Population structure and regeneration status of medicinal tree *Illicium griffithii* in relation to disturbance gradients in temperate broad-leaved forest of Arunachal Pradesh

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***Illicium griffithii* is exploited for its medicinal and spice properties in the industry. Population structure of *I. griffithii* Hook. f. Thoms. was studied by observing number of individuals of the species during 2003–2004 in three stands experiencing different degrees of disturbance in temperate broad-leaved forest of Arunachal Pradesh, northeast India. Individuals were categorized based on diameter classes, i.e. seedlings (0–2 cm), saplings (> 2–6 cm) and trees (> 6 cm). The stand density of trees (> 6 cm diameter) ranges from 564 ha^{-1} in disturbed stand to 904 ha^{-1} in undisturbed stand while basal area was recorded highest in undisturbed stand, (12.55 $m^2 ha^{-1}$) and lowest in highly disturbed stand (6.04 $m^2 ha^{-1}$). The density–diameter class distribution (individuals per hectare) follows the trend: seedlings < saplings < trees in all the three stands. This clearly indicates that the regeneration status of *I. griffithii* is poor. The diameter distribution pattern indicates decreasing number of individuals in higher diameter classes. This may be due to the harvesting of higher girth individuals for firewood and other purposes by local people. The overall population structure of *I. griffithii* reveals the dominance of adult individuals in the three stands, which emphasized the negative role of disturbance adversely impacting the regeneration of *I. griffithii*. On the other hand, due to free access, there is unchecked exploitation. Anyone can extract as much as (s)he can. Therefore, a policy should be made to protect the species legally. Also, local people should be made aware about its importance and the need for conservation by addressing the prevalent factors which affect natural regeneration of the species.**

Keywords: Conservation, density–diameter distribution, *Illicium griffithii*, population structure, regeneration status.

THE existence of a species in the community largely depends on its regeneration under varied environmental conditions. Regeneration is a critical phase of forest management, because it maintains the desired species composition and stocking after disturbances. The regeneration status/potential of a species in a community can be assessed from the population dynamics of seedlings and saplings in the forest community. Several authors have predicted regeneration status of tree species based on the age and diameter structure of their population[1–3]. The population structure characterized by the presence of sufficient number of seedlings, saplings and young trees depicts satisfactory regeneration behaviour, while inadequate number of seedlings and saplings of tree species in a forest indicates poor regeneration[4]. The successful regeneration of a tree species depends on its ability to produce large number of seedlings, and the ability of seedlings and saplings to survive and grow[5]. However, the presence of sufficient number of seedlings, saplings and young trees is greatly influenced by interaction of biotic and abiotic factors of the environment[6,7]. Moreover, the intensity, magnitude and frequency of disturbances also determined the structure and composition of plant communities in the forest ecosystem[2,8]. The disturbances have a negative impact, disrupting the climax and making it unstable[9]. They also have a positive impact[10], creating favourable niches for regeneration. Several workers have carried out studies on population structure and regeneration status in different forest ecosystems[11–13]. *I. griffithii* Hook. f. & Thoms. belongs to family Illiciaceae, and is one of the most frequently occurring *Illicium* species in the world. In Arunachal Pradesh, it is locally known as 'Lissi'. It is a small to medium sized tree, which occurs in subtropical and temperate broad-leaved forests of West Kameng, Tawang, Lohit and Lower Subansiri districts and is widely distributed in Bomdila, West Kameng district[14]. Fruits of *I. griffithii* are used in the pharmaceutical and spice industries. Dealers from nearby towns buy fruits of *I. griffithii* from the local people and they sell them in the market at a higher price, thus earning high profit. Local people collect fruits from the forest for their nominal source of income. This has led to shrinkage of seed bank and may interrupt regeneration of the species. In addition to collection of fruits, trees are cut for fuelwood and other purposes, which leads to degradation of the forest.

Therefore, in order to examine the effect of disturbance on regeneration due to fruit/seed collection, a study on the population structure and regeneration status of *I. griffithii* Hook. f. & Thoms. was undertaken in three stands of temperate broad-leaved forest of Arunachal Pradesh, exposed to different disturbance gradients.

The study was carried out in three stands of a temperate broad-leaved forest of *I. griffithii* in Bomdila, West Kameng district, Arunachal Pradesh (Figure 1), situated at 27°16.56′N lat. and 92°25.22′E long., at the elevation of 2805 m. According to stratification composition of forest cover, *I. griffithii* is observed to be present in the second and third storey[15]. The common associate tree species are *Pinus* sp., *Thuja* sp., *Daphne papyracea*, etc. The selected three stands were situated within a radius of 2 km. Being near the roadside and with free access, there is unchecked exploitation. The selected forest is subjected to persistent human interference for fruit/seed and fuelwood collection and other purposes. This has led to massive destruction and rapid depletion of *I. griffithii*. The three forest stands differed in disturbance

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index (%), calculated as the basal area of the cut trees measured at ground level expressed as a proportion of the total basal area of all trees, including illegally felled ones of > 6 cm dbh[16]. Stands were classified as disturbed (disturbance index 46.23%), moderately disturbed (disturbance index 32.62%) and undisturbed (disturbance index 18.63%). Variance within each disturbance regime is 190.45, which is significant at 0.0005 level.

The climate of the study site in Bomdila is monsoonal. Mean annual rainfall is 119 m. Maximum rainfall occurs during the month of May to October, receiving *ca.* 88% of the total annual rainfall. Winter (November to February) is pronounced and characterized by low temperature and rainfall. The mean maximum temperature is 16.84°C and minimum temperature is 5.1°C. Relative humidity of the area ranges from 60 to 92%.

Population structure of *I. griffithii* was studied during 2003–04 in the three stands experiencing different degrees of disturbance using quadrat method. For this, twenty-five quadrats of 10 m × 10 m size were placed randomly at each stand. All the individuals of *I. griffithii* occurring in each of the quadrats were listed and their circumference was measured. *I. griffithii* is a small to medium sized tree and so the individuals were classified into three categories, i.e. seedlings (0–2 cm), saplings (> 2–6 cm) and trees (> 6 cm) based on their diameter-class for the better analyses and interpretation. Density of adult trees (> 6 cm diameter) per hectare and basal area (m^2 ha^{-1}) were calculated. Cut stump and number of sprouts per stump found in the sampling area were also recorded.

The stand density and basal area of adult trees (> 6 cm diameter) in the three stands varied greatly along the disturbance gradients (Table 1). Maximum density was recorded in undisturbed stand (904 ha^{-1}) and minimum in disturbed stand (564 ha^{-1}). Basal area ranges from 6.04 m^2 ha^{-1} (disturbed stand) to 12.55 m^2 ha^{-1} (undisturbed stand), showing significant differences among the three stands. Distribution of stems in various diameter classes, i.e. seedlings (0–2 cm), saplings (> 2–6 cm) and trees (> 6 cm) in the total population of the species (Figure 2) showed significant difference among the stands ($\chi^2 = 31.16$, $df = 4$, $P < 0.05$). The density of seedlings was highest in moderately disturbed stand (296 ha^{-1}) and lowest in disturbed stand (264 ha^{-1}), while the density of saplings does not vary largely (332 ha^{-1} in disturbed stand to 384 ha^{-1} in undisturbed stand) among the three stands. The density–diameter class follows the trend: seedlings < saplings < trees in all the three stands (Figure 2). This clearly indicates that the regeneration status of *I. griffithii* is poor. It has been observed that seedlings were mostly found under the canopy. The pattern of cumulative

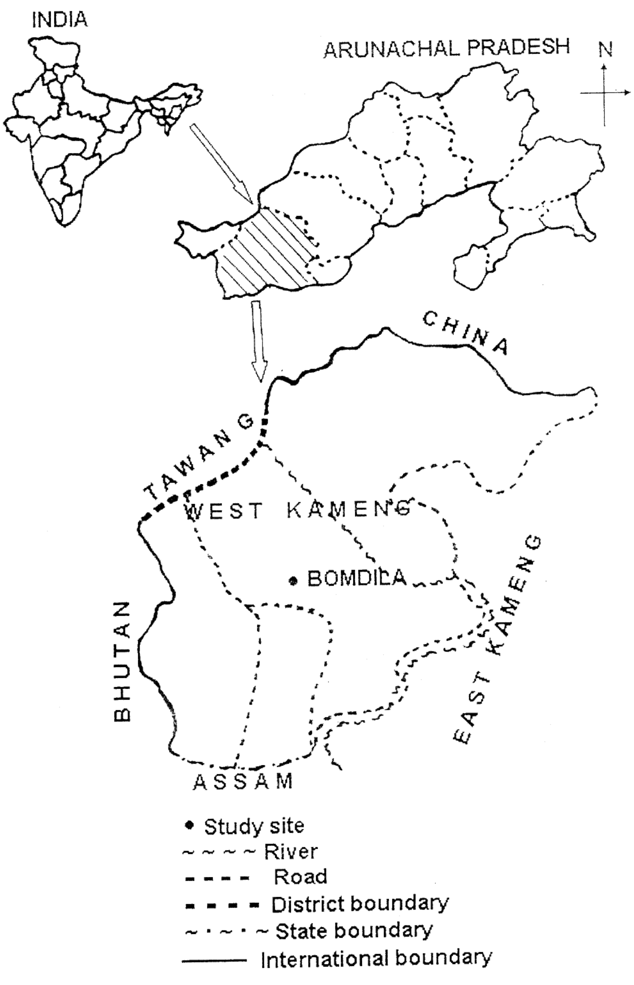

Figure 1. Geographical map of West Kameng district, Arunachal Pradesh showing the study site (Bomdila).

Table 1. Disturbance index, stand density (ha^{-1}) and basal area (m^2 ha^{-1}) of *Illicium griffithii* (> 6 cm dbh) in three stands

Parameter	Undisturbed stand	Moderately disturbed stand	Disturbed stand
Disturbance index (%)	18.63	32.62	46.23
Stand density (ha^{-1})	904	588	564
Basal area (m^2 ha^{-1})	12.55	6.55	6.04
Cut stumps (ha^{-1})	464	646	620

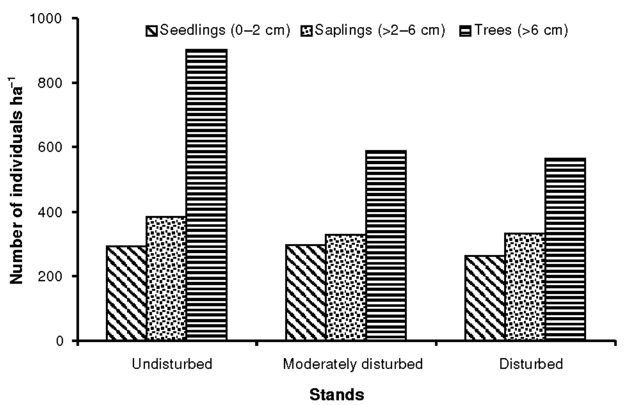

Figure 2. Population structure of *Illicium griffithii* in three stands (density ha^{-1}).

relative proportion of individuals in different diameter classes, i.e. 0–2, 2–4, 4–6 6–8, 8–10 up to 18–20 cm in the total populations of the species in the three stands indicates that individuals in higher diameter classes are becoming frequent (Figure 3). The cumulative proportion of individuals in the 0–2 cm category in undisturbed stand is much less compared to moderately disturbed and disturbed stand though not statistically significant ($\chi^2 = 0.11$, $P < 0.001$). However, cumulative % of stems in size class 8–10 cm is significantly different in undisturbed (0.59) and moderately disturbed stand (0.76), and undisturbed (0.59) and disturbed stand (0.76) comparisons, while in the case of moderately disturbed (0.76) and disturbed stand (0.76) comparison, it is not significantly different ($\chi^2 = 0.13$, $P < 0.001$). This may be attributed to the harvesting of higher girth individuals for firewood and other purposes by the local people.

The cut stumps are frequent in all the three stands. The number of cut stumps in the undisturbed stand is much less compared to the disturbed stand. ANOVA indicates that there is significant difference ($F = 13.44$, $df = 2$, $P <$ 00001) in the number of stems amongst disturbance regimes. However, cut stumps did not vary greatly in moderately disturbed and disturbed stands, exhibiting 646 and 620 stumps per hectare respectively (Figure 4). This may be due to extraction of trees for household uses by people inhabiting near the forest. Moreover, as far as sprouting stems/stumps are concerned, the proportion of stumps sprouting in different disturbance regimes shows insignificant difference ($\chi^2 = 0.64$, $df = 2$, $P < 0.05$). Similarly, sprouting of the cut stumps was common, and the number of sproutings per stump in the three stands, experiencing different degrees of disturbance did not differ significantly ($\chi^2 = 2.73$, $df = 2$, $P < 0.05$). Sprouting of cut stumps (per hectare) ranges from 77 (undisturbed stand) to 89% (disturbed stand), indicating that the species is a good coppicier. However, survival of sprouts is poor and they are frequently lopped for thin fuelwood. Hence they are not able to contribute much towards regeneration of the species (pers. obs.).

A number of studies relating to the regeneration of either specific species or the forest stand as a whole have focused on the impact of anthropogenic factors and natural disturbances. In the long run, most ecosystems change in their species composition and organization, but rapid changes are seen especially when they are exposed to human interferences and other causative factors affecting the regeneration of the species. The ability to regenerate forests after disturbances is an important part of the forest management. The number of saplings and seedlings per unit area permits to assess the regeneration potential of a species in the community[4]. Increased human population accompanied with an increase in cattle population has intensified disturbances. In temperate broad-leaved forest of *I. griffithii*, the species is repeatedly lopped for fruit and fuelwood, and collection of fruit is unscientific. The whole twig is lopped from the plant for collecting the fruit, which not only reduces vigour but also seed production and ultimately leads to poor regeneration of the species. Stand density (ha^{-1}) and basal area ($m^2\ ha^{-1}$) were recorded highest in the undisturbed stand and lowest in the disturbed stand. The differences in relative proportion of seedlings, saplings and trees among the three stands may be due to the interactive influence of an array of biotic and abiotic factors. Based on the observation of density of seedlings, saplings and trees, it is clear that the regeneration of *I. griffithii* is poor in view of the fact that the density of trees is higher than those of seedlings and saplings. The establishment and survival of seedlings is poor in all the three stands (Figure 2), which indicates that seeds reaching the ground are capable of germinating, but fail to convert into early sapling stage. Trampling by cattle and removal of cut trees are the underlying factors that hinder survival and establishment of seedlings to the sapling stage. It was mainly because of higher biotic interference prevailing in the forest. It has been argued that degradation reduces species number, stem density and regeneration potential of the forests[17]. Decline in the population of trees in diameter class 4–8 cm in undisturbed and moderately disturbed stands may indicate an interruption in the regeneration resulting from the chang-

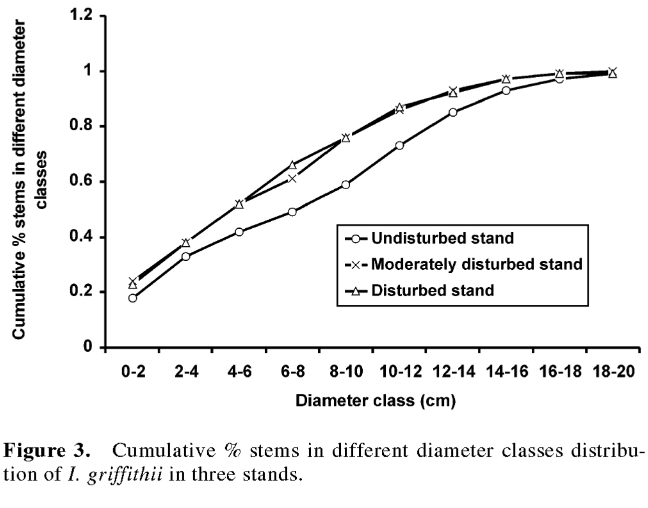

Figure 3. Cumulative % stems in different diameter classes distribution of *I. griffithii* in three stands.

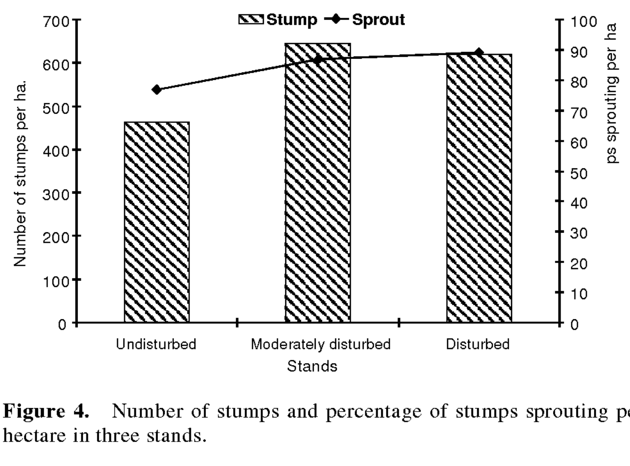

Figure 4. Number of stumps and percentage of stumps sprouting per hectare in three stands.

ing microclimatic conditions[18] and biotic influences. The presence of small and large individuals indicates frequent regeneration as well as dominance at maturity. However, in all the three stands the number of individuals decreases beyond the diameter classes, i.e. 8–10 cm in moderately disturbed stand and 10–12 cm in undisturbed and disturbed stands. On the other hand, higher number of individuals in intermediate diameter classes compared to lower and higher diameter classes reflected the imbalance in population structure of *I. griffithii*. Preponderance of such intermediate diameter classes may be due to infrequent recruitment and selective felling of trees of the larger diameter girth classes. If such a trend continues, it may be predicted that the population is on its way to extinction locally[19].

Variation in the number of individuals in different diameter classes among the three stands may be ascribed to the prevailing environmental factors and degree of disturbance. The overall population structure of *I. griffithii* in different diameter classes reveals dominance of trees and lowest number of seedlings in all the three stands. These clearly indicate that the regeneration status of *I. griffithii* is poor, justifying the negative role of disturbance[9] by creating adverse niches for regeneration of *I. griffithii*.

Frequent occurrence of cut stumps and higher contribution of stumps sprouting in all the three stands show the species is a good coppicier. The presence of maximum number of cut stumps in the moderately disturbed stand may be due to the selective removal of medium diameter trees which can easily be taken away by the local people. Small trees, do not fulfil their requirements. However, survival of sprouts is poor and they are frequently lopped for thin fuelwood. Hence they are not able to contribute much towards regeneration of the species (pers. observ.).

The poor regeneration status of *I. griffithii* in the three stands may be due to excessive harvest of fruits/seeds and trampling of seedlings and saplings by both human and cattle. However, the species shows good coppicing. Further studies on regeneration of *I. griffithii* through sprouting will be helpful for the better understanding of regeneration and management practices of the species.

Our findings indicate that if anthropogenic pressures continue to operate, future perpetuation of *I. griffithii* in the forest may be threatened. Hence, proper conservation measures have to be formulated to protect the species, taking into account its medicinal and economic values. Awareness programmes regarding the importance of *I. griffithii* and motivating the people towards sustainable harvesting may help minimize the pressure on this species.

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ACKNOWLEDGEMENTS. The work was supported by a partial funding from CSIR, New Delhi to M. L. Khan, A.D.K. thanks CSIR for Senior Research Fellowship. We are grateful to Dr K. S. Murali for valuable comments.

Received 5 November 2004; revised accepted 31 May 2005