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Population structure and sex-ratio of *Mallotus philippensis* Muel. Arg. within forest vegetation of north-eastern U.P., India

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Abstract: *Mallotus philippensis,* a dioecious evergreen sub-dominant tree, grows as close associate of sal within mixed natural forests as well as managed plantation forests of north-eastern U.P. A comparison of its male and female populations at two contrasting light regimes depicts that sex-ratio of *Mallotus philippensis* was always male-biased under low light and female-biased under high light regime irrespective of the kind of overstorey dominance. The structure of *Mallotus* population was of stable type under low light regime with greater proportion of trees in communities facing low disturbance. The distribution of sexually mature individuals was apparently random but close observation suggested several male and female guilds. The distance between any two adjacent female guilds was, however, greater than that between any two male guilds. The guilds of opposite sex were, however, farther than the guilds of same sex. Under low light regime, the size of male guilds in terms of the number of trees, was greater than the size of female guild as compared to that under fully exposed condition. The inter-guild distance for any two adjacent female guilds was greater than the same for any two male guilds. The result has been discussed in the light of ecological significance of sex-ratio and the association of species within forest vegetation of the region.

Resumen: *Mallotus philippensis,* un árbol sub-dominante perennifolio dioico, crece como un asociado cercano de sal en el interior de bosques nativos mixtos, así como en plantaciones forestales manejadas del noreste de U.P. Una comparación de sus poblaciones femenina y masculina en dos regímenes lumínicos contrastantes muestra que la proporción sexual de *Mallotus philippensis* siempre tuvo sesgos hacia los machos en condiciones de poca luz y hacia las hembras bajo condiciones luminosas, independientemente del tipo de dominancia en el dosel. La estructura poblacional de *Mallotus* fue de tipo estable bajo un régimen de poca luz, con una mayor proporción de árboles en las comunidades poco perturbadas. Aparentemente la distribución de individuos maduros sexualmente era aleatoria, pero una observación más cuidadosa sugirió que existían varios gremios masculinos y femeninos. Sin embargo, la distancia entre cualesquier dos gremios femeninos fue mayor que entre cualesquier dos gremios masculinos. Los gremios de sexo opuesto estuvieron, sin embargo, más alejados que los gremios del mismo sexo. Bajo un régimen lumínico de poca luz, el tamaño de los gremios masculinos en términos del número de árboles fue mayor que el tamaño del gremio femenino en comparación con el que estaba bajo una condición completamente expuesta. La distancia inter-gremio para cualquier par de gremios femeninos adyacentes fue mayor que la misma para cualquier par de gremios masculinos. El resultado se discute a la luz del significado ecológico de la proporción sexual y la asociación de especies en la vegetación forestal de la región.

Resumo: A *Mallotus philippensis*, uma árvore dióica sempreverde sub-dominante, cresce como associada próxima da meranti dentro das florestas naturais mistas e nas plantações ordenadas do nordeste U.P. Uma comparação das suas populações masculinas e femininas em dois regimes de insolação contrastantes mostrou que o ratio/sexo da *Mallotus philippensis* era sempre dominado por exemplares macho sob baixa insolação e feminina sob um regime de alta insolação independentemente do tipo de

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dominância do coberto superior. A estrutura da população de *Mallotus* era do tipo estável sob regime de baixa insolação com uma maior proporção de árvores nas comunidades que enfrentam baixo nível de distúrbios. A distribuição de exemplares sexualmente adultos era aparentemente casual mas uma observação mais cuidada sugere várias associações macho e fêmea. A distância entre qualquer associação fêmea adjacente era, contudo, maior do que entre qualquer associação macho. As associações de sexo oposto eram, contudo, mais distantes do que as associações do mesmo sexo. Sob regimes de baixa insolação, a dimensão das associações macho em termos do número de árvores era maior do que a dimensão das associações fêmea quando confrontada com aquelas sob condições de exposição plena. A distância inter associações para qualquer associação fêmea adjacente era maior do que a mesma para qualquer das duas associações macho. O resultado foi discutido na óptica da significância ecológica do ratio de sexos e da associação de espécies na vegetação florestal da região.

Key words: Forest vegetation, *Mallotus philippensis,* population structure, sex-ratio, spatial organisation.

Introduction

Dioecy is a common phenomenon of tropical forests and several species are represented by separate male and female individuals. Fisher (1930) pointed out that in the absence of modifying environmental factors, the ratio of male to female individuals should be 1:1 under the influence of natural selection, if there is an equal costs to parent of male and female offsprings (Allen & Antos 1993). In a few dioecious tropical trees, sex-ratio has been reported to be generally 1:1 and the male and female trees are distributed randomly (Bawa & Opler 1977). Dioecy may be favoured in spatially heterogeneous environment in order to have higher fitness to some microhabitat which may differ with respect to male and female function (Freeman *et al.* 1980). Generally the male and female plants tend to occur in distinct microhabitats which differ in the availability of resources and thus sex-ratio can often be altered by such agencies as light regime, soil moisture and nutrients (Bierzychudek & Eckhart 1988; Iglesias & Bell 1989). Biased population sex-ratio may be in part a consequence of differential costs associated with reproducing as male or as female (Sakai & Weller 1991). While Melampy & Howe (1977) demonstrated a female-biased sex-ratio of flowering individuals of *Triplaris Americana,* Armstrong & Irvine (1989) reported a male biased sex-ratio in *Myristica insipida.* Grant & Mitton (1979), however, found an elevational gradient in sex-ratio of *Populus tremuloides.*

Mallotus philippensis Muel. Arg., a dioecous evergreen tree species, is a common understorey component of the sal forests of north-eastern U.P. and grows widely under different set of conditions as determined by degree of disturbance, light intensity regime, overstorey dominance and stand maturity. It is so ubiquitous and so indispensable of the understorey for providing niches for several shade-tolerant species that it may be considered as one of the key-stone species (Paine 1966) of the forests of the region. Though some information are available on its community attributes (Gupta & Shukla 1991; Tiwari & Shukla 1995), the pattern of changes in sex-ratio and spatial distribution of male and female trees is little understood (Shukla & Pandey 1991). The present study, therefore, focuses on the population structure, spatial distribution of tress of both sexes and sex-ratio under different disturbance regimes and light environments.

Methods

The study was carried out within Chowk and Lachhmipur forests of Gorakhpur Forest Division (between 27°05′ and 27°25′ latitude, 83°20′ and 84°10′ longitude and at 95 m altitude). Sal stands covered most of the area of plantation forests. Stand age, disturbance level and the degree of exposure at understorey level were taken as variables. The observations on sex-ratio and population structure of *Mallotus* were made in mixed natural growth forests and in plantation forests of

sal (*Shorea robusta* Gaertn.) and of teak (*Tectona grandis* Linn. f.). Young (~30-yr) and old (~100-yr) stands of mixed forest were identified under three disturbance regimes and with exposed or shaded understorey for observations on sex-ratio and population structure. Sal stands were identified in an age series of 20-yr, 40-yr, 70-yr and 100-yr facing low, moderate or high disturbance. 100-yr sal stands with their understorey exposed to two different light regimes, were exclusively observed for the spatial distribution and guild characteristics of male and female sub-populations. The old teak plantation forests (~70-yr), facing low, moderate or high disturbance were marked for the comparison of population structure of *Mallotus*. The measure of disturbance level was based on the value of disturbance index (D.I.). The stands showing DI range of 5-30 were considered as less disturbed, of 31-60 as moderately disturbed and of >60 as highly disturbed (Pandey & Shukla 1999).

In order to study the population structure of *Mallotus*, the four growth stages-seedling, sapling, pole-tree and mature-tree, were recognized on basis of their growth features (Shukla & Ramakrishnan 1986). The zero year's (<1-year) individuals were treated as seedlings. The well-established individuals having 3-12 cm basal girth and showing little branching and trunk-crown differentiation, were treated as saplings. They were of ≤3 year old and generally had no clear and straight trunk. The juvenile trees of >3 years and 12-25 cm gbh (girth at breast height i.e. 1.37 meter from base) having clear trunk but small crown, were considered as pole trees. The sapling and pole-trees of sprout-origin were also considered. Individuals of >25 cm gbh with clear trunk having large and complex crown were considered as mature individuals. Flowering generally started at the age of about 5 years. As per the flowering event, the mature individuals were categorized into male, female and non-flowering ones. Since *Mallotus* is a dioecious tree and its sex could not be exactly determined under vegetative condition, the individuals which were not in flowering stage were categorised as non-flowering ones. The *Mallotus* population was sampled within one-hectare plots to study the effect of different level of disturbance and the type of overstorey dominance. All individuals of *Mallotus*, encountered within the sample plots, were recorded and segregated into seedlings, saplings, pole-trees and mature trees.

Exposed forests had lesser density of sal trees with a number of small gaps within the canopy which allowed greater light penetration and higher exposure of the forest floor. These communities were more disturbed. Under shaded environment, however, communities were quite dense in terms of sal trees which formed compact canopy and hardly allowed any direct light penetration onto the plane of forest floor. The light intensity at the forest floor was measured with portable lux-meter (Kyoritsu 5200) at ten random but nearly equidistant points in the months of November in case of each community. The light intensity at the forest-floor of the shaded communities generally ranged from 500 to 800 lux. The forest-floor of the sparse communities were quite exposed and generally experienced >2400 lux light at mid-day hours. The individuals of *Mallotus* occurring within one-hectare (100 m x 100 m) plots were identified and segregated into male, female and non-flowering ones in young and old mixed and sal forest communities.

The spatial structure of *Mallotus* in sal forests was determined by mapping the position of each tree true to the scale within a plot of 50 m x 50 m (a quarter of hectare) in the two old stands, one having the shaded and the other exposed understorey. The female-flowering commenced during November-December when male trees were already in full bloom. The inter-tree distances between the two closest neighbours of same sex and of opposite sex, were measured to the nearest cm. The size and strength of sub-populations or guilds of either sex were also noticed and demarcated in each of the two communities. The canopy cover of each trees of *Mallotus*, as reflected on the ground, was measured as average ground cover.

Results

Population structure of Mallotus

In major forest communities

The structure of *Mallotus philippensis* population in forest communities under different overstorey dominance clearly indicates a sharp divide with respect to the degree of disturbance. In general, the age pyramids of *Mallotus* in major forest stands (except teak stands) showed considerable proportion of seedlings at low disturbance. Highly disturbed stands had exorbitantly high proportion of sprouts (Fig. 1).

The least disturbed communities in mixed natural-growth forests had maximum proportion of *Mallotus* seedlings and there was a gradual decrease in per cent number of individuals of different age-states i.e. from seedling to tree stage. At moderate disturbance, the proportion of intact saplings was much greater while at high disturbance, the per cent intact saplings and pole-trees were much less. The proportion of seedlings decreased with increase in disturbance within mixed natural growth forests. Pole trees and mature trees also followed the same pattern but the per cent saplings were greater in stands experiencing moderate to high disturbance (Fig. 1).

Mallotus population in sal communities followed the same pattern as it did in mixed forests. In less disturbed sal forests, the per cent seedlings were relatively less than that of saplings. The proportion of seedlings and of intact saplings decreased with increase in disturbance. The proportion of trees and pole trees was comparatively similar at moderate and low disturbance within sal stand but their proportion, however, was greater at low disturbance. Per cent number of saplings of sprout-origin was greater at moderate as well as high disturbance but the proportion of intact saplings was greater only at moderate disturbance.

Teak communities showed highly unstable structure of *Mallotus* population. Seedlings were very rare in any of the teak stands. Only the least disturbed community had a few intact saplings. Teak communities facing moderate or high disturbance showed very poor understorey and rarely had any *Mallotus* sapling or tree (Fig. 1).

Along an age series of sal forests

Comparison of population structure of *Mallotus* was made for sal communities at different disturbance level along an age series of sal stands (~20-year, 40-year, 70-year and 100-year). The 20-year sal stand which faced low disturbance, showed relatively stable population of *Mallotus*. Seedlings were relatively less at high disturbance. Trees of *Mallotus* were much less in highly disturbed stands. The 40-year and 70-year sal stands also followed the same pattern. In the least disturbed 100-year sal stand, the *Mallotus* population was quite stable. The proportion of seedlings was maximum and that of trees was minimum in the old sal community. Although proportion of saplings were greater at both the disturbance levels, the proportion of intact saplings was greater only at moderate disturbance. At high disturbance, however, the proportion of trees was much lesser in

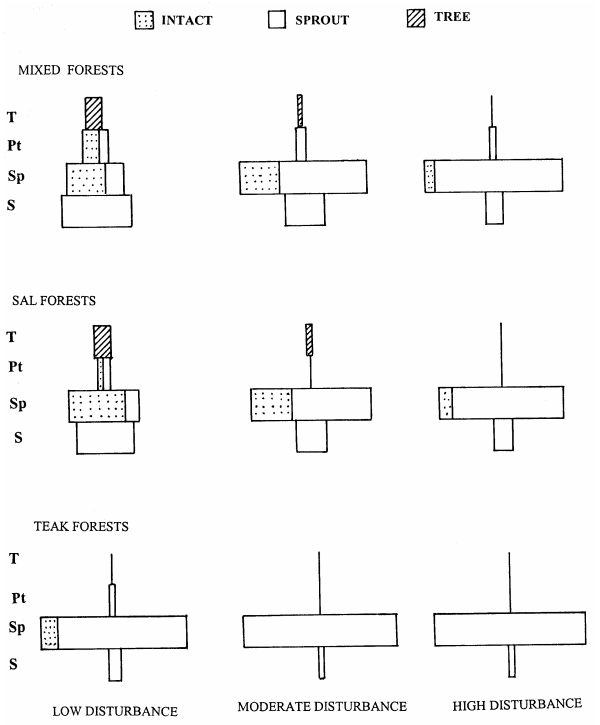

Fig. 1. Population structure of *Mallotus philippensis* at three disturbance levels in major forest communities. (T-tree, Pt – Pole-tree, Sp-Sapling, S-Seedling).

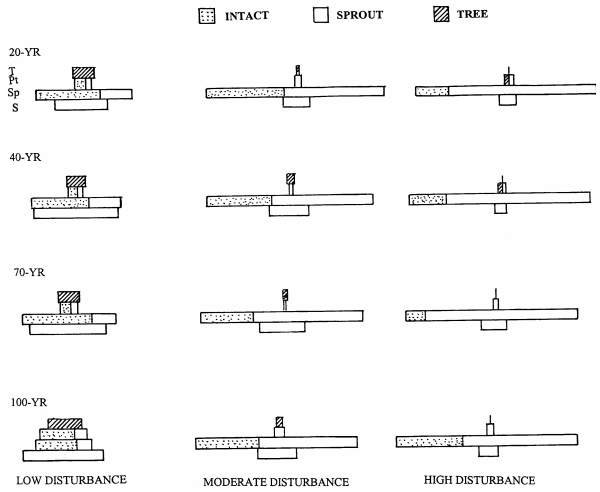

Fig. 2. Population structure of *Mallotus philippensis* at three disturbance levels in sal forests along an age series. (T-tree, Pt – Pole-tree, Sp-Sapling, S-Seedling).

stands of all age. Only 100-year sal stand had significant number of intact saplings (Fig. 2).

Proportion of juveniles, male, female and non-flowering individuals

The structure of *Mallotus* population with respect to flowering and non-flowering individuals was more conspicuously affected by light regime. Generally, the size of juvenile fraction was much greater than that of mature fraction. Juveniles constituted more than 80% of the *Mallotus* population in all sal stands along an age series. The highly disturbed old sal forests showed maximum percentage of juveniles as compared to any other stand. The sum of male and female individuals undergoing flowering, was always greater in old sal communities facing lesser disturbance as compared to highly disturbed stand. Mature fraction of *Mallotus* population was generally male-biased under low light regime but it was female-biased under high light regime irrespective of the maturity status of stands (Fig. 3A).

The percent number of juveniles, male, female and non-flowering individuals were compared among old and young mixed forests and sal stands facing high or low level of disturbance as well as having exposed or shaded understorey light environment. The percent number of juveniles was greater in all stands of mixed forests and managed plantation forests. The percent contribution of male individuals to *Mallotus* population was maximum in old mixed forest community. Under exposed condition, the *Mallotus* population of young mixed forests and sal stands showed a clear female-bias. The mature tree fraction of population was always male-biased in shaded environment but was female-biased in exposed understorey environment (Fig. 3B).

Sex-ratio

Sex-ratio (the number of male trees/the number of female trees) of *Mallotus* increased with the maturity status of sal communities. This increase was much faster for stands having shaded understorey environment than for stands with exposed understorey at high disturbance level. The sex-ratio was highly female-biased in young stands under exposed understorey environment and highly male-biased under shaded environment. The least disturbed old sal stands (~100-year) also showed highly male-biased sex-ratio (Table 1).

When compared with mixed forests, the sex-ratio of young and old sal stands showed similar pattern with respect to stand age, degree of disturbance and light condition at understorey level. Sex-ratio was, however, always male-biased under shaded environment irrespective of the kind of overstorey dominance (Table 2).

Spatial pattern

As evident from the position of *Mallotus* trees at sample plots, the distribution of sexually ma-

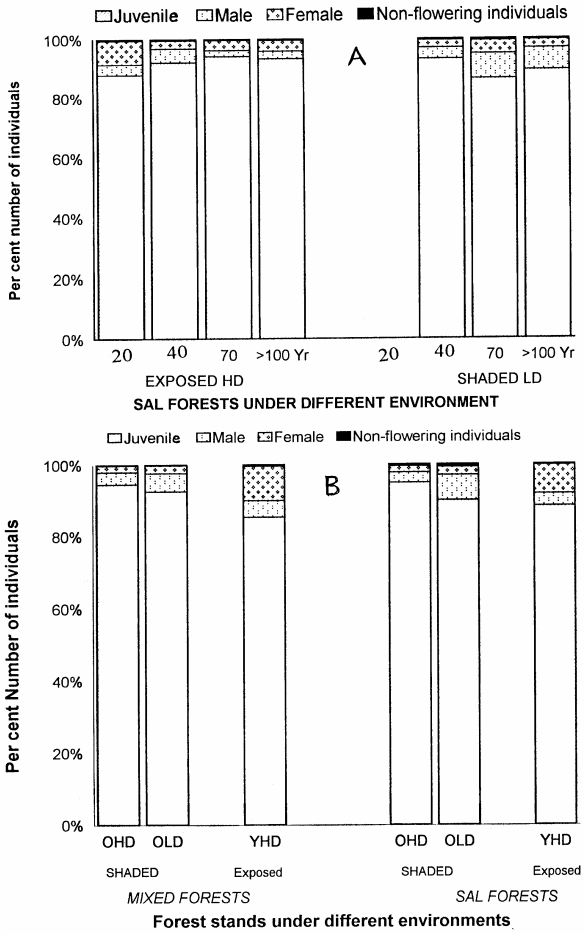

Fig. 3. **(A)** Proportion of juveniles, male, female and non-flowering mature individuals of *Mallotus philippensis* in an age series of sal stands with their understoreys exposed or shaded and facing low disturbance (LD) or high disturbance (HD). **(B)** Proportion of juveniles, male, female and non-flowering mature individuals of *Mallotus philippensis* in young (Y) and old (O) stands of mixed forest and sal forest facing low/high disturbance (LD/HD) under two different light regimes (shaded and exposed).

Table 1. Sex-ratio (No. of male/female individuals) of *Mallotus philippensis* under two different light environments (exposed vs. shaded understorey) along an age series of sal stands facing high vs. low disturbance. Young sal stands always faced high disturbance.

Age of sal stands (Yr)	High disturbance (Exposed understorey) (>2400 lux)	Low disturbance (Shaded understorey) (<800 lux)
~20	0.44	--
~40	0.61	1.22
~70	0.60	1.79
~100	0.71	2.90

Table 2. Sex-ratio (No. of male/female individuals) of *Mallotus* under two different light environments (exposed vs. shaded understorey) within young vs. old sal stands and mixed forest facing high vs. low disturbance. Young stands always faced high disturbance.

Forest stands	High disturbance (D.I. >60)	Low disturbance (D.I. <30)
Mixed forests:		
Young (exposed)	0.48	--
Old (shaded)	1.82	2.4
Sal forests:		
Young (exposed)	0.44	--
Old (shaded)	2.26	2.9

ture trees was quite random. Several guilds or sub-populations of male and female trees were recognized in stands having shaded as well as exposed understorey conditions (Figs. 4 & 5). The distance between any two adjacent female guilds was far greater than that between any two male guilds. Further, the distance between any two guilds of opposite sex was generally greater than that for similar sex. The inter-guild distances for opposite sex was, however, much less for stands with shaded understorey. The difference in relation to shaded and exposed conditions was significant at 5% probability level (Table 3).

The area-cover of male and female guilds was much greater in stands having exposed understorey. The area covered by male guild was, however, significantly lesser ($p<1\%$) than female guilds under both the understorey conditions (Table 4). The size of male guilds in terms of number of trees was

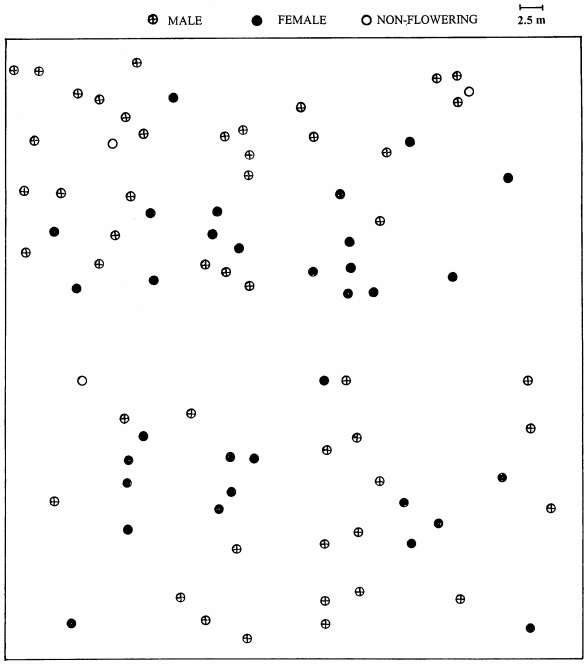

Fig. 4. Spatial distribution of male and female tree of *Mallotus philippensis* under shaded condition in a sample plot of 50 m x 50 m size.

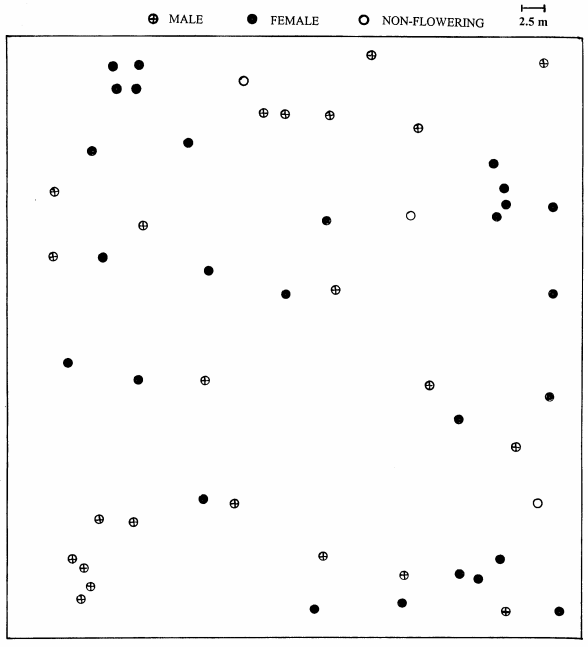

Fig. 5. Spatial distribution of male and female tree of *Mallotus philippensis* under exposed condition in a sample plot of 50 m x 50 m size.

Table 3. Distance (m) between the two nearest sub-populations of *Mallotus* of same sex and between those of opposite sex under two different light regimes in old sal forests.

Sub-populations of *Mallotus*	Shaded (<800 lux)	Exposed (>2400 lux)	Student's t-value
Male-Male	12.0 ± 2.0	16.0 ± 3.8	2.38*
Female-female	21.0 ± 4.9	32.5 ± 6.4	2.35*
Male-Female	16.3 ± 10.5	36.0 ± 4.0	2.94*

*Significant at 5% probability level.

Table 4. Mean area cover (m^2) of male and female sub-populations of *Mallotus* under two different light regimes within old sal forests.

Mallotus Sub-populations	Shaded (<800 lux)	Exposed (>2400 lux)	Student's t-value
Male	29.4 ± 4.3	50.6 ± 5.1	10.05*
Female	44.8 ± 9.2	67.2 ± 6.3	3.45*
t-value	4.78*	6.45*	

*Significant at 1% probability level.

Table 5. Number of mature tree individuals per sub-populations of male or female trees under two different light regimes within old sal forests.

	Shaded (<800 lux)	Exposed (>2400 lux)	Student's t-value
Male tree	4.3 ± 0.4	3.0 ± 0.7	5.0*
Female tree	3.5 ± 0.5	3.7 ± 0.5	0.78*
t-value	3.82*	2.51*	

*Significant at 5% probability level.

greater than that for female guilds under shaded understorey environment as compared to exposed condition (Table 5).

The inter-guild distance for any two adjacent female trees was lesser than that for male trees. These distances, however, were greater in exposed environment for both the sexes (Table 6). The inter-tree distance was also considered on whole stand basis. Interestingly, the mean distance between individuals of male trees was slightly lesser than that for female trees. At community level, the mean distance between the individuals of opposite sex was greater than that for the same sex. The inter-tree distances were generally greater ($p<5\%$) under exposed understorey environment (Table 7).

Discussion

The age structure based on the composition of population suggests the degree of stability of species in different communities. In general, *Mallotus* showed stable population in less disturbed stands. The structure of *Mallotus* population in forest communities under different dominance clearly indicates a sharp divide with respect to the degree of disturbance. The age pyramid of *Mallotus* in all the major forests (except teak stands) showed considerable proportion of seedlings at low disturbance. The less disturbed stands had greater proportion of *Mallotus* seedling. There was a gradual decrease in per cent number of individuals at different stages indicating that the species population was stable. At high disturbance, the count of individuals at seedling stage was comparatively lesser than at other maturity stages. The meagre number of seedlings may be attributed to disturbance in the form of fire in dry season (Puyravaud *et al.* 1995) and cattle-trampling during rainy season. The low seedling count at high and moderate disturbance may be attributed to predation by insects (Janzen 1970). It was observed that the breeding and outbreak of black-spotted red bugs coincided with peak seeding and dispersal of *Mallotus* seeds.

Table 6. Mean distance (m) between the nearest individual trees of same sex within sub-populations of *Mallotus* under two different light regimes.

	Shaded (<800 lux)	Exposed (>2400 lux)	t-value
Male-Male	4.1 ± 0.8	4.2 ± 0.9	0.16
Female-Female	3.9 ± 0.8	3.6 ± 0.5	0.9
t-value	0.54	1.68	

Table 7. Mean distance (m) of a *Mallotus* tree of a sub-population from the nearest individual trees of same sex or opposite sex situated outside the sub-population within old sal forests under two different light regimes.

	Shaded (<800 lux)	Exposed (>2400 lux)	t-value
Male-Male	5.1 ± 0.9	6.4 ± 1.9	2.11*
Female-Female	5.2 ± 0.6	8.5 ± 1.2	7.09*
Male-Female	6.1 ± 1.0	8.2 ± 2.3	2.51*

*Significant at 5% probability level.

These bugs heavily infested the fruiting trees and could be seen from base to the top of fruiting twigs. The proportion of intact saplings and pole-trees was greater in stands facing low disturbance as compared to highly disturbed sal stands and mixed forests. Such observations have also been made in other forests (Knight 1975). Since the establishment of seedlings is most strongly dependent on the occurrence of safe-sites and regeneration niches, the proportion of seedlings decreased with increase in disturbance. The proportion of saplings of sprout-origin was greater at moderate and high disturbance. It is well established that the occurrence of species in an area depends on the ability of its propagules to tolerate the vagaries of environment (Harper 1967). Much greater proportion of individuals of sprout-origin has also been observed in several species of tropical forests (Brokaw 1985; Khan *et al.* 1987).

Teak communities showed highly unstable population structure of *Mallotus*. Only the least disturbed teak stands had a few intact saplings. It signifies the importance of overstorey on availability of suitable sites (Clark 1991). It has been inferred that a much greater proportion of saplings at moderate disturbance may be due to canopy gaps created by disturbance (Chandrashekara & Ramakrishnan 1994). *Mallotus* population is thus able to maintain its existence also by vegetative propagation i.e. through sprouting and ramet production in disturbed environment in addition to meagre seedling establishment. The relatively stable population of *Mallotus* in disturbed sal forests of the region is achieved primarily because its recruitment is not seed-limited as also observed by Crawley (1990). The wide occurrence of *Mallotus* in regional forests suggests that it is a hardy species, well adapted to maintain itself in the presence of recurrent disturbance primarily through non-seed regeneration methods (Pandey & Shukla 2001).

The mature fraction of *Mallotus* population was always greater under low light. The tree population of *Mallotus* was always male-biased under low light regime and female-biased under high light regime. This observation, however, differs from that of Mukerji (1936) who observed that light intensity determined the frequency and distribution of sexes in *Mercurialis perennis* but female individuals were greater at low light intensity and the males were common in high light environment. The skewed sex-ratios have been reported for natural population of different plants (Lloyd & Webb 1977;Armstrong & Irvine 1989). In spatially heterogeneous environment such fitness may favour dioecy with sex-choice where the determination of plant sex depends on the environment (Freeman *et al.* 1976). Niche differences between the sexes may be due in part to energy requirements for male and female plants. It has been observed that plants of several species grown in bright sunlight, turns out to be female (Freeman *et al.* 1976; Charnov & Bull 1977). It results in male-biased ratio under low light regime and female-biased ones under high light regime. This biased sex-ratio may be, in part a consequence of differential costs associated with reproducing as male or female. Males avoid the physiological demands on females necessitated by seed production. Under stressful environments, therefore, males have higher fitness than females (Freeman *et al.* 1980). The occurrence of male-biased populations under shaded condition and female-biased ones under exposed condition, is consistent with resource allocation theories that predict a shift from male to female function under better condition when reproductive success is resource-limited (Goldman & Willson 1986).

Though the spatial distribution of sexually mature trees was quite random, some sort of non-randomness was also evident from the study of spatial structure of sub-populations and each sub-population could be easily demarcated. There are several reports of randomness of sexually mature trees (Bawa & Opler 1977) but Wheelwright & Bruneau (1992) found a clear non-random spatial distribution of male and female trees of *Ocotea tenera* in tropical forest in which male and female trees were discernible in separate clusters. They concluded that non-random spatial distribution in older trees in the natural population may be caused by labile sexual expression modified in the presence of neighbour trees. The distances between two sub-populations were less for same sex than that for opposite sex. Armstrong & Irvine (1989), however, found no inter-sexual differences in spacing of *Myristica insipida*. The area cover of male and female sub-populations was much greater in stands having better exposed understorey. Further, the area covered by female sub-population was significantly greater than that by male sub-population of *Mallotus*. Under shaded

environment, the size of male sub-population was greater than that of female sub-population in terms of number of individuals. This observation suggests that maleness is faovured under shaded condition (Freeman *et al.* 1976). At community level, the mean distance among the individuals of opposite sex was greater than that for the same sex. Similar observation was made by Meagher (1986) in a forest herb *Chamaelirium luterum*. In *Ocotea tenera*, however, the probability that a tree's nearest neighbour was of the opposite sex, was much higher than expected by chance (Wheelwright & Bruneau 1992).

Occurrence of species in an area depends on the ability of its propagules to tolerate the feature of environment (Harper 1967). The wide occurrence of *Mallotus* in regional forests suggests that it is hardy species, well adapted to maintain itself in the presence of recurrent disturbance primarily through non-seed regeneration methods. The occurrence of greater male trees under shaded environment and female trees under exposed environment may be due to the fact that males avoid the physiological demand on the females necessitated by seed production. So under stressful environment, therefore, males have higher fitness than females.

Thus, even under the pressure of recurrent anthropogenic disturbances, *M. philippensis* is able to show its constant presence in different forest communities of the region. In addition to recruitment by seeds, it exhibits efficient vegetative propagation and provides enough and essential understorey cover for the ecosystem attributes of these forests. Its bushy sprouts and evergreen nature provide niches for other herbs, climbers and wild fauna even in the presence of recurrent disturbance (Pandey & Shukla 2003). The fast resilience of species against disturbance is a boon to '*taungya*' people and rural poor of catchment villages who use it for various purposes.

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References

Allen, G.A. & J.A. Antos. 1993. Sex-ratio variation in the dioecious shrubs *Oemleria cerasiformis*. *American Naturalist* **141**: 537-553.

Armstrong, J.E. & A.K. Irvine. 1989. Flowering, sex-ratios, pollen-ovule ratios, fruit set and reproductive effort of *Myristica insipida* (Myristicaceae) in two different rain forest communities. *American Journal of Botany* **76**: 74-85.

Bawa, K.S. & P.A. Opler. 1977. Spatial relationship between staminate and pistillate plants of dioecious tropical forest trees. *Evolution* **31**: 64-68.

Bierzychudek, P. & V. Eckhart. 1988. Spatial segregation of sexes of dioecious plants. *American Naturalist* **132**: 43-53.

Brokaw, N.V.L. 1985. Gap-phase regeneration in tropical forest. *Ecology* **66**: 682-687.

Chandrasekara, U.M. & P.S. Ramakrishnan. 1994. Vegetation and gap dynamics of tropical wet evergreen forest in the western Ghats of Kerala, India. *Journal of Tropical Ecology* **10**: 337-354.

Charnov, E.L. & J.J. Bull. 1977. When is sex environmentally determined? *Nature* **266**: 828-830.

Clark, J.S. 1991. Disturbance and population structure on the shifting mosaic landscape. *Ecology* **72**: 1119-1137.

Crawley, M.J. 1990. The population dynamics of plants. *Philosophical Transactions of Royal Society, London* B. **330**: 125-140.

Fisher, R.A. 1930. *The Genetical Theory of Natural Selection*. Clarendon Press, Oxford.

Freeman, D.C., L.G. Klikoff & K.T. Harper. 1976. Differential resource utilization by the sexes of dioecious plants. *Science* **193**: 597-599.

Freeman, D.C., K.T. Harper & E.L. Charnov. 1980. Sex change in plants: Old and new observations and new hypotheses. *Oecologia* **47**: 222-232.

Goldman, D.A. & M.F. Willson. 1986. Sex allocation in functionally hermaphroditic plants: A review and critique. *Botanical Review* **52**: 157-196.

Grant, J. & J.B. Mitton. 1979. Elevational gradient in adult sex-ratios and sexual differentiation in vegetative growth rates of *Populus tremuloides* Michx. *Evolution* **33**: 914-918.

Gupta, O.P. & R.P. Shukla. 1991. The composition and dynamics of associated plant communities of sal plantations. *Tropical Ecology* **32**: 296-309.

Harper, J.L. 1967. A Darwinian approach of plant ecology. *Journal of Ecology* **55**: 247-270.

Iglesias, M.C. & G. Bell. 1989. The small-scale spatial distribution of male and female plants. *Oecologia* **80**: 229-235.

Janzen, D.H. 1970. Herbivores and the number of tree species in tropical forests. *American Naturalist* **104**: 501-528.

Khan, M.L., J.P.N. Rai & R.S. Tripathi. 1987. Population structure of some trees in disturbed and protected sub-tropical forests of north-east India. *Acta Oecologica* **8**: 247-255.

Knight, D.H. 1975. A phytosociological analysis of species rich tropical forest on Barro Colerado Island, Panama. *Ecological Monographs* **45**: 259-284.

Lloyd, D.J. & C.J. Webb. 1977. Secondary sex characters in plants. *Botanical Review* **43**: 177-216.

Meagher, T.R. 1986. Analysis of paternity with a natural population *of Chamaelirium luteum* I. Identification of most likely male parents. *American Naturalist* **128**: 199-215.

Melampy, M.N. & H.F. Howe. 1977. Sex-ratio in the tropical tree *Triplaris americana* (Polygonaceae). *Evolution* **31**: 867-872.

Mukerji, S.K. 1936. Contribution to the autecology of *Mercurialis perennis* L. *Journal of Ecology* **24**: 38-45.

Paine, R.T. 1966. Food web complexity and species diversity. *American Naturalist* **100**: 65-75.

Pandey, S.K. & R.P. Shukla. 1999. Plant diversity and community patterns along the disturbance gradient in plantation forests of sal (*Shorea robusta* Gaertn.). *Current Science* **77**: 814-818.

Pandey, S.K. & R.P. Shukla. 2001. Regeneration strategy and plant diversity status in degraded sal forests. *Current Science* **81**: 95-102.

Pandey, S.K. & R.P. Shukla. 2003. Plant diversity in managed sal (*Shorea robusta* Gaertn.) forests of Gorakhpur, India: species composition, regeneration and conservation. *Biodiversity and Conservation* **12**: 2295-2319.

Puyravaud, J.P., D. Shridhar, A. Gaulier, S. Aravajy & S. Ramalingam. 1995. Impact of fire on a dry deciduous forest in the Bandipur National Park, Southern India: Preliminary assessment and implications for management. *Current Science* **68**: 745-751.

Sakai, A.K. & S.G. Weller. 1991. Ecological aspects of sex expression in sub-dioecious *Schiedea globosa* (Caryophyllaceae). *American Journal of Botany* **78**: 1280-1288.

Shukla, R.P. & P.S. Ramakrishnan. 1986. Architecture and growth strategies of tropical trees in relation to successional status. *Journal of Ecology* **74**: 33-46.

Shukla, R.P. & U.N. Pandey. 1991. On the reproductive phenology and sex-ratio of *Mallotus philippensis*. *Current Science* **61**: 354-356.

Tiwari, A.K. & R.P. Shukla. 1995. On the neighbourhood relationship of two common understorey trees of *Shorea robusta* community. *Annals of Botany* **75**: 127-132.

Wheelwright, N.T. & A. Bruneau. 1992. Population sex-ratios and spatial distribution of *Ocotea tenera* (Lauraceae) trees in tropical forest. *Journal of Ecology* **80**: 425-432.