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Population status, regeneration and seed germination of eight legumes of *Shorea* forest in North-Eastern Uttar Pradesh

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Abstract
The less disturbed sal forests had considerable number of sprouts/ ramets of leguminous shrubs. Except for Moghania bracteata and Desmodium triangulare, all other species were quite abundant in less disturbed sal forests. In general, Moghania, showed much greater sprouting than Desmodium at low disturbance and has maximum number of sprouts/ ramets in most of the observed stands. A few young genets and sprouts of the species also encountered in some safe pockets of highly disturbed sal forests. In general, species with greater sprouting efficiency had lesser percentage of seed germination. High stress (burning) severely affected the ramet proliferation but high disturbance (cutting) favoured the ramet production. In most of the cases, there was significant difference between low and high disturbance or heat stress in terms of number of ramets/ genets and inter- ramet distances along the age series of genets. In most of the cases t- values were differ significantly at < 0.05 P- level (d.f 8) between low/ high disturbance in terms of inter-ramet distance. Germination experiment was performed, under controlled conditions, with seeds of different eight species of Desmodium and Moghania. These eight species, common associates of sal forest, were germinated under constant darkness and constant light, at room temperatures. The germination process was monitored for 20 days. The germination in most of the species was better in the dark. Differences between the percentage of day- light and dark germinations were significant at < 0.05 P- level for all the species except M. chappar. The study on population status and regeneration pattern of these legumes can be used in a multiple of ways including high quality forage to wild animals, contributing rich organic nutrient for rehabilitation to degraded forests and also providing firewood to local people.

Keywords: population status, regeneration, seed germination, disturbances, stress/burning

1. Introduction

Legumes are an important component of the 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] and to provide valuable proteins to the wild animals like those of agro-ecosystems do to the agricultural fields and to the human beings and their domesticated animals (Duke 1980, Isley 1982) [20, 9]. Legumes can readily establish themselves and quickly produce an herbage cover (Graham 1942) [11]. Thus, the abundance and diversity of legumes within the natural and managed plant communities can be an important factor in determining plant succession and ecosystem functioning (Chapin *et al.* 1986; Mooney *et al.* 1987; Vitousek *et al.* 1987) [3, 26, 33]. Seed germination and vegetative propagation are the two major means of regeneration in many perennials (Cook 1983) [7] but the species of harsh environment are known to regenerate by non-seed method (Calagham 1988). Legumes regenerating largely through seeds are less likely to maintain themselves in community facing recurrent biotic disturbances. In populations where recruitment occurs primarily via vegetative reproduction rather than by seed, disturbance may play an important role in rhizome dynamics and ramet production (Hartnett 1987). In some cases, disturbance may cause significant changes in the size or structure of a plant population by influencing the structure and regeneration of adult plants (Hartnett & Richardson 1989) [16].

A few studies have examined the influence of disturbance regimes on the population status and life-history traits of individual species (Platt 1975). In the nitrogen fixing woody legume the amount of nitrogen fixed increases with the age of plant. These legumes provide good quality fodder and wood, which are used in construction work, furniture making and also for fuel. Several studies on the population structure and regeneration strategy of perennial herbaceous legumes are also available (Ehrlen 1995) [10]. Despite their widespread occurrence and importance from both socio-economic and ecological points of view, little information exists on ecological aspects of associated legume species of sal forest. The information on the effect of disturbance on regeneration and population size of common wild legumes is necessary to understand the status of these vital plant resources and the effect of disturbance-induced changes on their population structure and over all communities of forest vegetation.

2. Methods

Population status

The study was conducted in forest of Sohagibarwa wildlife Sanctuary under north- eastern U.P. The sanctuary is located between 27°05′ and 27°25′ latitude and 83°20′ and 84°10′ longitude and 95m altitude. The climate is seasonal and subtropical. 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 month, i.e. January-june and November-December the monthly annual rainfall is less than 100 mm. 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 (Figure 1). The deciduous plantations of Gorakhpur Forest Division consist mostly of sal (*Shorea robusta* Gaertn), planted mainly through *taungya* system.

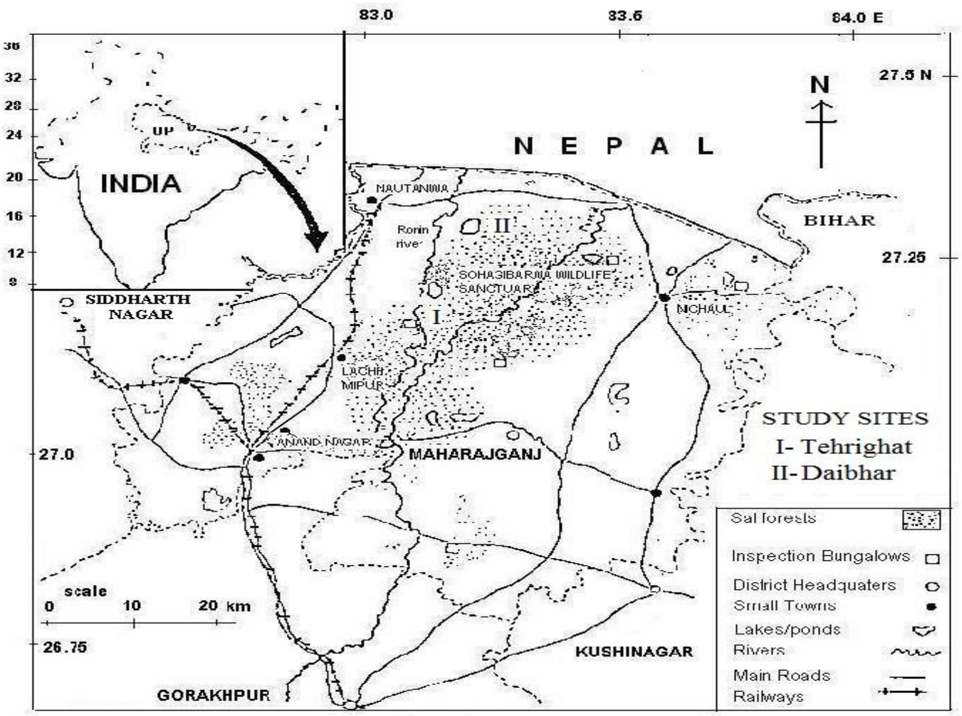

FIG. 1. Study site shown within the Sohagibarwa Wildlife Sanctuary in the Gorakhpur Forest Division, India

Two stands of sal forests was identified within buffer zone of sanctuary which faced low disturbance and within peripheral region which faced high disturbance. The age of two stands was 50 ± 5 yr (Table 1). The disturbance level was measured through disturbance index or DI (Pandey & Shukla 1999) [28]. In each of the above forest, 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. Thus a total of 40 quadrats per plot were sampled for each treatment. The data on the number of trees, genets and sprouts were suitably multiplicated to represent them on per hectare basis. All the species of *Moghania* and *Desmodium* were identified and the number of their genets and sprouts/ramets were counted. The individuals with separate identity at the 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 individuals initially having organic connection with the mother plant or genet. The age of woody shrubs was ascertained on the basis of growth-features (Halle *et al.* 1978; Shukla & Ramakrishnan, 1986) [13, 31] 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

Table 1: Characteristics of the study sites fall under sal forest of North- eastern Uttar Pradesh.

Attributes	Study sites	
	Site- I	Site-II
Place	**Tehrighat**	**Daibhar**
Clipping and cutting	rare	Less common
Cattle grazing, browsing and trampling	absent	Less common
Stress (Burning)	Very rare	Once in 4- 5 years but not regular
Severity/ intensity of fire	Dry leaves may burn	Small shrubs burn and flames goes up-to the height of <1 m.
Level of disturbance/stress	High disturbance/ stress	Low disturbance/ stress
No. of woody species	113	126
Disturbance Index	>60	< 40
No. of herbaceous species	11	8
Common plant associates	Desmodium gangeticum (L.) Dc, Desmodium pulchellum (L.) Benth, Desmodium triangulare (Retz.) Merr, Moghania bracteata (Roxb.) in Li, Moghania chappar (Ham. Ex. Benth.) Ktze, Moghania lineata (L.) Ktze, Moghania prostrate, Mallotus philippensis, Carya arborea, Semicarpus, Bridilla stipularis, Alstonia scholaris, Pongamia pinnata, Piper, Milleusa, Terminalia tomentosa.	

Number of ramets and inter-ramet distances

Two ramet-producing leguminous species, *Moghania lineata* and *M. chappar* were observed in sal forests of 50 ± 5 yr. of age facing different degree of disturbance (cutting) and burning (heat stress). Disturbance level was determined on the basis of DI as described earlier. High and low degree of burning was determined on the basis of its recurrence (stands facing annual burning were treated as high-stress stands and those burnt at the interval of 2-3 yr. were treated as low-stress stands). The individuals of 2 yr. to ~ 6 yr. of age were excavated and their ramets were traced by digging out the surface soil. The mean inter-ramet distance (IRD) was based on 5 replicates. Generally the most vigorous and old shoot of the complex was genet and all further shoots were ramets. The number of ramets/genet and IRD of a species at the two different level of disturbances were compared and the significance of differences was tested statistically.

Seed Germination

Mature dry fruits were collected from well growing *Moghania* and *Desmodium* plants and the seeds extracted from these fruits were sun-dried and preserved at room temperature. Germination tests were performed in the laboratory under two different light regimes i.e. in (Petridishes covered with black paper) and in day light condition. For each treatment, 100 seeds were used for germination were moderately scarified by tumbling them with sharp gravel in a glass bottle for five minutes. The imbibed seeds were kept on water- soaked filter-paper underlined with cotton in petridishes of 5cm diameter. Observation on germination was recorded daily up to incubation period of 20 days. Germination value (GV; It is the product of peak value and mean daily germination), which measures both the speed and completeness of germination (Czabator, 1962) [8] and the mean daily germination was calculated at the end of germinability test.

3. Results

The less disturbed sal forests also showed appreciable number of sprouts/ramets of leguminous shrubs. An observation on the proportion of genet and basal sprouts and the total number of potential shoot per hectare for 8 species under two common legume genera, *Moghania* and *Desmodium*, compared the sal stands and mixed forests facing low or high disturbance (Figure 2). Except for *M. bracteata* and *D. triangulare*, all other species were quite abundant in sal forests than in mixed forests. These two species, however, had sufficient number of basal sprouts but only at low disturbance. In general, *Moghania* showed much greater sprouting than *Desmodium* at low disturbance and had maximum number of sprouts in most of the observed stands. *D. heterocarpon* was very rare at high disturbance while *D. pulchellum* avoided shading and was present in gaps irrespective of forest types and degree of disturbances. The *D. triangulare* was present but only at low disturbed forest.

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. *D. pulchellum* was noticeable only in highly disturbed sal forests. Figure 3 shows the number of ramets per genet for three leguminous species at low or high heat stress (burning) and/or disturbances (cutting). In general, the number of ramet per genet increased with increase in the age of genet. This increase was most spectacular in *M. chappar.* High heat stress severely affected ramet proliferation but higher disturbance favoured ramet production. The gap between the number of ramets/genet at high and low disturbance levels increased with the increasing age of genet plant.

The inter-ramet distances (IRD) generally increased with genet age. *M. chappar* did not show much change in inter-ramet distances with respect to low or high burning but *M. lineata* and *Dalbergia lanciolaria* showed significant decrease in IRD at high burning. Further IRD in *D. cassioides,* unlike other two species, decreased beyond 5 yr. of genet age. With respect to IRD, the two disturbance levels showed a pattern opposite to that of burning (Figure 4). Table 2 shows the test of significance (t-test) between low and high disturbance and heat stress in terms of number of ramets/genet and inter-ramet distances along the age series of genets. In most cases differences were significant at 5% P-level (at d.f. 8).

Seed germination percentage of *Demmodium*, in general, was greater than that of *Moghania*. Except for *D. gangeticum*, all the other species showed much greater percentage of seed germination in dark. Of the three *Desmodium* species, *triangulare* showed maximum germination and among *Moghania* species, the germination percentage was maximum for lineate. Differences between the percentage of day- light and dark germinations were significant at 5% P- level for all the species except *M. chappar* which showed very low and quite similar germination percentage in day-light as well as in dark conditions (Table 3). *D. pulchellum*, *D. triangulare* and *M. lineata* showed better percentage in day light. However, initially for few days, the germination in most of the species was better in the dark. The trajectories of the cumulative germination were quite different for most of the species (Figure 5).

Figure 6 shows the germination value of different species of *Desmodium* and *Moghania* under two different light regimes along 20 days of incubation period. In general, peak of germination value was reached after 8 days in day –light condition and much earlier (after 4- 6 days) in dark for the species of *Desmodium*. *Moghania* species, however, showed no difference of time period with respect to light regime. *D. gangaticum* and *M. bracteata* showed remarkabley peaks as compared to other species. Table 4 displayed the regression equation and its coefficient for species of *Desmodium* and *Moghania* between number of days as independent variables with percent of seed germination as dependent variable under dark and daylight conditions. The r^2- values varied from 0.51-0.89 and from 0.49- 0.87 in dark and daylight conditions respectively. The *D. gangeticum* and *M. lineata* show much rapid seed germination than the other congeneric species.

Table 2: Test of significance (t- values) of differences between the effect of high and low disturbance between and between high and low stress (burning) on the number of ramet/ genets and on the inter- ramet distances in case of two ramet producing leguminous species.

Species	Age	No. of ramet/ genet		Inter- ramet distances	
		Disturbance High vs. Low	Burning High vs. Low	Disturbance High vs. Low	Burning High vs. Low
Moghania chappar	3	0.51	1.98*	1.92*	2.86*
	4	0.21	1.54**	1.73**	1.85**
	5	1.06	2.84*	1.45**	0.90
	~6	1.33	3.91*	1.10	0.79
Moghania lineata	3	0.63	1.98*	4.85*	8.70*
	4	0.64	2.67*	3.50*	5.31*
	5	3.19*	7.03*	4.18*	3.98*
	~6	4.69*	4.78*	4.30*	5.46*

(* Differences are significant at 5% level; ** at 10% level. [(n1+n2)- 2=*]

Table 3: Per-cent seed germination of different species of Desmodium and Moghania under daylight and dark conditions.

	Species	% germination in dark	% germination in daylight	t- values
1	Desmodium gangeticum (L.) Dc.	50.5 ± 8.2	71.5 ± 20.7	2.24*
2	Desmodium pulchellum (L.) Benth.	66.0 ± 11.8	42.0 ± 8.6	3.29*
3	Desmodium triangulare (Retz.) Merr.	84.7 ± 9.8	35.5 ± 14.2	5.70*
4	Moghania bracteata (Roxb.) Li.	21.5 ± 13.7	15.5 ± 7.0	0.78
5	Moghania chappar (Ham.Ex.Benth.) Ktze.	38.5 ± 14.6	19.5 ± 9.9	2.72*
6	Moghania lineata (L.) Ktze.	50.5 ± 4.2	34.5 ± 4.1	5.63*
7	Moghania prostrata	4.0 ± 1.0	1.25 ± 0.43	5.05*

*t- values are significant at 5% P- level

Table 4. Summary of regression relationship of different legumes between germination percentage and of days (with function of time) in darkness and day light condition.

	Species	Regression equation in dark	r^2	Regression equation in daylight	r^2
1	Desmodium gangeticum (L.) Dc.	y = 6.933x + 6.444	0.89	y = 3.358x + 36.58	0.80
2	Desmodium pulchellum (L.) Benth.	y = 3.183x + 23.57	0.83	y = 1.941x + 19.92	0.67
3	Desmodium triangulare (Retz.) Merr.	y = 3.208x + 43.05	0.72	y = 2.166x + 14.77	0.74
4	Moghania bracteata (Roxb.) Li.	y = 2.158x + 0.877	0.74	y = 0.816x + 9.977	0.63*
5	Moghania chappar (Ham. Ex.Benth.)Ktze.	y = 3.1x + 0.8	0.77	y = 1.108x + 12.7	0.49*
6	Moghania lineata (L.) Ktze.	y = 3.191x + 1.588	0.85	y = 1.583x + 12.22	0.87
7	Moghania prostrata	y = 1.25x + 21.44	0.51*	y = 0.158x - 1.122	0.79

*Values does not significant at < 0.01 P- level at d.f. = 16

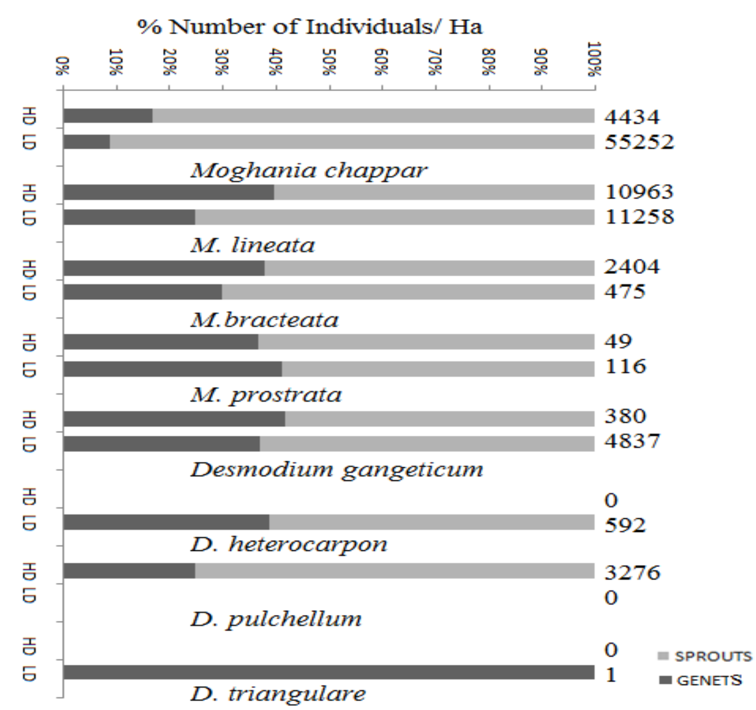

Figure 2. Per cent number of genets and sprouts(the total number of potential shoot/ Ha is shown on top of each barof 8 leguminous shrubs in sal forests facing high/ low (HD/LD) disturbances.

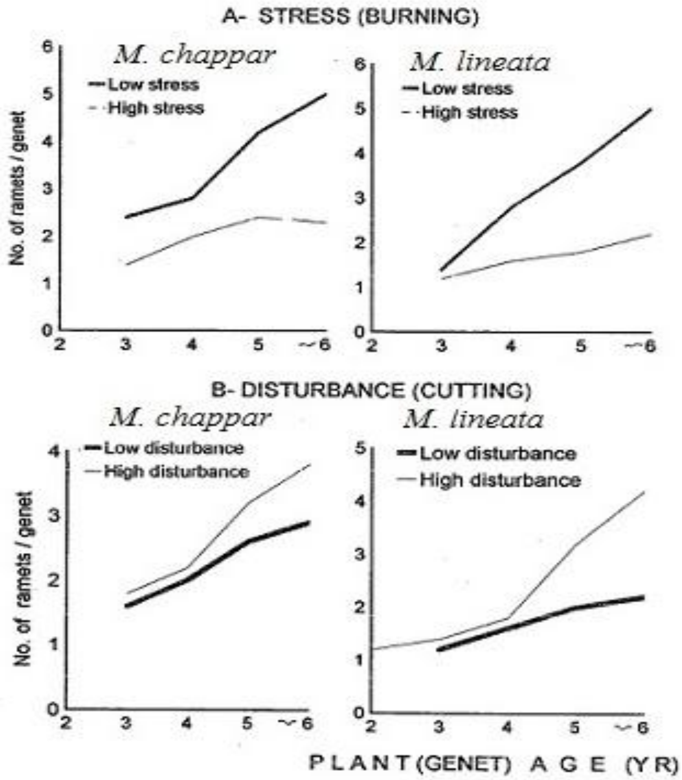

Figure 3. Number of ramets/ genet in common, ramet- producing, woody legumes in disturbed sal forests facing (A) low or high degree of stress or burning (LB/ HB) and (B) low or high degree of disturbance or cutting (LD/ HD).

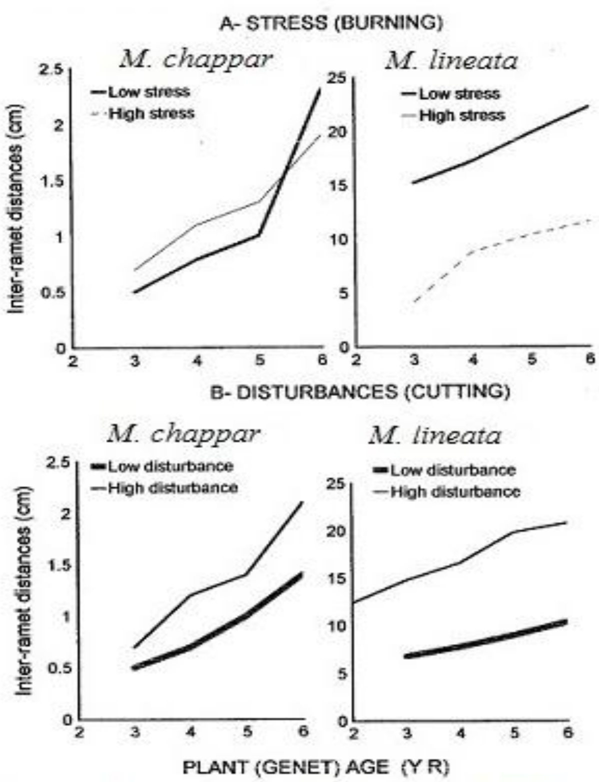

Figure 4. Inter ramet distances (cm) within genet of different age for two legumes in disturbed sal forests facing (A), low or high degree of stress or burning (LB/ HB) and (B), low or high degree of disturbance or cutting (HD/ LD)

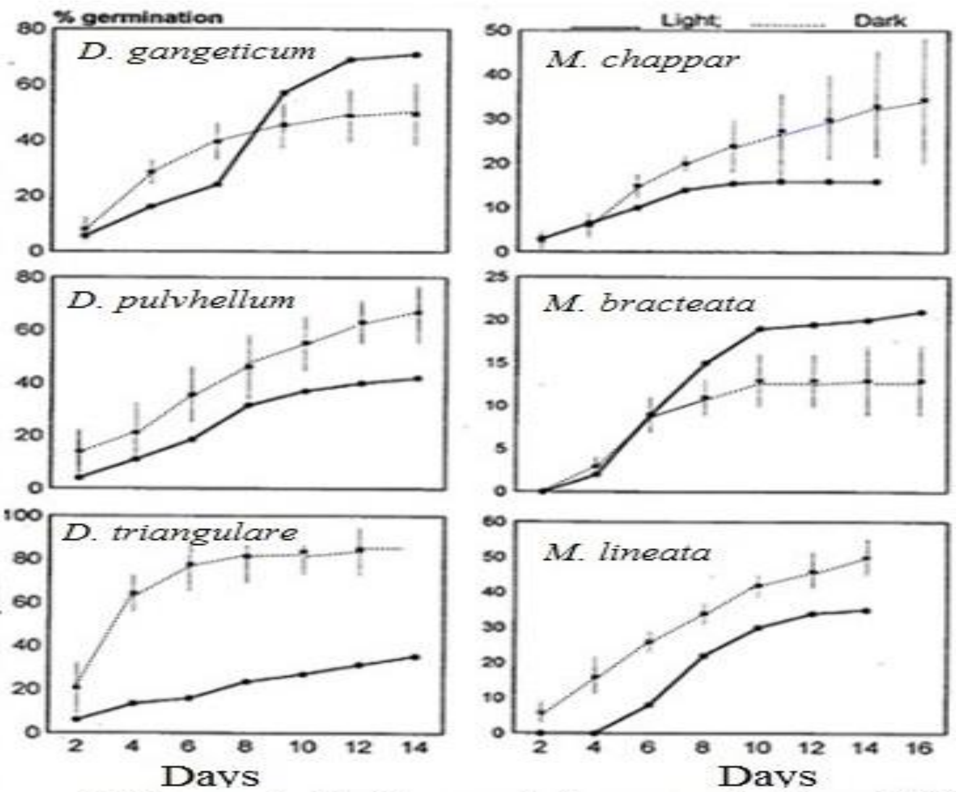

Figure 5. Change in the % cumulative germination of different species of *Desmodium* and *Moghania* during 15 days of incubation under daylight and dark conditions.

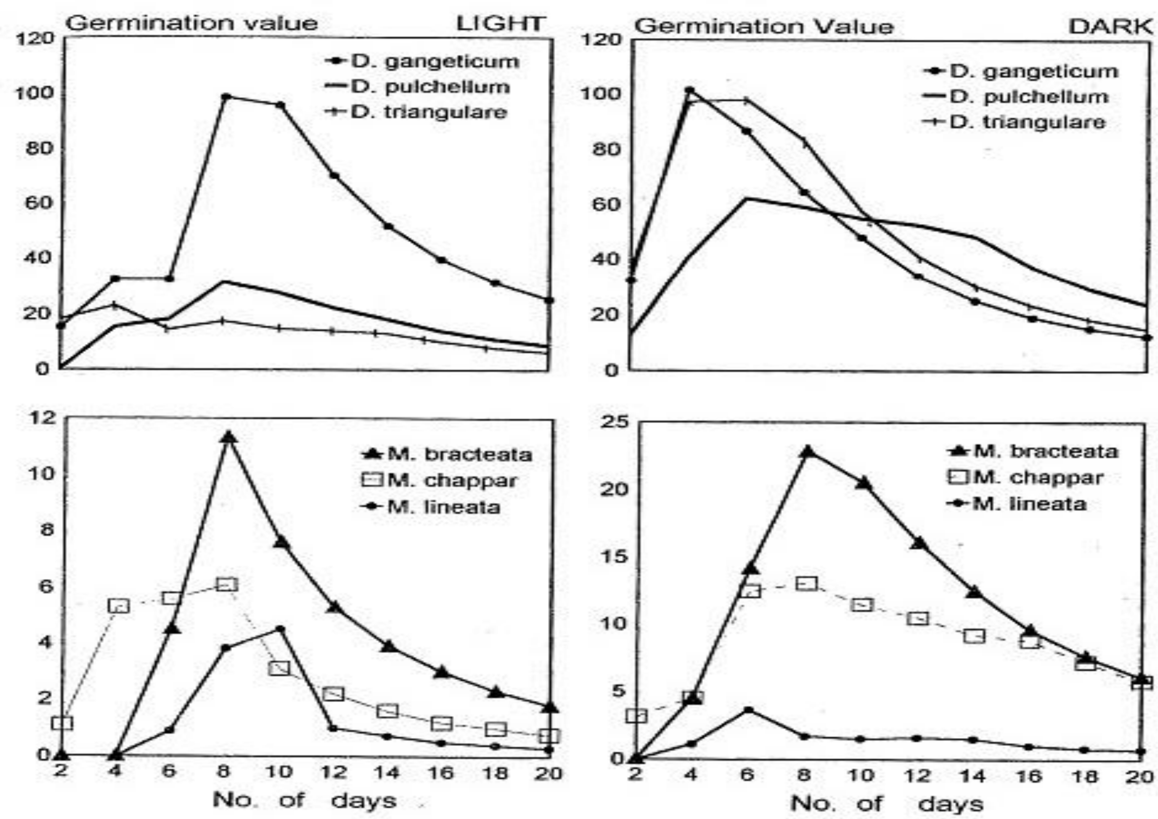

Figure 6. Germination value of different species of *Desmodium* and *Moghania* during 20 days of incubation under daylight and dark conditions

4. Discussion

The leguminous shrubs are one of the most significant component of forest vegetation due to their economic and ecological importance. The total number of genets as well as sprouts of legumes was greater in sal forest facing low disturbance. 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) [17]. Further, the establishment of seedling is most strongly dependent on the occurrence of 'safe site' (Harper 1977) [18] or "regeneration niches" (Grubb 1977) [12]. Different species utilize different regeneration niche that poses an important limiting factor to the population success. Occurrence of suitable site for recruitments often depends on the dynamics of the overstorey so it might also be viewed as one component (Clark 1991) [4]. At low disturbance there was considerably good number of young genets. It is better for a genet to develop a few large shoots rather than many smaller shoots. Under certain conditions, it has been reported that a single fire or clipping can substantially diminish the population size of the species (Lloret & Lopen-soria 1993) [24] which show poor sprouting. The smaller and smaller population size of non-sprouters like *M. prostrata* and *D. heterocarpon* may be attributed to such factors.

The population status of constituent species may indicate the degree of stability and development in the community. In general, most of the legumes showed fairly good population status in less disturbed stands irrespective of the type of forest communities and composition of the overstorey. At high disturbance, *P. Pinnata, B. purpurea, D. triangulare* and *M. bracteata,* however, showed only old populations indicate that the populations are likely to become locally extinct if recurrence of disturbance is continued. In contrast, *M. lineata* and *D. pulchellum* showed young populations even at high disturbance. These species are, therefore, well adapted to cope up with adversity caused by stress and disturbance through their efficient sprouting. Mallik and Gimingham (1983) [25] 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 (Zammit 1988) [34] of those species where investment to shoot-stock is meagre. As mentioned earlier such species can not withstand the onslaught of recurrent disturbance. 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.

After disturbance, regeneration in most of the species occurs mainly by producing new coppice shoots from a woody root-stock (Hartnett 1990) [14]. Therefore, they have to allocate resources to maintain subterranean stock and the multistemmed structure. Although adult mortality takes place during the first dry period after fire, it seems to be balanced by seedling establishment (Le Maitre *et al*. 1992) [22]. Cutting of undertrees 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 (c.f. Lieberman & Li 1992) [23] in the form of cutting and trampling. 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 & Foster 1986) [19]. Further, they reduce the dominance of competitively superior species (Connell 1978) [5]. 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. It has been found that reiterated individuals, shaded by trees, do not flower and maintain themselves by vegetative reproduction for many years (Kawano and Magai 1985).

Physiological integration between ramets may decrease the risk of entire parent genotype extinction, a factor sometimes considered as the most important one, favouring vegetative propagation (Cook 1979) [6]. The number of ramets within unit area differs with habitats. Schaal and Leverich (1996) [30] 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 in least burnt stands. Heat stress had a negative effect on the number of legumes in recurrently burnt stands. Such observation has also been made elsewhere (Moreno & Oechel 1991) [27]. It has been observed that good sprouting species had low percentage of seed germination while poor sprouting species had greater percentage of seed germination (Bazzaz, 1993) [1]. In present case also, *Moghania* were mostly good sprouters but had much lesser seed germination percentage than *Desmodium.* The inter-ramet distances was generally, greater in stands facing low burning and/or high disturbance and it increased with the increase in age of mother plant. Hartnett and Bazzaz (1985) [15] 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 regeneration of legumes and maintenance of their population in forest stands of north-eastern U.P. Besides information on the present status of common legumes, the results provide clues for the management option in these forests and for the maintenance of legume diversity in such stochastic environment.

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