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Rattan species richness and population genetic structure of *Calamus flagellum* in North-Eastern Himalaya, India

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Abstract—Rattans, the climbing palms, are one of the most important non-wood forest produce supporting the livelihood of many forest dwelling communities in India. However, extensive harvest, loss of habitat and poor regeneration has resulted in dwindling of rattan populations necessitating an urgent need to conserve the existing rattan genetic resources. In this study, using GIS tools, an attempt has been made to develop species richness maps of rattans in the North-Eastern Himalaya, a mega-diversity region in India. At least four sites of extremely high species richness were identified that could be prioritized for *in situ* conservation. Further, using molecular tools, genetic variability was assessed in six populations of an economically important rattan, *Calamus flagellum*. The population that was least disturbed or harvested maintained comparatively higher levels of genetic diversity than those that were disturbed. The study, perhaps the first in the region, emphasizes the need for developing strategies for the long-term conservation of rattans in the North-Eastern Himalaya.

Key words: Rattans; *Calamus flagellum*; contours of conservation; species distribution; genetic diversity; North-Eastern Himalaya.

INTRODUCTION

Rattans are spiny climbing palms belonging to the family *Palmaceae*. They are known for their strength, durability, elasticity, lightness and natural resistance to impacts and are used for making variety of products [1, 2]. Generally referred to

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as ‘canes of commerce’, the rattans form one of the important non-wood produces in South-East Asia. As per a conservative estimate, approximately half a million people are directly employed in harvesting and processing of canes in rural areas of South-East Asia [2, 3]. The international trade in rattans is estimated to be worth over US$ 6.5 billion a year [4]. With about 600 species in 13 genera, their distribution is restricted to tropical and sub-tropical Asia and equatorial Africa [5]. After China, India is one of the richest sources of rattans, harbouring over 70 species in five genera, *viz.*, *Calamus*, *Daemonorops*, *Zalacca*, *Korthalsia* and *Plectocomia* [2]. They are distributed along the wet evergreen forests of the Western Ghats of Peninsular India, sub-Himalayan tracts of the North-Eastern Himalaya region and the Andaman and Nicobar Islands [2, 6, 7]. The North-Eastern Himalaya, including the states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, is considered to be one of the major hot-spots of rattan diversity and accounts for about 50% of the total rattan flora in India [2].

Of the 21 species in the North-Eastern Himalayas, 17 from four genera occur in the state of Arunachal Pradesh (26°28′–29°39′N latitude and 91°30′–97°30′ E longitude) alone, with *Calamus* being the most widely distributed genus [8, 9]. An important feature of this north-easterly state adjoining China is that nearly 82% of the geographic area is under forest [8] and unlike other parts of India, most of this area is owned by tribal (indigenous) communities with only 20% of the forest owned by the government. Many of the tribal communities in the state depend substantially on locally available bioresources, including rattans. For example, *Calamus flagellum*, locally referred to as ‘raidang’, is extensively harvested in Arunachal Pradesh for use in furniture industry, especially for frame works. The extensive extraction of rattans, along with changes in land use patterns and feature of shifting cultivation practiced in the state has reportedly threatened several economically important species, including the rattan such as *C. flagellum* [6]. Consequently, in recent years there has been an increasing concern over the loss of natural populations of rattans in the North-Eastern states of India. However, unlike the attention rattans have received in the Western Ghats in peninsular India, [9–14], there have been no systematic attempts in addressing the conservation of rattans of northeast India [6–8, 12]. As a first step towards addressing the status, threats and conservation strategies in respect of rattans of north-east India, we have attempted to (a) identify the hot-spots of distribution of rattan cane species in the North-Eastern Himalaya region and (b) study the population and genetic structure of *Calamus flagellum*, an economically important rattan species, mainly restricted to the state of Arunachal Pradesh [9]. These studies would have strong implications for formulating strategies for the conservation of rattan genetic resources of the North-Eastern Himalaya region.

MATERIALS AND METHODS

Geographical focus of the study

The study was conducted the North-Eastern Himalaya (NEH), India, one of the global biodiversity hot-spots in the world (Fig. 1). While the entire NEH region was considered for the identification of hot-spots, estimation of the intra-specific genetic diversity in *C. flagellum*, was restricted only to the state of Arunachal Pradesh in which the species is largely distributed.

Identification of hot-spots of rattan species richness in the NEH region

Data on the distribution of rattan species in the Northeastern states of India were obtained from flora, herbaria, books and other published sources including forest department records and other archival material. The latitude and longitude of the places of occurrence were obtained and digitized using GIS MapInfo software. Based on the number of records of occurrence of a species at a place, contours of species richness were constructed using a 3D Mapper program in the GIS MapInfo frame and the hot-spots of species richness were identified [11]. Using similar approaches but based on the records of occurrence of economically important and endemic species of rattans, separate maps were developed for economically important and endemic species of rattans as well.

Population structure and genetic diversity of an economically important rattan, C. flagellum, in Arunachal Pradesh

We assessed the intra-specific genetic variability of *C. flagellum*, one of the extensively extracted species of rattans in the forests of Arunachal Pradesh. Based on the

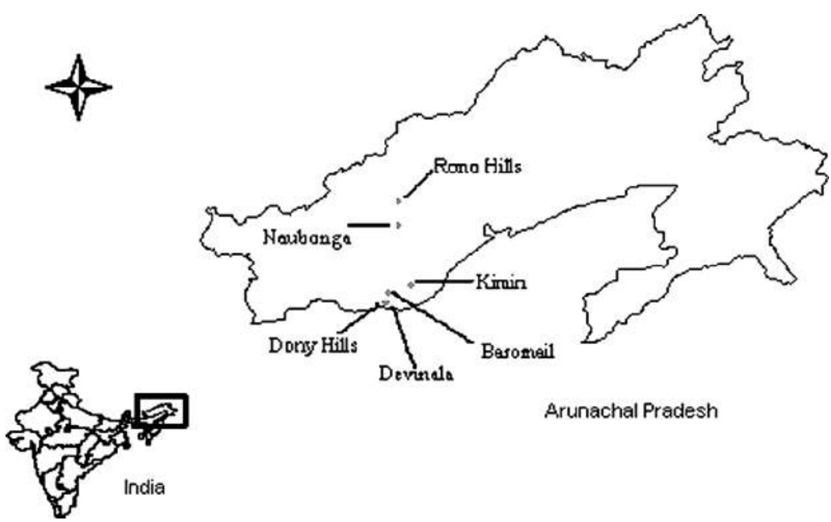

Figure 1. Location of the study areas in Arunachal Pradesh.

information obtained from the local forest division and ranges, the approximate spatial locations and distribution of the rattan was developed. After preliminary field survey, 6 distinct populations at Baromail, Devinala, Rono Hills, Naobonga, Kimin and Doni hills in Arunachal Pradesh were identified and sampled for further studies (Fig. 1).

Population structure

At each of the selected sites, 10 grids of 10×10 m each were laid randomly and the following population parameters were recorded.

(a) Density: the number of clumps of the rattan in each quadrate (10×10 m) was recorded. Based on this, the density of clumps per quadrate was computed.

(b) Regeneration: as an index of regeneration, the number of seedling and saplings (<1 m height) were recorded in each of the quadrates and divided by the number of adults in the regeneration quadrate to obtain an index of regeneration per adult [2].

(c) Average number of culms per clump: the number of culms per clump was recorded for each quadrate and the mean number of culms per clump per quadrate was computed.

(d) Disturbance or harvesting index: in each quadrate, the ratio of the number of cut or broken culms were recorded and expressed as percentage of the total number of clumps to provide a measure of the harvesting or disturbance intensity [15, 16].

Differences among the six sites or populations were statistically evaluated by conducting a one-way ANOVA.

Genetic diversity

At each site, leaf samples from 15–20 randomly selected individuals of *C. flagellum* were collected for genetic diversity estimation. As far as possible the collections were made from the quadrate in which the species were censed. In case sufficient samples were not obtained from within the quadrates, individuals were collected from outside the quadrates. The harvested leaves were air dried and stored in dry place for further use.

(a) DNA extraction and PCR amplification: genomic DNA was extracted following cTAB protocol [17] with some minor modifications. The extracted DNA was verified by agarose gel electrophoresis (0.8%) and DNA content was quantified by measuring OD at 260 nm. Genetic analysis was carried out employing DNA based Inter Simple Sequence Repeat (ISSR) molecular markers. As a PCR-based marker, ISSR has a few advantages over other conventional markers. ISSR primers anneal directly to simple sequence repeats and thus, unlike SSR markers, no prior knowledge of target sequences is required for ISSRs. Also, the sequences that ISSRs target are abundant throughout the eukaryotic genome and evolve rapidly; consequently ISSRs may reveal a much higher number of polymorphic fragments per primer than RAPDs. PCR amplification was carried out in a 15 μl reaction mixture containing template DNA (20 ng), primer (0.3 μM), *Taq* polymerase (0.5 units), 10× assay buffer and dNTPs (1 mM). A total of 20 ISSR primers were screened, of which 10 primers (ISSR 4, UBC826, UBC888, UBC807, UBC868, UBC809, UBC827, UBC811, UBC890 and UBC855) that gave consistent results and higher number of polymorphic bands was selected. Amplified PCR products were separated on a 1.5% agarose gel stained with ethidium bromide (0.5 μg/ml). The gel was visualized under a UV light and captured using Herolab Gel Documentation Unit.

(b) Scoring and data analysis: binary coding was used to score the gels [18]. Presence of a PCR-amplified product was scored as 1 and its absence as 0. Based on the absence or presence of amplified products, various genetic diversity parameters were analysed using population genetics software (Popgene version 1.32 [19]) and Statistica software.

(c) Gene diversity: Nei's gene diversity [20] which is equivalent to the total population differentiation for an effectively infinite population was computed as:

$$h = 1 - \sum P_i^2,$$

where P_i is the frequency of the occurrence of the ith-amplified product.

The gene diversity was calculated for each amplified product and then averaged over all the amplified PCR products for a given population. The standard deviation of the gene diversity index over all amplified products was computed.

(d) Polymorphic percentage: the proportion of polymorphic amplification product for each population was estimated. An amplified product was considered polymorphic only if the frequency of the most frequent ISSR amplification product was below 95%.

(e) Mean similarity index: based on the presence or absence of the amplification products, similarity index was computed as 1 − squared Euclidean distance $(1 - \sum_i (x_i - y_i)^2)$ between all possible pairs of individuals within each study site. The mean similarity index (SI) across the study sites was compared using Student's t-test and one-way ANOVA.

RESULTS

Hot-spots of rattan species richness

The NEH region collectively harbours 4 rattan genera, namely *Calamus*, *Daemonorops*, *Plectocomia* and *Zalacca*. Of the eight states in this region, four, *viz.*,

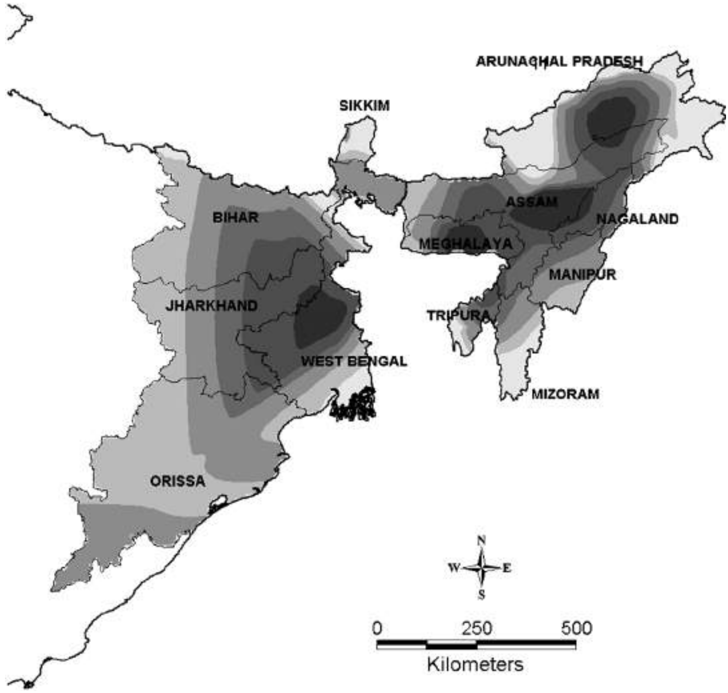

Figure 2. Contour map of rattan species richness in North-Eastern India. The contours are constructed based on 330 records over 21 species. Note: the rattan species include *C. acanthospathus*, *C. erectus*, *C. flagellum*, *C. floribundus*, *C. gracilis*, *C. guruba*, *C. inermis*, *C. khasianus*, *C. kingianus*, *C. latifolius*, *C. leptospadix*, *C. nambariensis*, *C. palustris*, *C. tenuis*, *C. viminalis*, *Daemonorops jenkinsiana*, *Plectocomia assamica*, *P. bractealis*, *P. khasiyana*, *P. himalayana* and *Zalacca secunda*.

Assam, Sikkim, Meghalaya and Arunachal Pradesh, account for the major distribution of rattan species (Fig. 2). Nine of the 21 species are endemic to the north-eastern region (Fig. 3). Assam, Meghalaya and Arunachal Pradesh have a relatively higher number of endemic rattans followed by West Bengal (Fig. 3). It is estimated that 12 (belonging to three genera, *Calamus*, *Daemonorops*, *Plectocomia*) of the 21 rattans are economically important to this region (see Table 1 for the distribution details and their economic importance). Of these, the state of West Bengal harbours about 9 economically important species. The remaining sites of high richness are in the states of Meghalaya, Assam, and Arunachal Pradesh (Fig. 4).

Population structure

All the six populations of *C. flagellum* studied (Baromail, Devinala, Ronohills, Naobonga, Kimin and Doni Hills) experienced different degrees of harvesting as evident from the per cent cut and broken stems (Table 2, F-test, $P < 0.072$). The population at Baromail was found to be least harvested or disturbed (cut stems $=$ 6%) while that at Rono Hills was highly harvested or disturbed (cut stems $=$ 14%).

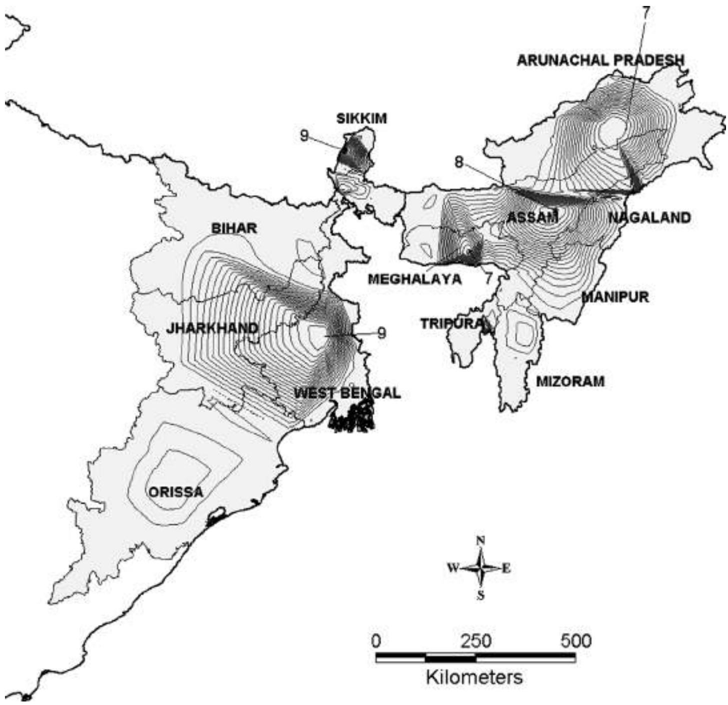

Figure 3. Contour map of endemic species of rattans in North-Eastern India. The numbers in the map indicate the number of endemic species specific to the area. The contours are constructed based on 192 records over 9 species. Note: the endemic species include *C. erectus*, *C. khasianus*, *C. kingianus*, *C. nambariensis*, *Plectocomia assamica*, *P. bractealis*, *P. khasiyana*, *P. himalayana* and *Zalacca secunda*.

Mean density of stems per quadrate was significantly different among the sites (Table 2; F-test, $P < 0.0001$). Density of clumps was highest for Baromail (5.8 ± 1.2) followed by that in Devinala (5.0 ± 4.3). The population at Rono Hills was the least dense (3.0 ± 0.8; Table 2). The sites also differed significantly with respect to the mean number of culms per clump (Table 2, F-test, $P < 0.0001$). The population at Baromail had the highest mean number of culms (40.7 ± 7.11) with that in Rono Hills the least (16.1 ± 4.22). Mean regeneration, as measured by the proportion of seedlings and saplings to the total number of adults per quadrate, ranged from as low as 3.7 in Naubonga to as high as 11.2 in Baromail (Table 2, F-test, $P < 0.0001$). In summary, there were significant differences with respect to key population parameters among the six *Calamus flagellum* populations studied in Arunachal Pradesh.

Population genetic diversity

The mean gene diversity and per cent polymorphic loci of the six populations are presented in Table 3. The average Nei's gene diversity over all the six populations was 0.201. The Baromail population was significantly more diverse

Table 1.
Economically important rattans of North East India

Species	Distribution	Uses
C. acanthospathus	Sikkim, West Bengal, Assam, Arunachal Pradesh, Meghalaya, Nagaland	Ropes, cables for suspension bridges, walking sticks, baskets. Thicker canes used for umbrella handles, polo sticks and furniture frames
C. erectus	West Bengal, Sikkim, Arunachal Pradesh	Leaves used for roofing
C. flagellum	Arunachal Pradesh and Meghalaya	Baskets, Tender shoots are edible
C. floribundus	Assam, Khasi Hills and Silhet	Coal baskets for railways
C. guruba	North Bengal, Assam and Meghalaya	Slender cane of 0.6–0.8 cm diameter for multipurpose use
C. inermis	North Bengal and Sikkim	Furniture and bridge making
C. latifolius	Sikkim, West Bengal, Assam, Arunachal Pradesh, Meghalaya	Walking sticks, umbrella handles baskets. One of the most beautiful rattans in India
C. leptospadix	Sikkim, Meghalaya, Nagaland and Manipur	Basket making
C. tenuis	All north eastern states of India except Sikkim and Mizoram	Basket making, furniture and chair seats
C. viminalis	West Bengal and Sikkim	Thicker canes used for umbrella handles, polo sticks, furniture frames and walking sticks
D. jenkinsianus	All except Nagaland and Manipur	Long and soft canes used for basket making, crooks of umbrella handles
Plectocomia himalayana	North Bengal and Sikkim between 1200 and 2200 m	Basket making, cordage and crooks of umbrella handles

(Nei's gene diversity 0.265 ± 0.186) compared to all other populations. Populations at Devinala, Doni Hills and Naubonga were least diverse. Per cent polymorphism was highest for the Rono Hills (77.61%) and Baromail populations (76.10%) with Devinala population having the least percent polymorphism (54.04%).

Besides Nei's gene diversity, we also computed, on the amplification polymorphism data, genetic similarity index among all possible pairs of individuals within each of the six populations (Table 4). The mean genetic similarity index for Baromail population was least ($SI = 0.713 \pm 0.05$), indicating that the population was genetically most diverse among all the populations examined (Table 4).

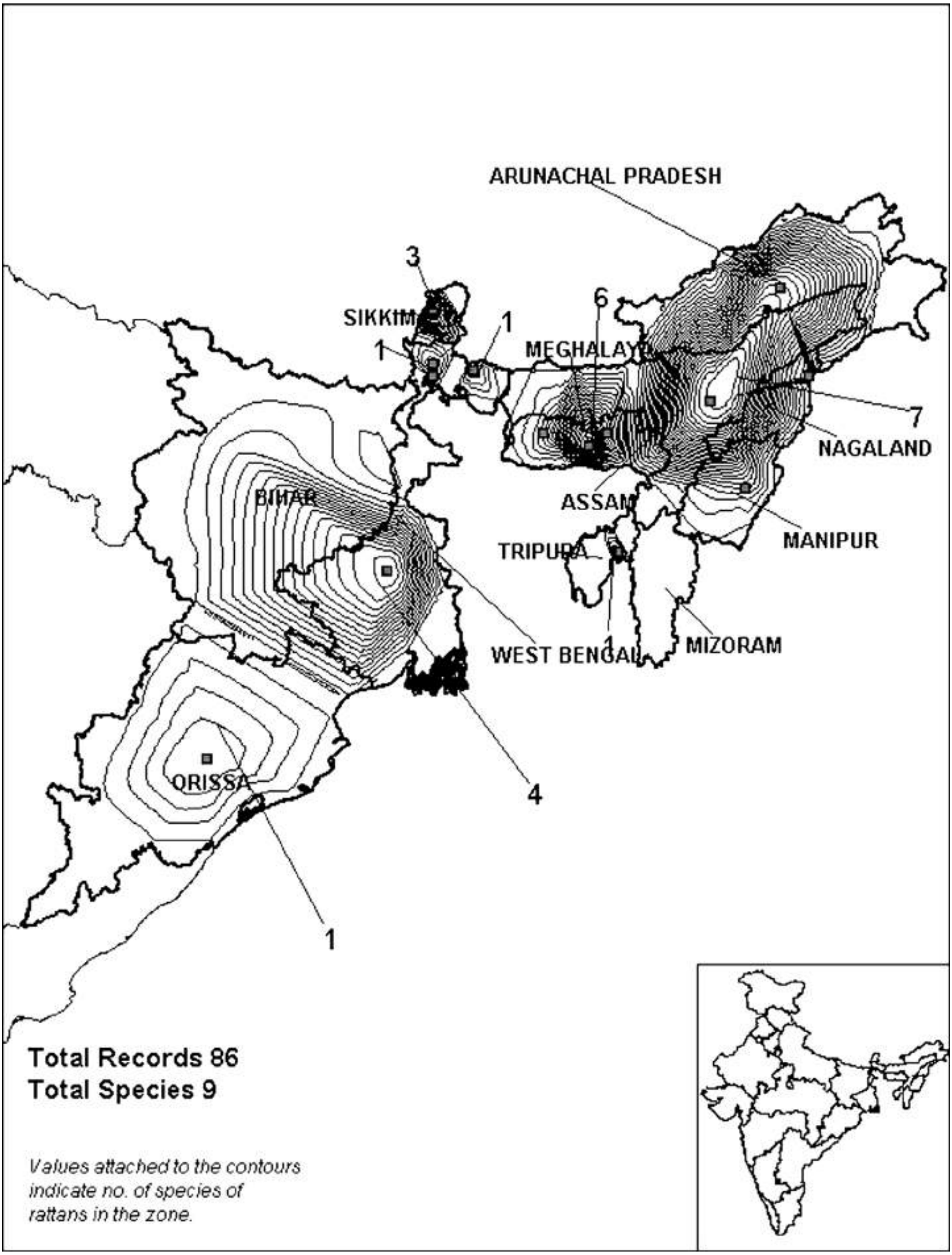

Figure 4. Contour map of economically important species of rattans in North-Eastern India. Values attached to the contours indicate number of species in that zone. The contours are constructed based on 192 records over 12 species. Note: the economically important species include *Calamus acanthospathus*, *C. inermis*, *C. guruba*, *C. latifolius*, *C. leptospadix*, *C. tenuis*, *C. viminalis*, *C. floribundus*, *C. flagellum*, *C. erectus*, *Daemonorops jenkinsianus* and *Plectocomia himalayana*.

Table 2.
Population structure for the six populations of *Calamus flagellum* in Arunachal Pradesh

Study sites	Mean regeneration/ adult/quadrat	Mean density (No./quadrat)	Mean culms/ clump	Ratio of cut or broken stems to total stems
Kimin	5.1 ± 1.60	3.5 ± 1.17	20.7 ± 7.76	0.09 ± 0.06
Baromail	11.2 ± 3.25	5.8 ± 1.22	40.7 ± 7.11	0.06 ± 0.07
Naubonga	3.7 ± 1.16	3.4 ± 1.07	20.3 ± 6.60	0.11 ± 0.056
Rono Hills	5.0 ± 1.63	3.0 ± 0.81	16.1 ± 4.22	0.14 ± 0.05
Doni Hills	6.4 ± 1.96	4.5 ± 1.08	29.7 ± 7.62	0.08 ± 0.03
Devinala	6.5 ± 2.22	5.0 ± 1.33	33.80 ± 7.87	0.09 ± 0.07
F-test*	15.702 ($P < 0.0001$)	9.172 ($P < 0.0001$)	18.248 ($P < 0.0001$)	2.15 ($P < 0.072$)
Critical difference ($P = 0.05$)	2.24	1.22	7.55	0.06

*A one-way ANOVA was conducted across the sites with data of the quadrates treated as replications.

Table 3.
Genetic diversity parameters of six populations of *Calamus flagellum* in Arunachal Pradesh

Study sites or populations	N	Mean gene diversity	SD (±)	No. of amplification products	Polymorphic loci (%)
Kimin	12	0.198[a]	0.179	122	64.12
Baromail	13	0.265[b]	0.186	108	76.10
Naubonga	12	0.168[a]	0.173	108	56.64
Rono Hills	12	0.260[bc]	0.179	112	77.61
Doni Hills	12	0.18[a]	0.19	171	56.34
Devinala	11	0.14[a]	0.16	87	54.02

N = number of individuals. Dissimilar letter indicates that the values are significant at $P < 0.05$. The test of significance of the gene diversity index was computed over the number of amplification products for each of the populations.

Table 4.
Mean genetic similarity index of six populations of *Calamus flagellum* in Arunachal Pradesh

Study sites or populations	N	Mean genetic similarity index	SD (±)
Kimin	66	0.783[a]	0.068
Baromail	77	0.713[c]	0.056
Naubonga	66	0.816[d]	0.049
Rono Hills	65	0.715[c]	0.063
Doni Hills	66	0.794[a]	0.050
Devinala	55	0.837[bd]	0.090
F-test*	42.903 ($P < 0.0001$)		

N = number of pairs of individuals over which the mean genetic similarity index was computed. Dissimilar letter indicates that the values are significant at $P < 0.05$ (following Student's t-test).

*A one-way ANOVA (with unequal replications) was conducted across the sites with data of the mean genetic similarity index of pairs of individuals within a site treated as replication.

The genetic diversity estimates, both Nei's gene diversity index as well as the genetic similarity index of the populations, were not significantly correlated with either the population parameters or the relative disturbance index of the population.

DISCUSSION

Micro-hotspots of rattans

The rattans form an important component of traditional livelihoods of a large proportion of forest fringe communities in the North-Eastern region of India, just as they do in the Western Ghats of India [2]. Consequently, a number of economically important species have been subjected to intense extraction pressures [10, 13, 21]. For example, an endemic rattan, *Plectocomia assamica* found in the lower hill forests of Assam and Arunachal Pradesh has been over-exploited for making bridges over streams and rivers [2]. Five of the endemic rattans, *viz.*, *C. kingianus*, *C. erectus*, *C. nambariensis*, *P. bractealis* and *P. khasiyana* are reported to have become infrequent in their native habitat [22]. In fact nine (*Calamus flagellum*, *C. leptospadix*, *C. floribundus*, *C. acanthospathus*, *C. gracilis*, *C. latifolius*, *C. kingianus*, *C. khasianus* and *Plectocomia himalayana*), of the 21 species found in the north-eastern states have become vulnerable due to destruction of their habitats, poor flowering and fruiting habits [23]. Efforts to assess the conservation requirements of the rattan species in the region has been constrained by the lack of studies on the status and threats to the species, unlike those existing for the rattans of the Western Ghats [7, 8]. Assessment of the hot-spots of species richness and the population and genetic structure of focal species is of crucial importance for developing rational plans for the conservation of populations and the constituent species [16, 24, 25]. In this study, we have initiated attempts to address the conservation status of rattans of North-Eastern region at two levels, namely at inter-specific and at intra-specific level.

Using GIS tools, we have identified at least 4 sites of extremely high species richness that could be regarded as 'micro-hotspots' of the rattan species richness in the North-Eastern region of the country. These sites together account for 14 (66.6%) of rattan species in north-eastern India. Further these four sites are also home to a large proportion of both economically important and endemic species of rattans. The studies reported here are perhaps the first to generate the so called 'contours of conservation' [26] that highlight the landscape foci that uniquely posses a large proportion of species richness [11]. Clearly these studies offer a spatially explicit perspective of the species richness of rattan in north eastern India based on which prioritization of sites for conservation action can be proposed. In fact an overwhelming success in conservation of the rattan genetic resources of north-eastern India could be achieved by focusing attention on these four identified sites.

Population structure and genetic diversity

It is now well known that high levels of dependencies on non-timber forest products can lead to increasing pressure on the forest resources [27]. In fact, evidence of the such increasing pressure is already reflected in the (a) dwindling resource status of several economically important plants such as sandal, rattans and bamboos [11, 25, 28], (b) in the endangerment of populations of several scores of economically important plants, especially the medicinal plants [29] and (c) in the local extinctions of populations of several species [30]. With increasing population pressures and changes in land use systems, the threat to the species is expected to only further increase.

In this study, we examined the population genetic features of an economically important rattan, *Calamus flagellum* in the state of Arunachal Pradesh. Populations differed significantly with respect to their mean densities, mean culms per clump and regeneration. However an important feature was that the populations also differed in the extent to which they were disturbed. The population at Baromail, which was least disturbed, had the highest density of culms as well as the highest regeneration. Genetic diversity estimates (both Nei's gene diversity index and mean genetic similarity index) were also significantly higher for the Baromail population compared to the other populations. Despite indications to the effect, we failed to obtain statistically significant correlations between the estimates of genetic diversity and that of the extent of disturbance across the six populations. Several earlier workers have reported a significant causal relationship between the levels of disturbance and the genetic diversity of populations of non-timber forest product species [11, 16, 31]. In a recent study, Ramesha [21] reported a significant negative correlation between the levels of disturbance and harvesting of rattans and genetic diversity of populations of rattans in the Western Ghats. In fact based on the general relation that disturbance to populations are going to have cascade effects on populations including in the lack of reproductive individuals, especially so in rattans harvested for their stems, Ravikanth *et al.* [11], argued that any effort towards maintaining the population structure of rattan could ensure the maintenance of genetic diversity of the population. The issue is especially critical in rattans, as these are slow growing and dioecious and invariably depend entirely upon seeds for their propagation [2, 11].

Clearly more studies are required to assess the status of, and threats to, the rattan resources of the NEH region to plan a robust conservation plan for the economically important rattan species of this region. Considering the economic importance of the species to local livelihoods, it is expected that the pressure on these resources are only further going to increase in the region. In this context, an overarching plan to conserve the rattan genetic resources will need to incorporate strong spatial data sets on their distribution and concentration, as well as in establishing the impact that indiscriminate harvesting may have on the population genetic parameters. Our study, perhaps the first in the region, has identified the contours of conservation based on which long term plans for the conservation of endemic and economically important rattan species can be developed in the NEH region.

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REFERENCES

1. A. C. Lakshmana, *Rattans of South India*. Evergreen, Bangalore (1993).
2. R. Uma Shaanker, K. N. Ganeshaiah, K. Srinivasan, V. Ramanatha Rao and L. T. Hong, *Bamboos and Rattans of the Western Ghats: Population biology, Socio-economics and Conservation Strategies*. ATREE, UAS, IPGRI, Bangalore (2004).
3. S. Biswas, Rare and endangered flora of Eastern Himalayas and measure for its conservation, *Recent Research in Ecologic and Environmental Pollution* **6**, 267–273 (1991).
4. International Tropical Timber Organisation, Bamboo & Rattan: Resources for the 21st Century, *Tropical Forest Update* **7** (4) (1997).
5. J. Dransfield, The rattan taxonomy and ecology, in: *Proceedings of Training Courses Cum Workshop, Rattan: Taxonomy, Ecology, Silviculture, Conservation, Genetic Improvement and Biotechnology*, A. N. Rao and V. Ramanatha Rao (Eds), p. 114. IPGRI-APO and INBAR, Sarawak (1996).
6. S. Thomas, K. Haridasan and S. K. Borthakur, Floristic study on rattans and its relevance in forestry of Arunachal Pradesh, *Arunachal Forest News* **16** (1–2), 19–24 (1998).
7. C. Renuka, Palms of India: Status, threats and conservation strategies, in: *Forest Genetic Resources: Status, Threats and Conservation Strategies*, R. Uma Shaanker, K. N. Ganeshaiah and K. S. Bawa (Eds), pp. 197–209. IBH, New Delhi (2001).
8. A. Saxena, K. Haridasan and S. P. Ahlawat, Conservation of forest genetic resources of Arunachal Pradesh and Eastern Himalayas, in: *Forest Genetic Resources: Status, Threats and Conservation Strategies*, R. Uma Shaanker, K. N. Ganeshaiah and K. S. Bawa (Eds), pp. 237–251. IBH, New Delhi (2001).
9. C. Renuka, Indian rattan distribution — an update, *Indian Forester* **25**, 591–598 (1999).
10. G. Ravikanth, K. N. Ganeshaiah and R. Uma Shaanker, Mapping genetic diversity of rattans in the Central and Western Ghats: Identification of hotspots of variability for *in situ* conservation, in: *Forest Genetic Resources: Status, Threats and Conservation Strategies*, R. Uma Shaanker, K. N. Ganeshaiah and K. S. Bawa (Eds), pp. 69–83. IBH, New Delhi (2001).
11. G. Ravikanth, K. N. Ganeshaiah and R. Uma Shaanker, Identification of hotspots of species richness and genetic variability in rattans: an approach using geographical information systems (GIS) and molecular tools, *Plant Genetic Resources Newsletter* **132**, 17–21 (2002).
12. C. Renuka, Rattans of North Eastern India — A cause for great concern, *Arunachal Forest News* **14** (2), 8–11 (1996).

13. A. Narwade, Genetic diversity and structure of endemic and non-endemic species of rattan in Central-Western Ghats, MSc Thesis, University of Agricultural Sciences, Bangalore (2003).
14. A. C. Lakshamana, Rattans in Karnataka — an Account, in: *National Workshop on Rattans (canes)*, 1999, pp. 28–33. Institute of Wood Sciences and Technology, Bangalore (1999).
15. S. Padmini, M. Nageswara Rao, K. N. Ganeshaiah and R. Uma Shaanker, Genetic diversity of *Phyllanthus emblica* in tropical forests of South India: Impact of anthropogenic pressures, *Journal of Tropical Forest Science* **13** (2), 297–310 (2001).
16. R. Uma Shaanker, K. N. Ganeshaiah and M. Nageswara Rao, Genetic diversity of medicinal plant species in deciduous forests of India: Impacts of harvesting and other anthropogenic pressures, *Journal of Plant Biology* **28** (1), 91–97 (2001).
17. J. J. Doyle and J. S. Doyle, A rapid DNA isolation procedure for small quantities of fresh tissues, *Phytochemical Bulletin* **19**, 11–15 (1987).
18. J. F. Wendel and N. F. Weeden, Visualization and interpretation of plant isozymes, in: *Isozymes in Plant Biology*, D. E. Soltis and P. S. Soltis (Eds), pp. 46–73. Chapman and Hall, London (1989).
19. F. C. Yeh and T. J. B. Boyle, *Population Genetic Analysis POPGENE version 1.2*, A joint project of the Agriculture/Forestry molecular biology and biotechnology center. Center for International Forestry Research, University of Alberta, Calgary, Alberta (1997).
20. M. Nei, Analysis of gene diversity in sub divided populations, in: *Proceedings of the National Academy of Science of the USA* **70**, 3321–3323 (1973).
21. B. T. Ramesh, Population genetic variability of rattans in protected areas of Central-Western Ghats, MSc Thesis, University of Agricultural Sciences, Bangalore (2003).
22. S. K. Basu and R. K. Chakraverty, in: *A Manual of Cultivated Palms in India*, p. 166. BSI, Calcutta (1994).
23. S. K. Basu, Conservation status of rattans in India, in: *Rattan Management and Utilization. Proceedings of Rattan (cane) Seminar, India, Trichur*, S. Chand Basha and K. M. Bhat (Eds), pp. 67–75. IDRC, Ottawa, Ontario (1992).
24. G. Namkoong, M. P. Koshy and S. Aitken, Selection, in: *Forest Conservation Genetics: Principles and Practice*, A. Young, D. Boshier and T. Boyle (Eds), pp. 101–111. CABI, Wallingford (2000).
25. M. Nageswara Rao, R. Uma Shaanker and K. N. Ganeshaiah, Mapping genetic diversity of Sandal (*Santalum album* L.) in South India: Lessons for *in-situ* conservation of Sandal genetic resources, in: *Forest Genetic Resources: Status, Threats and Conservation Strategies*, R. Uma Shaanker, K. N. Ganeshaiah and K. S. Bawa (Eds), pp. 49–67. IBH, New Delhi (2001).
26. K. N. Ganeshaiah and R. Uma Shaanker, Contours of conservation — A national agenda for mapping biodiversity, *Current Science* **75** (3), 292–298 (1998).
27. R. Uma Shaanker, K. N. Ganeshaiah, S. Krishnan, R. Ramya, C. Meera, N. A. Aravind, A. Kumar, D. Rao, G. Vanraj, J. Ramachandra, R. Gautheir, J. Ghazoul, N. Poole and B. V. Chinnappa Reddy, Livelihood gains and ecological costs of non-timber forest product dependence: assessing the roles of dependence, ecological knowledge and market structure in three contrasting human and ecological settings in South India, *Environmental Conservation* **31** (3), 242–253 (2004).
28. B. Chalavaraju, S. Deepali Singh, M. Nageswara Rao, G. Ravikanth, K. N. Ganeshaiah and R. Uma Shaanker, Conservation of bamboo genetic resources in Western Ghats: Status, threats and strategies, in: *Forest Genetic Resources: Status, Threats and Conservation Strategies*, R. Uma Shaanker, K. N. Ganeshaiah and K. S. Bawa (Eds), pp. 99–113. IBH, New Delhi (2001).
29. D. K. Ved, Medicinal plants trade in India — An overview, in: *Proceedings of the Conference on Policies, Management, Utilization and Conservation of Non-timber Forest Products (NTFP's) in the South Asia Region*, A. J. Hiremath, G. Joseph and R. Uma Shaanker (Eds), pp. 62–66. ATREE, Bangalore (2003).

30. D. K. Ved, C. Prathima, C. L. N. Morton and D. Shankar, Conservation of India's medicinal plant diversity through a novel approach of establishing a network of in situ gene banks, in: *Forest Genetic Resources: Status, Threats and Conservation Strategies*, R. Uma Shaanker, K. N. Ganeshaiah and K. S. Bawa (Eds), pp. 183–195. IBH, New Delhi (2001).
31. S. F. Sewort, Demographic effects of collecting rattan and their implications for sustainable harvesting, *Conservation Biology* **18** (2), 424–431 (2004).