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Population status and non- seed regeneration of *Mallotus philippensis* in sal and mixed forests of North-Eastern U.P., India

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Abstract
Non seed regeneration is an important regeneration strategy found in different vegetation and may play an important role in ecosystem recovery. The present study compares the effect of disturbance on population status and regeneration strategy of *Mallotus philippensisin* in sal and mixed forest of the region with reference to ramet vs genet. High disturbance induced ramet proliferation from the genets of almost all the girth classes in *Mallotus* and the number of ramets per genet steadily increased as the genet aged. A positive relation between genet size and the number of ramet was also observed. This phenomenon explains the pattern of distribution of *Mallotus* in disturbed environment which enables the species to provide the minimum understorey cover to the recurrently disturbed sal forests. Branching order of ramet increased with increase in disturbance level in *Mallotus*. Genets facing disturbance of D_0 level, showed little ramet production. Number of ramets per genet varies from 24.5±3.5 to 112±21 while the inter ramet distance varies from 32.3±5.3 cm to 56.2±9.7 cm under different forests. At D_3 level of disturbance, spacers, branched upto III order or more results into vast expansion of root-stock and production of a number of ramets. The sum of basal area for all the ramets per genet complex increased with genet maturity. Inter-ramet distance was greater in plots facing high burning or low disturbance. The population and growth strategy of *Mallotus*, evidently, helped the recovery process of the degraded forest ecosystem.

Keywords: population status, disturbance, regeneration, ramet, genet, inter ramet distance, *mallotus*

Introduction

The perception of mature forests as homogenous stands of large trees has given way to the more dynamic idea that, due to natural disturbances, forests consist of mosaic of areas at different stages of regeneration (Pandey and Shukla 2003, Tripathi and UmaShankar 2014) [1, 2]. In populations where recruitments occur primarily via vegetative rather than seed, disturbance plays an important role in the rhizome dynamics and ramet production (Callaghan *et al*. 1992) [3]. There are diverse modes of non-seed regeneration which differ in their dispersal ranges. Many terrestrial plants grow vegetatively by extending runners, sprouts, rhizomes or roots (Clarke *et al* 2010, Pandey and Shukla 2018) [4, 5]. As in many perennial herbs, a number of woody plants show the continuity of root-stocks in the form of inter-ramet connections which make the genet physiologically integrated system. The Phenomenon is well documented in several herbs (Ye *et al*. 2006) [6] but such reports are fewer in case of woody species (Clarke *et al*. 2010; Pandey and Shukla 2020) [4, 7]. The connection between any two ramets may disappear after a few years of ramets growth or may persist for many years (Guerrero-Campo *et al*. 2006) [8]. Species found in harsh environment are known to regenerate mainly by non-seed methods as evident from the studies on growth the regeneration of several clonal species (Charpentier *et al*, 2012) [9]. Even some trees such as an aspen (*Populus tremulodies*) and a sumac (*Rhus javanica* var. *roxburghii*) are capable of clonal spread from root suckers. Very few studies are available on ramet growth of woody plants (Bond and Midgley 2001; Pandey and Shukla, 2019) [10, 11] and even fewer have examined the sex-related differences in clonal woody plants (Pathak and Shukla 2004) [12]. The ability of tropical trees to sprout is widely known. It is ubiquitous mode of regeneration following disturbance. *Mallotus philppenis*, a common under storey element of the regional forest, regenerate by seed germination as well as by vegetative means or non-seed methods. The non-seed regeneration occurs through sprouting as well as through ramet formation. The information on the effect of disturbance on seeding establishment and non-seed regeneration is necessary to understand the community level changes in major forest communities and the status of *Mallotus* which is a vital understorey component and fuel wood resources

Study area and methods

The study was conducted in Sohagibarwa Wildlife Sanctuary in Gorakhpur Forest Division, Uttar Pradesh. The Sanctuary is located at 27°05′ to 27°25′N and 83°20′ and 84°10′E at about 95 m elevation. The division, however, consisted mostly of plantation forest of sal (*Shorea robusta* Gaertn.) planted mainly through the ‘taungya system’ (Champion and Seth 1968) [13]. As the sal aged, the community developing in association with planted sal gained considerable plant diversity and fairly mimicked the composition of the patches of natural growth forest (Map I). Plantation forests of sal and mixed natural-growth forests facing low or high level of disturbance were identified for the study of non-seed regeneration in *Mallotus*. A sample plot of 100m x 100m was identified in each of the above mentioned stands to estimate individuals and sprouts on per hectare basis. Each sample plot was sub-divided into four quarters. One of the quarter showing average vegetation was marked to record all the individuals and sprouts of *Mallotus* occurring in it. The position of emergence of sprouts was quite variable. The sprouts from apparently intact tree generally originated from base of its trunk. The sprouts emerging upto 1m trunk height were rare. The age of sprouts was determined on the basis of their growth pattern (Shukla and Ramkrishnan, 1986) [14]. Genets and ramets were distinguished by tracing the origin and course of rootstock. The genets were categorized into different girth classes (A=<10cm, B=11-25cm, C=26-40cm, D=41-55cm, E=56-70cm and F=>70cm) in order to analyze the distribution of genets remets and sprouts in relation to the maturity status of *Mallotus* tree.

The horizontal spread of rootstock and the spatial pattern of remets of different age were studied by excavating the whole root system of -10 genets of different girth classes and the position of ramtes were drawn to scale. In a given genet-complex, the original tree or genet-proper generally showed the thickest stem base. The ramets were the discrete shoots arising from root-stock which in turn originated from the genet. The ramets were potentially independent but most often maintained organic connection with their genets. The distances between genet and first ramet (GRD) and that between adjacent ramets (IRD) were measured and the basal diameter of ramets was also recorded. Initially, the extent of remet production was compared in stands facing high vs. low level of disturbance or stress. The disturbance level was considered as high in plots where DI was <60 and low in plots where DI was <30 (Pandey and Shukla 1999)[15]. The effect of different degree of burning was also observed. Plots facing recurrent burning i.e. at least once a year or more, were considered as facing high heat stress and those burnt at most at alternate years, were considered as facing low heat stress. The phenomenon was also observed in case of male, female, and non-flowering *Mallotus* at different levels of disturbance (D_0-D_3). Intact individuals were taken as facing zero (D_0) disturbances. The fully reiterated individuals of sprout-origin faced D_1 level of disturbance.

Results and Discussion

In addition to regeneration by seed, many perennial plants are known to regenerate by vegetative means (Grime 2002)[16]. Vegetative propagation in *Mallotus* was mainly through ramets. At low disturbance, total number of genet individuals of *Mallotus* was greater than the same at high disturbance. This shows that abundance of a species in an area depends on the ability of its propagules to tolerate the feature of environment and to withstand the interference from other plants (Harper, 1967)[17]. The number of sprouts per hectare was greater at high disturbance. Thus sprouting event was clearly related to the level of disturbance. In general, the number of individuals of *Mallotus* was much greater in forest stands facing low disturbance. Further, the individuals were more numerous in sal stands than the same in mixed forest irrespective of disturbance level. The number of sprouts, however, showed opposite trend with respect to the degree of disturbance in both the sal and mixed forest stands. At high disturbance, they were far much greater. However, the amount of sprouts (on per hectare basis) was much lesser in mixed forests than in sal stands. Thus, sprouting even was clearly related to the level of disturbance (Figure 1a). Frequent disturbance is reported to cause significant changes in the plant population size by influencing the structure and regeneration of plants (Tripathi and Khan 1992; Sagar *et al*. 2008) [18, 19].

The genets of younger girth classes were readily available irrespective of the disturbance level but their survival was considerable only at low disturbance. Contribution of ~1-year sprouts to the total sprouts was higher in both conditions. The sprouts of ~1-year were exceptionally high at higher disturbance. This may be due to high sprouting efficiency of *Mallotus*. This results shows the similarly with that of Paciorek *et al*., (2000) [20] in which the importance of population to the community dynamics depended on the rate of physical damage and sprouting of damaged individuals. The much greater number of ~1-year sprouts at high disturbance shows recurrent sprouting. Putz and Brokaw (1989) [21] reported that tropical forest suffers frequently through disturbance after which many species can resprout which help to maintain the understorey of the forest. The distribution of individuals under different girth classes showed that younger girth class (<5cm) covered the largest number of individuals in both the stands. The survival of individuals was, however, much better at low disturbance. The number of individuals under different girth classes decreased quite sharply (Figure 1b). The mean number of sprouts per genet showed a clear trend with increase in girth of individuals. In general, the mean number of sprouts per genet was greater at high disturbance. This may be due to high sprouting efficiency of *Mallotus* at high disturbance. According to Bellingham and Sparrow (2000) [22] sprouting ability may very between species and, therefore, may be an important determinant and thus may play a key role in prevailing environmental conditions. This result supports Pandey and Shukla (2001) [23] where sprouting ability becomes important for those species whose individuals mostly spend their entire lives in the understorey. The contribution of ~1- year old sprouts to the total sprouts per hectare was exceptionally high at high disturbance in sal stands. The older sprouts (>4-year) became much rarer at high disturbance while they were still in considerable number at low disturbance (Figure 1c).

The mean number of sprouts per genet showed a clear trend of increase with increase in girth or individuals. Genets of older girth classes (>55cm), however, had lesser and lesser number of sprout both in sal as well as in mixed forests. In general, the number of sprouts per genet was much greater at high disturbance. A maximum number of sprouts per genet of girth class 41-55cm were noticed in spite of wide deviation from mean sprout number, especially at low disturbance (Figure 2). High disturbance induced ramet proliferation from genets of almost all the available girth classes and the number of ramets steadily increased as the genet aged. At low disturbance, however, the ramet proliferation was quite rate and limited to old genets only. The inter-ramet distance (IRD) showed a slow and gradual increase with increasing maturity status of genets, especially at high disturbance. The number of ramets and inter-ramet distances as related to the frequency of burning (stress), showed a trend opposite to that of the effect of disturbance i.e. number of ramets was much lesser at high burning showing little increase with genet maturity. Plots facing low burning, however, showed greater number of ramets arising especially from nature genets (< 55cm). the inter-ramet distance (IRD), on the other hand, was greater in plots facing high burning but the difference from low burning was not significant (Figure 3).

Expansion of clonal plants is influenced by the degree of integration among sister remets in a genet and the length of time they remain connected. At low disturbance, ramet proliferation was evident only in older girth classes. So disturbance acts as selection pressure for ramet production. In *Mallotus*, the number of ramets as related to frequency of burning (stress) shoed opposite trend to that of the effect of disturbance i.e. number of ramets was lesser at high burning. The deep-seated spacer in *Mallotus* could produce ramet even in the presence of recurrent burning. Pandey and Shukla (2019) [11] observed that reactivation of such meristematic tissues and suckers, even after high intensity fire, may give rise to new shoots. The number of ramets per individual of *Mallotus* was greater at low burning and at high disturbance. Thus at high disturbance, the species which depends exclusively on their seeds for regeneration and cannot propagate themselves vegetatively, may gradually become rate. High disturbance witnesses more ramet production in *Mallotus*. In such a situation *Mallotus* can thus, utilize the riches vacated by species being rarer. The inter-ramet distance (IRD) was lesser than genet to first ramet distance (GRD) in both male and female individuals of *Mallotus*. IRD as well as GRD decreased with increase in disturbance indicating a relationship with physical environment. According to Keser *et al*. (2014) [24], in woody perennials where there is no need of below ground storage, the rhizomes are replaced by foraging roots which explore the vacant sites. The subterranean architecture of genet complex of *Mallotus* showed continuity of the root suckers in the form of inter-ramet connections or spacer which make it physiologically integrated system. Physiological integration between ramets may decrease the risk of entire parent genome extinction, a factor sometimes considered as the most important ones favouring the vegetative propagation (Liu *et al*, 2016) [25]. In *Mallotus*, the spacer roots generally proliferated from one side of the root system. Branching order of ramet increased with increase in disturbance level in *Mallotus*. Genets facing disturbance of D_0 level, showed little ramet production. At D_3 level of disturbance, spacers, branched upto III order or more results into vast expansion of root-stock and production of a number of ramets. This shows that *Mallotus* occupied the area in an economical and effective manner in terms and of amount of root-stock material needed to reach the unoccupied sites. Clonal Integration is expected to allow the genet as a whole to do well even in the inhospitable condition (De Kroon and Hutchings, 1995)[26].

The number of ramets arising out from the genets of male, female and non-flowering individuals of different girth classes and sum of the basal area of ramets was compared. Individuals of different girth classes (~10 replicates) each facing increasingly high disturbance (D_0-D_3) were identified in several plots. At D_0 level of disturbance, ramet production was limited only to old girth classes (<55cm) in case of both the male and female trees. The sum of their basal area was also quite high. At D_1 level of disturbance (Fully reiterated individuals of sprout-origin), the ramet formation was evident in younger genets of >25cm girth in both male and female Individuals. The trends in the number of ramets per genet and the basal area showed no marked difference with increase in genet maturity. At D_2 level of disturbance, the individuals of *Mallotus* often showed multi-forked stump with identifiable leader axis while at D_3 level, individuals showed little stump and bushy structure, devoid of any clear leader axis. Thus at these two disturbance levels, only the non-flowering individuals could be encountered. At D_2 level, genets of all the girth classes showed ramet production which, of course, increased with genet maturity. At D_3 level, however, no genet having stumps of >55cm girth was noticed. The number of ramets slowly increased with increasing genet maturity. In general, the sum of basal area for all the ramets per genet complex increased with genet maturity. Inter-ramet distance was greater in plots facing high burning or low disturbance. IRD or spacer on subterranean horizontal root stock was greater at low disturbance or high burning. Thus *Mallotus* can propagate vegetatively through root-stock and may spread over much larger distance. Oborny (2012) [27] observed that clonal species regularly encounter the favourable and non-favourable patches maximizing the resource acquisition. Such a plastic response allows plant to forage for the best microsite available within the environment. At the lease disturbance (D_0) level ramet production in *Mallotus* was limited to older girth classes in both male and female trees while at D_1 level, ramet proliferation was evident even in younger girth classes (> 25 cm). At D_2 and D_3 levels, only the non-flowering individuals were encountered. Ramet production increased with increase in disturbance indicating increased foraging. The sum of basal area of ramets was markedly greater for female individuals i.e. female trees were comparatively more vigorous. The sum of basal area of ramets showed a gradual increase with genet maturity except at D_3 level at which it increased quite abruptly (Figure 4). In mixed forests, the general pattern of ramet production and sum of basal area was quite similar to that of sal forests but the number of ramets per genet complex was always quite lesser (Figure 5). In general, the distance from genet to first ramet (GRD) was always greater than the average inter-ramet distances (IRD). Further, GRD was not very different for genets of different maturity at D_0 and D_1 level disturbance, at which male and female individuals were compared. At D_3 level, however, a marked decrease in GRD and IRD was noticed. In mixed forests also, the pattern of change in GRD and IRD was similar to sal forests but the values in general were slightly greater for mixed forests (Table 1). After disturbance, individuals of greater diameter may often fail to sprout or may show lesser sprout production because of decrease in the number of dormant buds (Paciorek *et al* 2000) [20]. Thus, an increase in sprouting efficiency of *Mallotus* at higher disturbance explains the cause of is dominance in disturbed sal stands. Chronic disturbance may lead to dominance of species that can recover quickly from injury (Knight, 1975) [28]. Clonal plants affect ecosystem functions related to nutrient and water cycle and, therefore, new researches linking spatial and temporal patterns of clonal species in relation to soil properties must be taken up (Cornelissen *et al*. 2014) [29].

Thus even under the pressure of recurrent anthropogenic disturbance, *Mallotus philippensis* is able to show its constant presence in different forest communities of the region. In addition to recruitment by seed, it exhibits efficient vegetative propagation through sprouts and remets and provides minimum understorey cover which is essential for the ecosystem attributes of these forests. Its bushy sprouts and evergreen behaviour provides niches for rare herbs, climbers and wild fauna even in presence of recurrent disturbance. Locally, it provides cheap fuel-wood. Young shoots are used as tooth-sticks and branches as basket material. The fast resilience of species against disturbance is a boom to 'taungya' people and rural poor of catchment villages who use it. The species is capable of providing usable biomass without much danger of extermination.

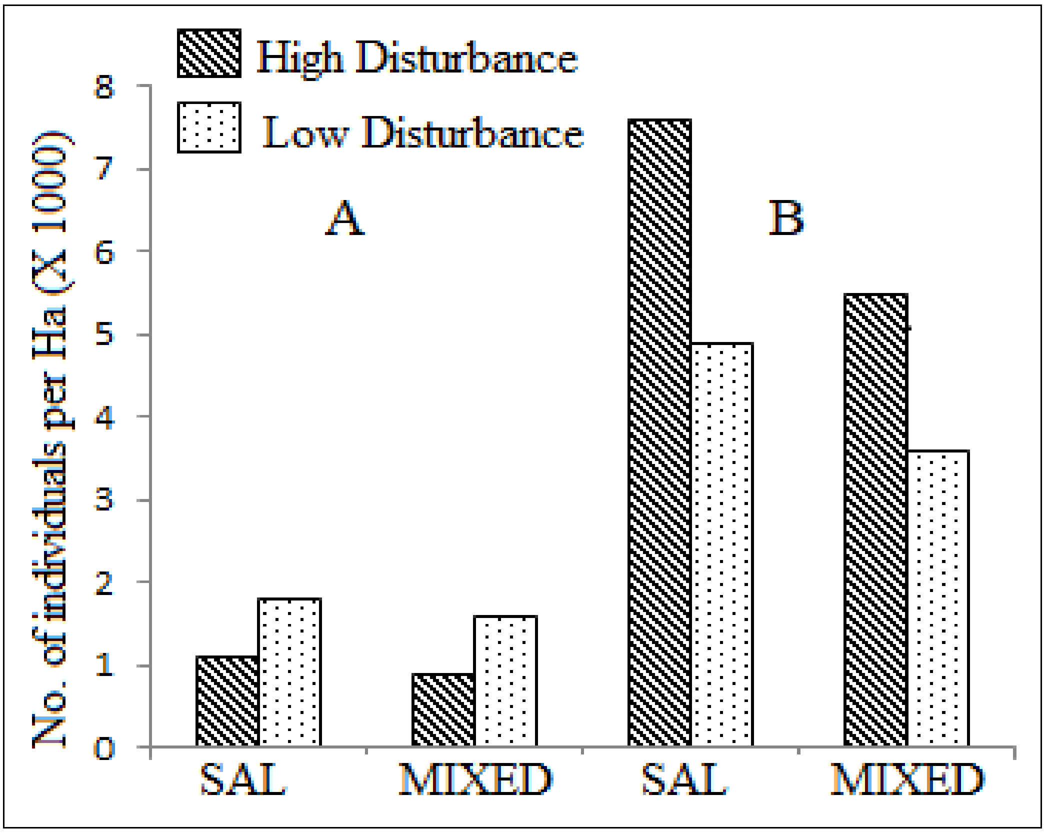

Fig 1a: No. of individuals (A) and of sprouts (B) on per hectare basis under high and low disturbance in sal and mixed forests.

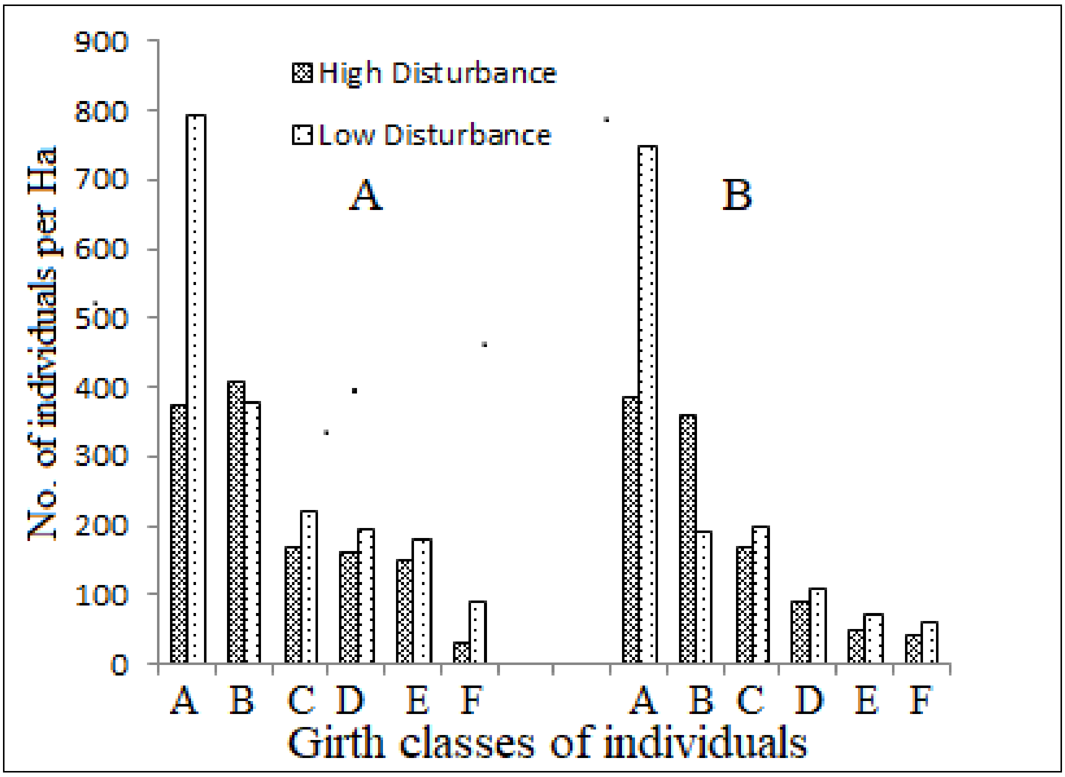

Fig 1b: Distribution of individuals under different girth classes (on per hectare basis) at two disturbance levels in (A) sal and (B) mixed forests. (Girth classes: A<10cm; B 11-25cm; C 26-40cm; D 41-55cm; E 56-70cm; F>70cm)

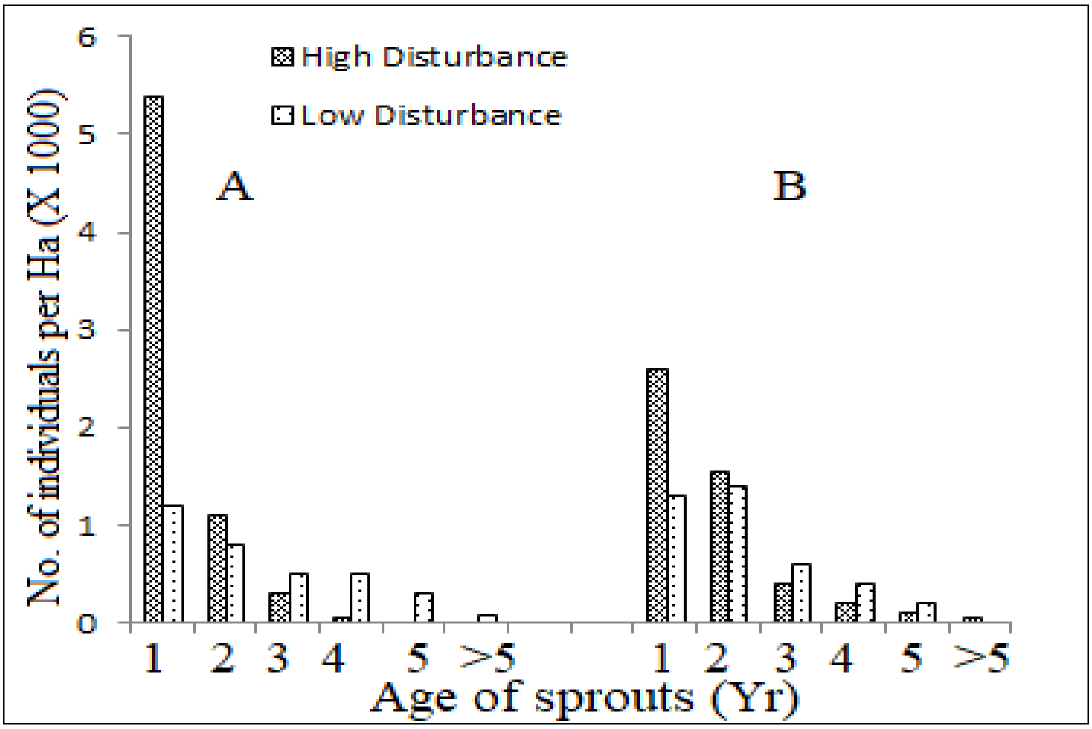

Fig 1c: Distribution of sprouts of differenct age (on per hectare basis) at two disturbance levels in sal (A) and mixed forests (B)

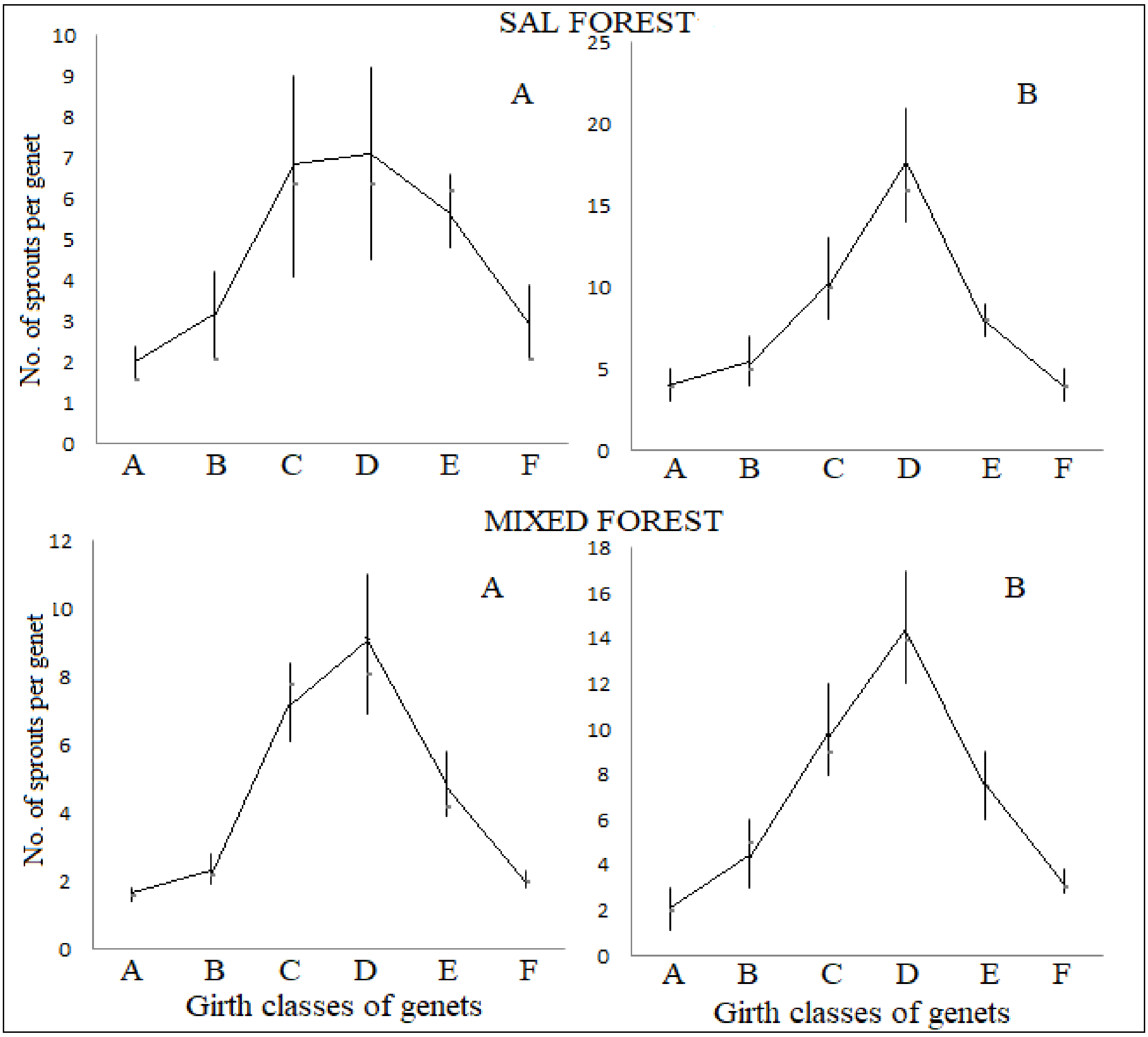

Fig 2: Mean number (±SD) of sprouts per genet of different girth classes at low (A) and high (B) disturbance level (Girth classes: A<10cm; B 11-25cm; C 06-40cm; D 41-55cm; E 56-70cm; F>70cm)

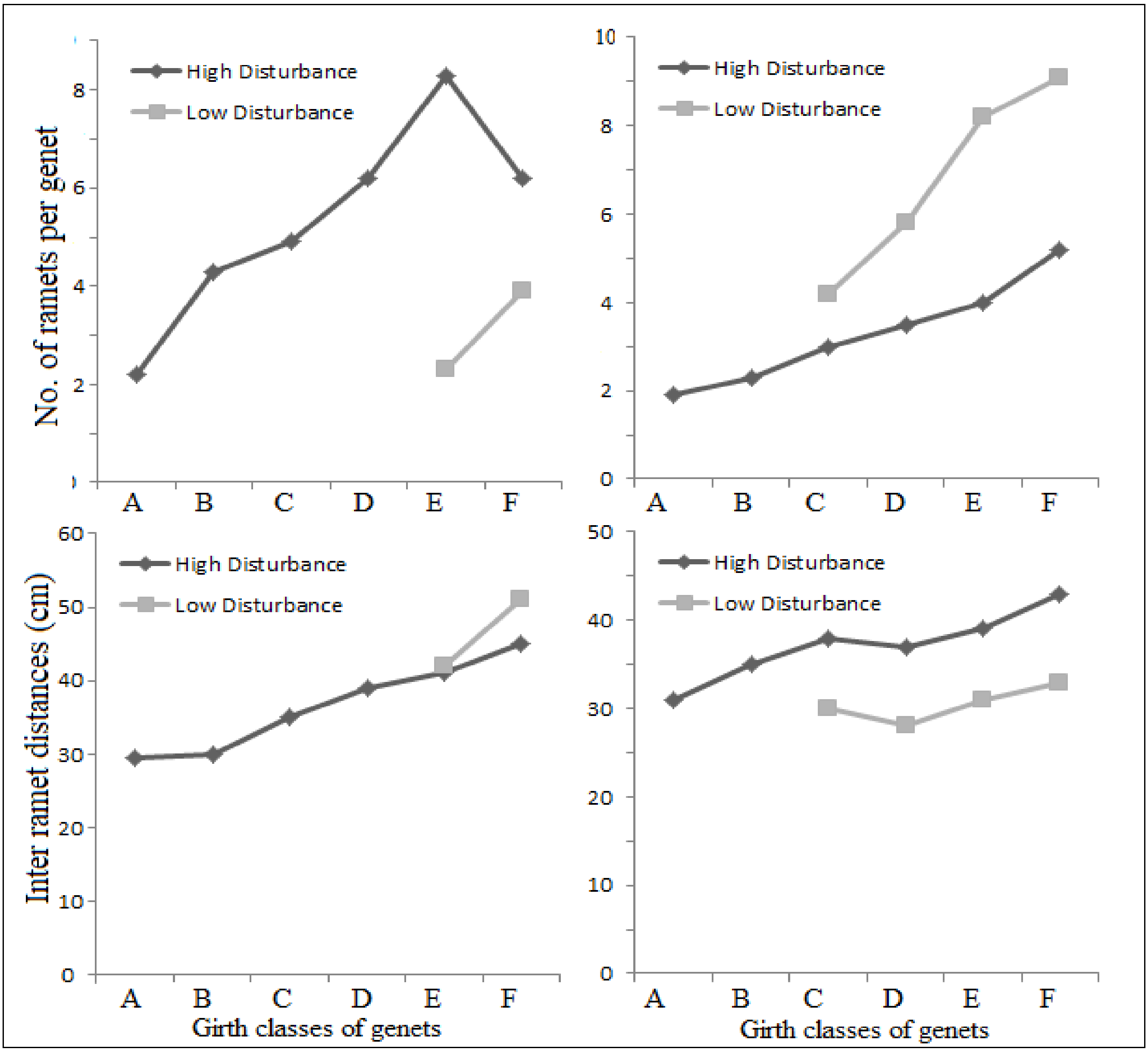

Fig 3: Ramets per genet and Inter- ramet disturbance (IRD) hi different girth classes of genets at high or low level of disturbance (A,B) and burning (C,D) in sal forests. (Girth classes: A <10cm; B 11-25cm; C 26-40cm; D 41-55cm; E 56-70cm; F >70cm) Disturbance: Disturbance Index (DI: High DI >60. Low DI < 30.

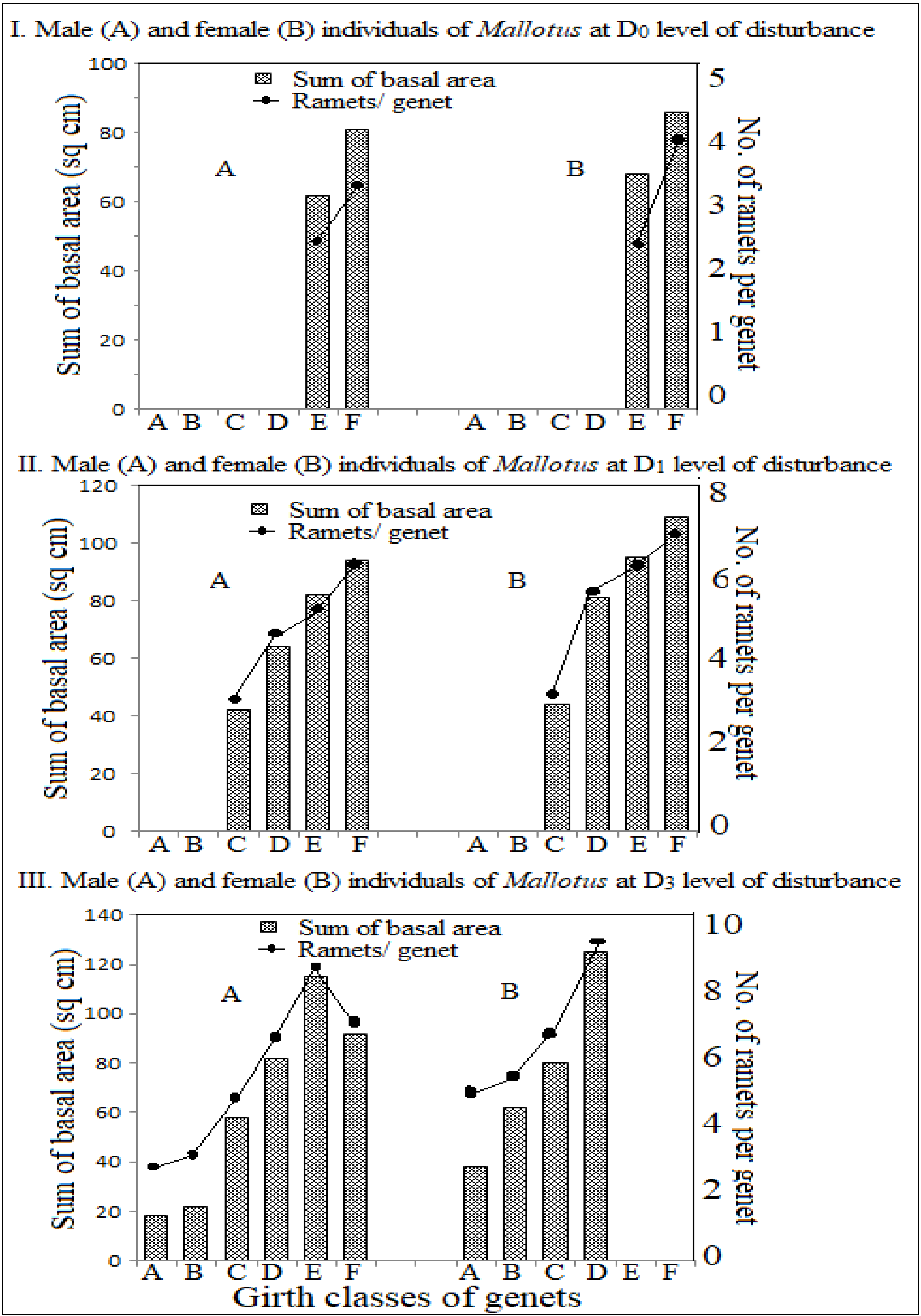

Fig 4: Number of ramets/ genet and sum of basal area of Mallotus under different girth classes.
(Girth classes: A <10cm; B 11-25cm; C 26-40cm; D 41-55cm; E 56-70cm; F >70cm)

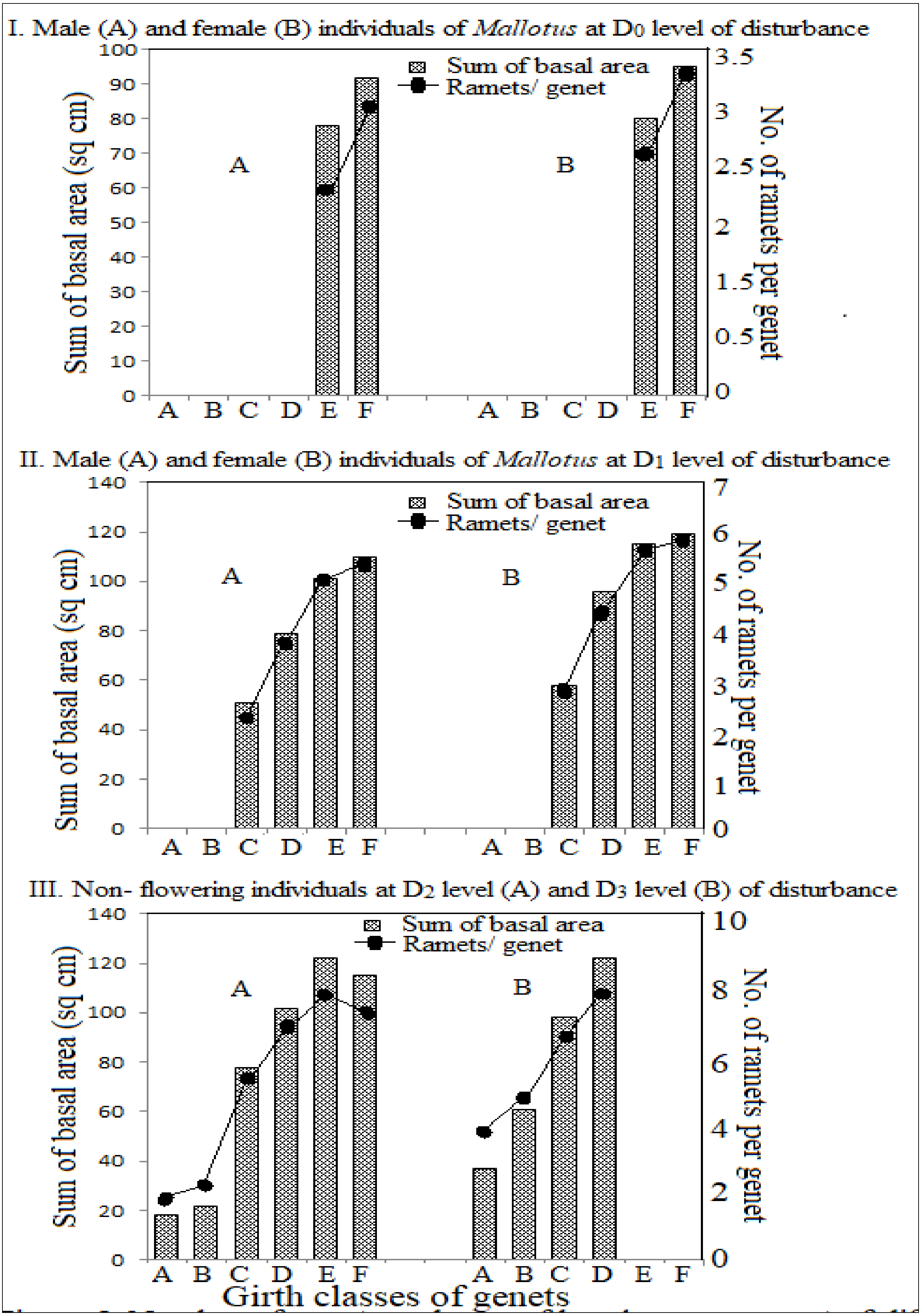

Fig 5: Number of ramets and sum of basal area per genet of different girth classes hi mixed forest.
(Girth classes: A <10cm; B 11-25cm; C 26-40cm; D 41-55cm; E 56-70cm; F >70cm)

Map 1: Study site shown within the Sohagibarwa wildlife Sanctuary in the Gorakhpur Forest Division, India

Table 1: Genet to 1st ramet distance (GRD), inter ramet distance (IRD) in sal forests and number of ramet/ genet, basal area/ genet in mixed forests for *Mallotus* under different level of disturbances.

		Sal forests		Mixed forests	
***Mallotus* at different disturbance level**	**Girth classes (cm)**	**GRD (in cm)**	**IRD (in cm)**	**No. of ramet/ genet**	**Basal area/ genet (sq cm)**
At D_0 level of disturbances					
Male	56- 70	34.4 ± 5.2	40.2 ± 4.5	51.6 ± 4.8	78.1 ± 6.6
	>70	43.5 ± 3.4	44.4 ± 5.2	78. ± 8.6	83.4 ± 9.1
Female	56- 70	33.1 ± 3.7	41.1 ± 3.2	71.5 ± 4.4	78.2 ± 6.6
	>70	39.7 ± 6.1	48.2 ± 4.4	85.1 ± 7.2	96.1 ± 10.5
At D_1 level of disturbances					
Male	26- 40	30.3 ± 3.8	34.5 ± 5.1	42.9 ± 5.1	43.2 ± 6.7
	41- 55	34.2 ± 5.3	36.1 ± 5.2	65.2 ± 6.9	76.5 ± 8.2
	56- 70	36.8 ± 6.1	37.6 ± 5.2	100 ± 14	101 ± 9
	>70	42.2 ± 3.3	41.8 ± 5.5	102 ± 10	107 ± 9
Female	26- 40	34.8 ± 5.2	36.1 ± 4.4	55.2 ± 5.3	59.2 ± 7.8
	41- 55	39.4 ± 4.6	37.5 ± 2.5	81.5 ± 8.6	74 ± 6
	56- 70	42.8 ± 5.5	39.2 ± 6.6	101 ± 16	106 ± 15
	>70	46.5 ± 6.9	47.2 ± 5.6	103 ± 21	114 ± 18
At D_2 level of disturbances					
Non- flowering individuals	<10	35.5 ± 7.5	40.9 ± 6.9	24.5 ± 3.5	19.9 ± 3.3
	11- 25	38.5 ± 6.3	43.5 ± 5.2	26.2 ± 3.6	23.2 ± 4.6
	26- 40	40.5 ± 5.5	42.3 ± 6.3	74.5 ± 8.5	79.8 ± 8.4
	41- 55	43.2 ± 6.2	46.8 ± 5.8	91 ± 11	98.2 ± 16.2
	56- 70	47.5 ± 5.5	52.8 ± 8.4	98 ± 13	121 ± 21
	>70	53.2 ± 5.6	56.2 ± 9.7	95.2 ± 11	111 ± 14
At D_3 level of disturbances					
Non- flowering individuals	<10	28.2 ± 4.2	32.3 ± 5.3	58 ± 8	39.5 ± 3.8
	11- 25	32.5 ± 5.2	34.2 ± 4.2	60 ± 5	58 ± 6
	26- 40	36.8 ± 4.4	37 ± 4	82 ± 6	88 ± 9
	41- 55	41.8 ± 6.8	46.8 ± 6.6	112 ± 21	132 ± 28

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References

1. Pandey SK, Shukla RP. Plant diversity in managed sal (Shorea robusta Gaertn.) forests of Gorakhpur, India: species composition, regeneration and conservation. Biol Conserv,2003:12:2295-2319.
2. Tripathi AK, UmaShankar. Pattern of species dominance, diversity and dispersion in “Khasi Hill Sal” forest ecosystem in northeast India. Forest Ecosystem,2014:1:23. DOI 10.1186/ s40663-014-0023-2.
3. Callaghan TV, Carlsson BA, Jonsdottir IS, Svensson BM, Jonasson S. Clonal plants and environmental change: introduction to the proceedings and summary. Oikos,1992:63:341-347.
4. Clarke PJ, Lawes MJ, Midgley JJ. Resprouting as a key functional trait in woody plants—challenges to developing new organizing principles. New Phytol,2010:188:651-654.
5. Pandey SK, Shukla RP. Plant population structure and species diversity status at two disturbance regimes within mixed forests and sal forests of Gorakhpur, India. Int J Ecol Environ Sci,2018:44:43-58.
6. Ye X-H, Yu F-H, Dong M. A trade-off between guerrilla and phalanx growth forms in Leymus secalinus under different nutrient supplies. Ann Bot,2006:98:187-191.
7. Shukla RP, Pandey SK. Vegetation and Plant Diversity. SSPH, New Delhi,2020:232.
8. Guerrero-Campo J, Palacio S, Rontome CP, Marti GM. Effect of root system morphology on root-sprouting and shoot-rooting abilities in 123 plant species from eroded lands in north-east Spain. Ann Bot,2006:98:439-447.
9. Charpentier A, Anand M, Bauch CT. Variable offspring size as an adaptation to environmental heterogeneity in a clonal plant species, integrating experimental and modelling approaches. J. Ecol,2012:100:184-195. 10.1111/j.1365-2745.2011.01899.x
10. Bond WJ, Midgley JJ. Ecology of sprouting in woody plants: the persistence niche. Trends Ecol Evol,2001:16:45-51.
11. Pandey SK, Shukla RP. Effect of disturbance on population structure, regeneration and conservation of Moghania chappar in sal forests of Gorakhpur, India. Trop Ecol,2019:60:337-349. https://doi.org/10.1007/s42965-019-00035-y
12. Pathak SD, Shukla RP. Population structure and sex-ratio of Mallotus philippensis Muel. Arg. within forest vegetation of north-eastern U.P., India. Tropical Ecology,2004:45(2):271-280.
13. Champion HG, Seth SK. General silviculture for India. Publication Branch, Department of Printing and Stationary Government of India, Delhi,1968.
14. Shukla RP, Ramakrishnan PS. Architecture and growth strategies of tropical trees in relation to successional status. J Ecol,1986:74:33-46.
15. Pandey SK, Shukla RP. Plant diversity and community patterns along the disturbance gradient in plantation forests of sal (Shorea robusta Gaertn). Current Science,1999:77:814-818.
16. Grime JP. Plant Strategies, Vegetation Process, and Ecosystem Properties. 2nd edition. Chichester, New York: John Wiley Second Edition,2002.
17. Harper JL. A Darwinian Approach to Plant Ecology. Journal of Ecology,1967:55:247-270.
18. Tripathi RS, Khan ML. “Regeneration pattern and population structure of trees in subtropical forest of North East India,” in Tropical Ecosystem-Ecology and Management, K. P. Singh and J. S. Singh, Eds.,1992:431-441, Wiley Eastern Limited, New Delhi, India.
19. Sagar R, Raghubanshi R, Singh RS. Comparison of community composition and Species diversity of understorey and overstorey tree species in a dry tropical forest of northern India. J Environ Manag,2008:88:1037-1046.
20. Paciorek CJ, Condit R, Hubbel SP, Foster RB. The demographics of resprouting in tree and shrub species of a moist tropical forest. J Ecol,2000:88:765-777.
21. Putz FE, Brokaw NVL. Sprouting of broken trees on Barro Colorado Island, Panama. Ecology,1989:70:508-512.
22. Bellingham PJ, Sparrow AD. Resprouting as a life history strategy in woody plant communities. Oikos,2000:89:409-416.
23. Pandey SK, Shukla RP. Regeneration strategy and plant diversity status in degraded sal forests. Current Science,2001:81:95102.
24. Keser LH, Dawson W, Song YB, Yu FH, Fischer M, Dong M *et al.* Invasive clonal plant species have a greater root-foraging plasticity than non-invasive ones. Oecologia,2014:174:1055-1064.
25. Liu F Liu J, Dong M. Ecological Consequences of Clonal Integration in Plants. Front. Plant Sci,2016:7:770. Doi: 10.3389/fpls.2016.00770
26. De Kroon H, Hutchings MJ. Morphological plasticity in clonal plants: the foraging concept reconsidered. Journal of Ecology,1995:83:143-152.
27. Obornya BC, Mony B, Herben T. From virtual plants to real communities: A review of modelling clonal growth. Ecological Modeling,2012:234:3-19.
28. Knight DH. A phytosociological analysis of species rich tropical forest on Barro Colorado Island, Panama. Ecological Monograph,1975:45:259-289.
29. Cornelissen JHC, Song YB, Yu FH, Dong M. Plant traits and ecosystem effects of clonality: a new research agenda. Ann Bot,2014:114:369-376.