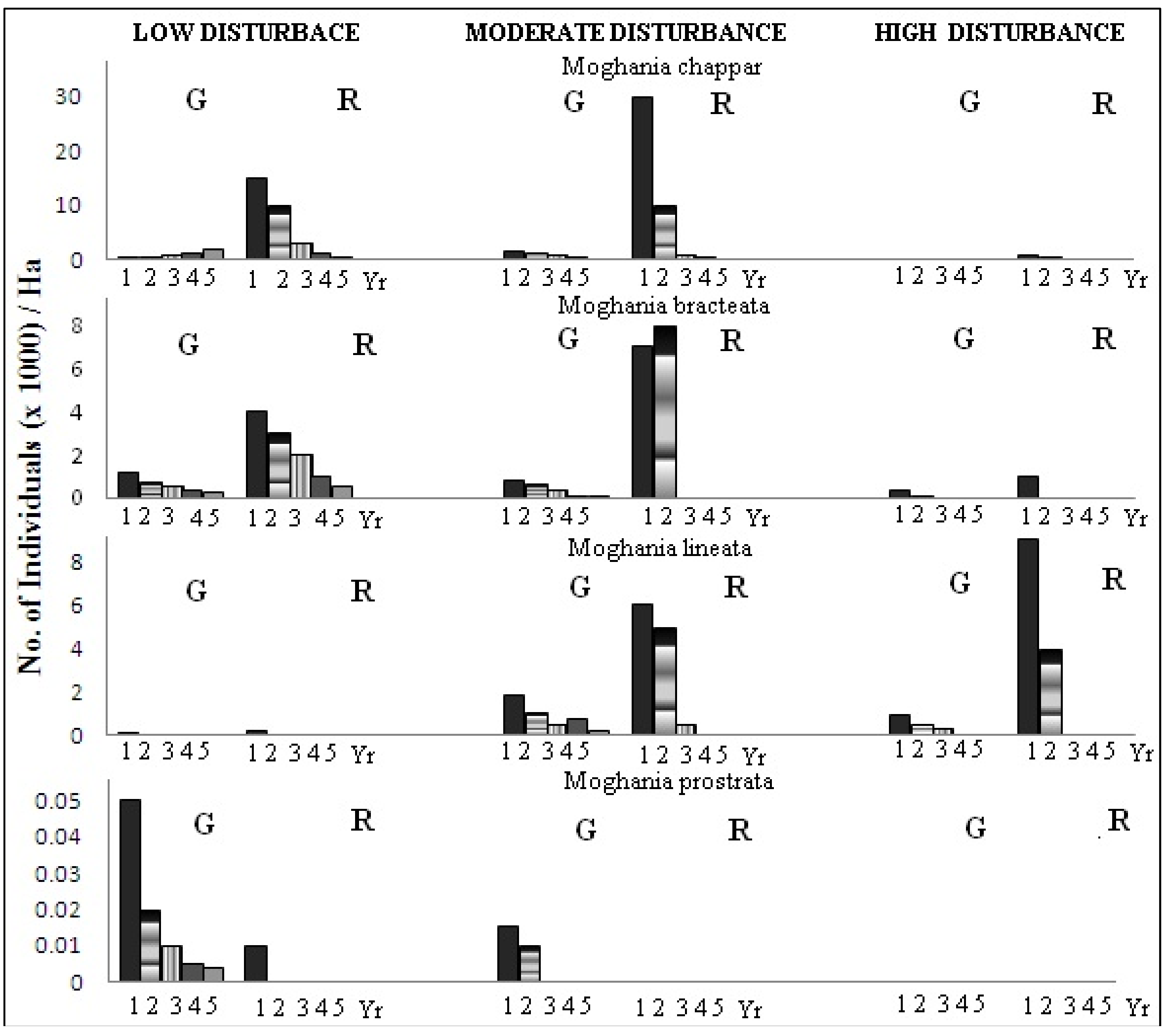

Fig 3: Distribution of genets (G) and ramets/sprouts (R) among different age classes (year) for the congeneric *moghania* species in sal forests under different disturbance regime

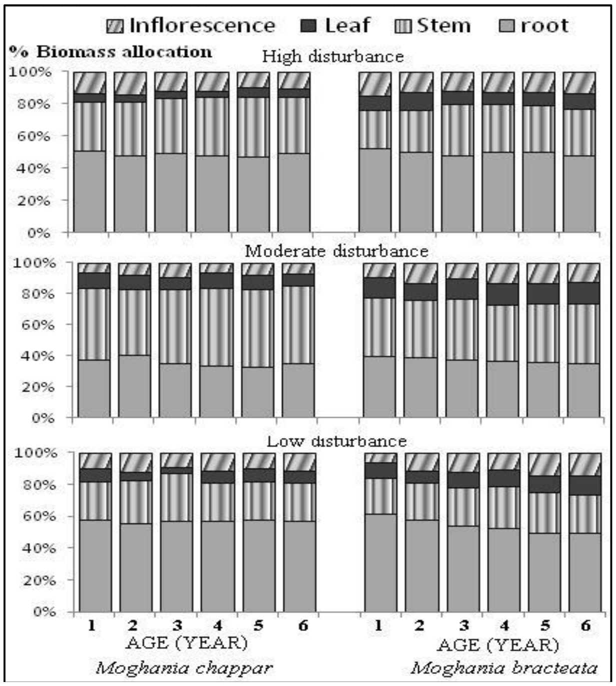

Fig 4: Percent biomass allocation to different compartments of M. chappar and M. bracteata ranging from 1 to 66 yr in sai forests at three different disturbance levels

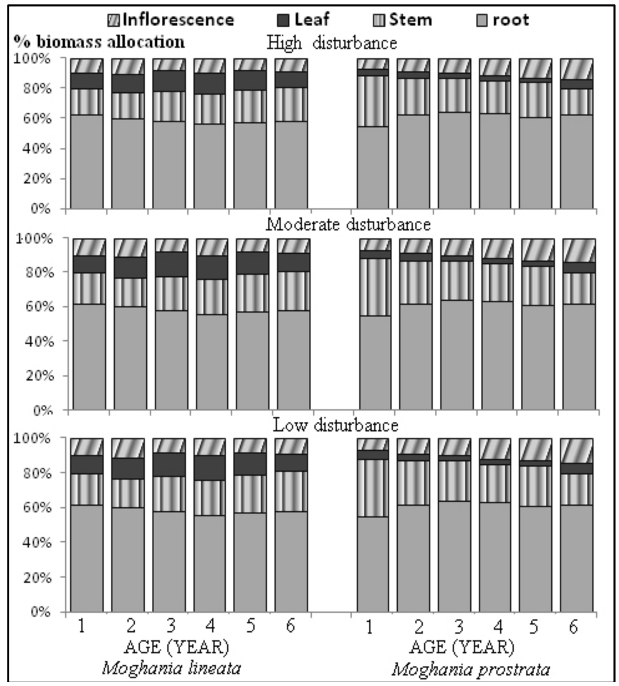

Fig 5: Percent biomass allocation to different compartments of M. prostrata ranging from 1 to 6 yr in sal forests at three different disturbance levels

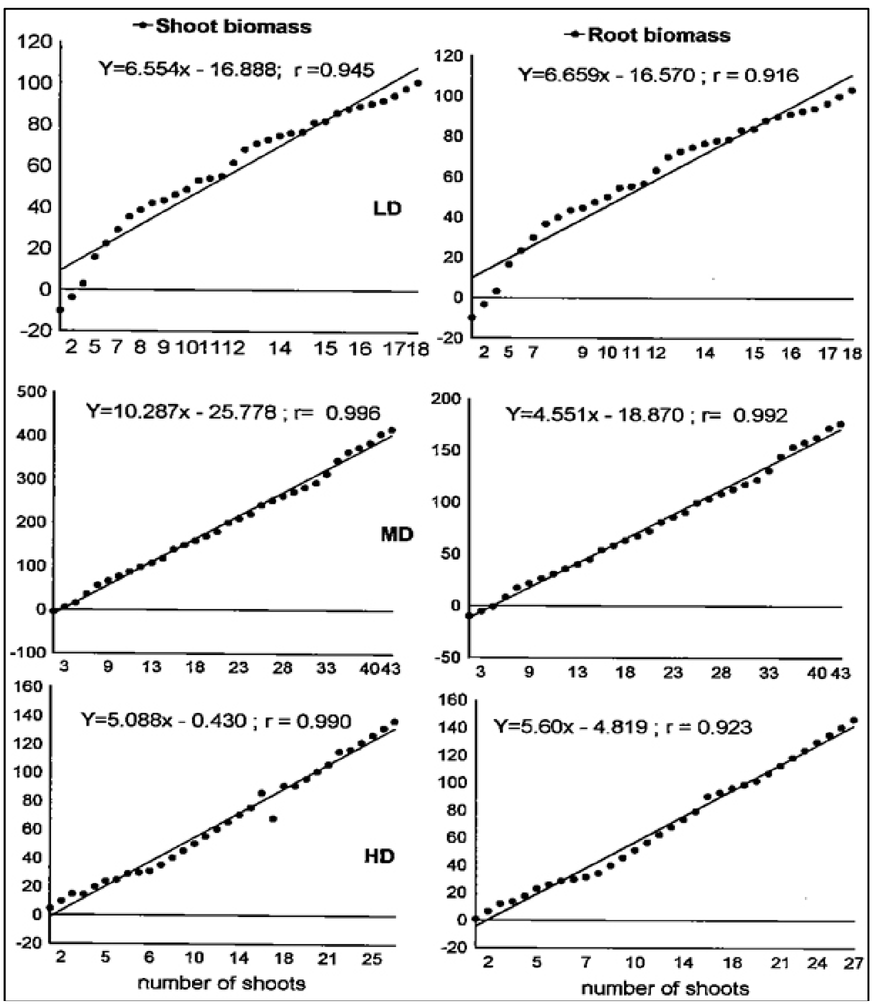

Fig 6: Correlation of shoot biomass and of root biomass with the number of shoots (including basal sprouts) of *Moghani chappar* at three disturbance levels

Table 1: Analysis of variance (ANOVA) table for total biomass of four different species of *Moghania* in an age series facing three different levels of disturbance.

	Source of Variance			
Species	**Within the disturbance level (Between columns)**		**Between the age of the mother plant (Between the rows)**	
	d.f.	F- value	d.f.	F- value
Moghania Chappar	2	17.06*	5	1.46
Moghania bracteata	2	19.38*	5	1.94
Moghania lineate	2	19.24*	5	1.05
Moghania prostrata	2	15.46*	5	1.65

Table 2: Analysis of variance (ANOVA) table for above ground biomass of four different species of *Moghania* in an age series facing three different levels of disturbance.

	Source of Variance			
Species	**Within the disturbance level (Between columns)**		**Between the age of the mother plant (Between the rows)**	
	d.f.	F- value	d.f.	F- value
Moghania Chappar	2	18.17*	5	1.27
Moghania bracteata	2	22.55*	5	1.69
Moghania lineata	2	19.24*	5	1.05
Moghania prostrata	2	17.18*	5	1.67

Table 3: Changes in shoot: ratio from 1 to ~6 year age in four congeneric species of *Moghania*, facing different degree of disturbances in sal forests.

Plant Age (yr)	***Moghania chappar***			***Moghania bracteata***			***Moghania lineata***			***Moghania prostrata***		
	Level of disturbance			**Level of disturbance**			**Level of disturbance**			**Level of disturbance**		
	Low	**Moderate**	**High**	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**
1	0.83	1.77	0.98	0.88	1.67	0.61	1.10	1.84	0.52	1.01	0.47	0.89
2	1.03	2.47	1.08	1.08	1.86	0.75	1.10	2.03	0.65	0.65	0.59	0.65
3	1.09	2.63	1.04	1.18	1.86	0.83	1.03	1.90	0.68	0.62	0.52	0.47
4	1.10	2.68	1.08	1.11	2.17	0.89	1.24	1.72	0.78	0.59	0.51	0.52
5	1.03	2.80	0.97	1.10	2.55	0.92	1.09	1.93	0.71	0.61	0.51	0.65
6	0.97	2.75	1.0	1.26	0.94	0.94	1.14	2.08	0.66	0.77	0.50	0.54

4. Discussion

The age structure of the population of constituent species may indicate the degree of stability and development in the community. In general, ramet and genet individuals of *Moghania* spp. showed stable population structure in less as well as moderately disturbed forest stands. At moderate disturbance, genets of *M. prostrata,* however, showed only old populations which indicate that the populations are likely to become locally extinct if recurrence of disturbance is continued. In contrast, *M. lineata* and *M. bracteata* showed young populations even at low to moderate disturbance. These species are, therefore, well adapted to cope up with adversity caused by stress and disturbance through their efficient sprouting. The abundance of a species in an area depends on the ability of its propagules to tolerate the features of the environment and to withstand interference from other plants (Harper 1967) [12]. Under certain conditions, it has been reported that a single fire or clipping can substantially diminish the population size of the species (Lloret and Lopen-soria 1993) [17] which show poor sprouting. The smaller and smaller population size of non-sprouters like *M. prostrata* may be attributed to such factors. 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) [6]. It is also suggestive that such species are probably the more recent arrivals to the site. 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) [18] reported that several Ericaceae are able to resprout quickly after cutting or burning because they invest shoot-stock photosynthates in their shoot growth. Fire can damage the meristematic tissue of the stump of those species where investment to shoot-stock is meagre (Saha and Howe 2003) [15]. As mentioned earlier such species cannot withstand the onslaught of recurrent disturbance. In stochastic environment, the meta-populations a collection of Cohorts shows a hierarchal structure which consists of the distribution of genets of different age and each genet consists of a distribution of ramets of different size (Bertson and Weiner 1991) [4]. *Moghania* spp. at moderate disturbances had stable population structure with maximum number of young individual i.e. upright pyramid with considerable number of old ramets. At high disturbance, however, most of the individuals were of early to 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). After disturbance, regeneration in most of the species occurs mainly by producing new coppice shoots from a woody root-stock. Therefore, they have to allocate resources to maintain subterranean stock and the multistemmed structure. Cutting of under-trees and large shrubs of legumes, however, quickly brings about apparently irreversible changes in the species composition and physiognomy of the vegetation. Dense shrubby vegetation enriches the understorey of the forest and the legume population stabilizes even if there is moderate disturbance in the form of cutting and trampling. However, gap produced in canopy are known to be important for establishment and growth of most plant species and provide rare habitats for high light-requiring species (Hubbell and Foster 1990) [16].

Plants undergo architectural changes in response to differences in the management schedule, disturbance modes, environmental variation and resource availability. In general, sexual reproduction is enhanced in individuals growing under resource-rich environment. Physiological integration between ramets (as in case of *M. chappar* and *M. lineata*) may decrease the risk of entire parent genotype extinction, a factor sometimes considered as the most important one, favouring vegetative propagation (c.f. Cook 1979) [9]. The number of ramets within unit area differs with habitats. Schaal and Leverich (1996) [28] reported that the same plant show more clones and smaller clones in a population in which burning is used in its management than in another population in which periodic cutting is used. However, in present case, the number of ramets was high at moderately disturbed stands. High disturbance had a negative effect on the number of legumes in recurrently burnt stands. Species like *M. lineata,* continued to respond due to delayed reactivation of meristematic tissue, and because buds that survive were deeper to reach the surface. Such observation has also been made elsewhere (Moreno and Oechel 1991) [20]. The number of ramets/ sprouts was generally, greater in stands facing low and/or moderate disturbance and it increased with the increase in age of mother plant.

The reproductive strategy and resource allocation pattern explain the ecological success of species in a given environment (Abrahanson 1979) [1]. The four species of *Moghania* showed considerable difference with respect to biomass allocation to different compartments. Several empirical studies on life- history strategy have shown that reproductive effort varies with plant size (Samson and Werk 1986) [27]. For annuals, the estimation of reproductive allocation is quite simple but a different approach may be required for perennials (Newell and Tramer 1978) [21]. The iteroparous shrubs of *Moghania* had a considerable accumulative belowground biomass. Such species not only exploit the favourable condition during wet summer but also survive the unfavourable dry summer by retaining at least the belowground parts. A few species like *M. chappar* and *M. lineata* may occupy quite unproductive environment and may tolerate different stresses. The preponderance of such species, which can survive the hot summer in the form of root-stock or underground root, may be the result of selection in considerable disturbed, stressful and changing environment (Sun and Liddle 1993) [31]. At high disturbance, *M. chappar* and *M. bracteata* tend to allocate more biomass towards their roots resulting in slower growth of above ground parts and delayed sexual reproduction. High belowground biomass allocation suggests the disturbance-resistance and alternate survival strategy of the species under highly stressful environment. At moderate moderate disturbance, the biomass allocation towards root-stocks was much greater as compared to that allocated towards sexual reproduction The change in biomass allocation pattern is expected if species like *M. chappar* tend to avoid the problem of ramet-crowding by fragmentation of root-stocks as they increase in size and become massive (Sackville Hamilton *et al*. 1987) [27]. The biomass allocation towards sexual reproduction of *M. chappar* was always greater at low disturbance for a given age which generally decreased with aging genets.

Though the increment in shoot was significantly correlated with root biomass but at individual level the aboveground biomass was much lesser at high disturbance. Rana *et al* (1989) [25] reported that biomass can drastically modify by the level of exploitation and management practices. In general, moderate disturbance favoured the growth of shoot biomass which may be attributed to the presence of enough effective leaf area on the remaining shoots and lesser competition at the ground level because of considerable disturbance. Sustained increase in underground biomass at high disturbance supports the view that a relative greater energy allocated to root may be crucial for species to exist in adverse environment and to support the early sprouting and shoot growth during the next growing season (Whittaker and Woodwell 1968) [33]. At moderate disturbance, shoot biomass was comparatively greater than that of root biomass (Sharma *et al* 1998) [29]. As in less regenerative species, here in case of *M. prostrata*, shoot root ratio was low. Shoot: root ratio is often >1 at moderate disturbance especially 1yr to 5 yr of age. The amount of annual production of stem showed direct relation with thickness of woody underground root-stock. Further, the number of shoots (sprouts) was positively correlated with biomass accumulation of root as well as shoot system. In general, the total as well as aboveground biomass extraction suggests that the level of disturbance is of overriding importance as compared to the age of mother plant. Hartnett and Bazzaz (1985) [13] have shown that under experimental conditions clone form can vary phenotypically, with few longer ramets being produced by shoots facing nutrient or water stress. These observations are of considerable significance with respect to the maintenance of *Moghania* population in forest stands and allocation of biomass into different compartment of the plant. Congeneric species of *Moghania* showed considerable displacement in the release of resources often used by local inhabitants. The extraction and distribution of such minor forest resources may be directly related to disturbance level. A deeper understanding of survival and growth strategy based on long term observation at species level is required for sustainable management of forest resources.

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