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# Tree diversity in sacred groves of the Jaintia hills in Meghalaya, northeast India

K. UPADHAYA, H.N. PANDEY*, P.S. LAW and R.S. TRIPATHI
*Department of Botany, North-Eastern Hill University, Shillong 793 022, India; *Author for correspondence (e-mail: pandeyhn@yahoo.com; fax: +364-550-108)*

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**Abstract.** Biodiversity of woody species was investigated in Ialong and Raliang sacred groves of the Jaintia hills in Meghalaya, northeast India. These groves represent the climax subtropical broad-leaved forest of the area. A total of 738 individuals belonging to 82 species, 59 genera and 39 families was identified in a 0.5 ha plot of the Ialong sacred grove, whereas the same area in the Raliang sacred grove had 469 individuals of 80 species, 62 genera and 41 families. About 32% species were common to both groves. Lauraceae, with 10–17 species, was the dominant family. The canopy and subcanopy strata were respectively composed of 28 and 33% of the total tree species in the forest. The number of species as well as stem density were greater for the trees of lower dbh (5–15 cm) class compared to the higher ($>$ 66 cm) dbh class. The majority of the species showed a contagious distribution pattern and low frequency. The basal area varied from 57.4 to 71.4 $m^2\ ha^{-1}$. Species richness within the forest varied from 3 to 15 per 100 $m^2$ in Ialong and 3 to 12 per 100 $m^2$ in Raliang. The dominance–distribution curves showed high equitability and low dominance in both groves.

## Introduction

The humid tropical forests in the eastern Himalayas and northeast India, which harbour about 5000 endemic species, are very rich in plant wealth (Olson et al. 1998). Species richness of these forests has been recognized by taxonomists like Hooker (1872–1897), Kanjilal et al. (1934–1940), Rao and Panigrahi (1961), Rao (1969, 1974, 1977) and Balakrishnan (1981–1983), who carried out botanical explorations in different parts of northeast India. Recently, various studies have been carried out to quantify plant diversity and to understand the ecology of forest communities of the region (Khan et al. 1987; Khiewtam and Ramakrishnan 1993; Rao et al. 1997; Jamir 2000). Several researchers (Pascal and Pelissier 1996; Parthasarathy and Karthikeyan 1997; Ayyappan and Parthasarathy 1999; Parthasarathy 2001) have studied floristic diversity in the humid tropical forests of the Western Ghats of India, another biodiversity-rich area in the Indian subcontinent.

The Meghalaya state (25°02′ to 26°10′ N latitude and 89°45′ to 92°45′ E longitude) in northeast India, comprising the Khasi, Jaintia and Garo hills, covers an area of 22 429 $km^2$. The moist tropical and humid subtropical forests found in the state are rich in plant diversity. About 3128 flowering plants, including endemic, rare and primitive taxa have been reported from the state by Khan et al. (1997). The indigenous tribes of the state have an age-old tradition of preserving small patches of old growth forests as a part of their culture and religious beliefs. These forests, popularly known as sacred groves, are biodiversity-rich communities, which provide refuge for a large number of endemic and rare plant taxa of the region. In India, several studies have been made on the vegetation structure, composition and ecology of the sacred groves of Meghalaya (Barik et al. 1992; Khiewtam and Ramakrishnan 1993; Rao et al. 1997; Jamir 2000) and some other parts of India (cf. Chandrashekara and Sankar 1998; Ramakrishnan et al. 1998). This paper deals with the diversity of woody species (trees and lianas) and the structure of the two sacred groves located in the Jaintia hills of Meghalaya.

## Study site

The study was conducted in Ialong and Raliang sacred groves in the Jaintia hills, the eastern district of Meghalaya. These groves are remnants of subtropical broad-leaved forest (Champion and Seth 1968), which presumably is the climax vegetation of the area. The important tree species that constituted the forest canopy were *Engelhardtia spicata*, *Ficus* sp., *Castanopsis purpurella*, *Syzygium tetragonum*, *Sarcosperma griffithii*, *Prunus jenkensii* and *Neolitsea cassia*. These groves have been protected since time immemorial by the *Jaintia* tribe due to their strong religious beliefs. The Ialong sacred grove is located about 8 km east of Jowai town at an altitude of 1350 m a.s.l. (latitude 25°28′ N and longitude 92°25′ E), while the Raliang sacred grove is 28 km away from Jowai town in the northeast direction (altitude 1300 m a.s.l., latitude 25°30′ N, longitude 92°18′ E). The Ialong sacred grove is spread over an area of about 30 ha on a steep hill slope (20° to $>$ 60°), while the Raliang sacred grove covers an area of 20 ha on a gently sloping (10–25°) hill.

The climate of the area is monsoonic with distinct alternate wet and dry seasons. The wet season extends from April to October, followed by a dry period from November to March. During the wet season monthly rainfall ranges from 131 to 1557 mm, while in the dry period it is usually $<$ 50 mm per month. The annual rainfall was 6539 mm during the study period (1999–2000). Relative humidity also exhibited marked seasonal variation and was closely related to precipitation. The mean monthly temperature varied from a maximum of 26 °C in the month of April to a minimum of 5 °C in January (Figure 1).

The soil of the sacred groves was loamy (Raliang) to loamy sand (Ialong) and acidic (pH 4.5–4.62).

## Methods

Vegetation sampling was done during 1999–2000 by randomly laying 50 quadrats of 100 $m^2$ in each of the two groves. All woody species ($\geq$ 5 cm dbh) in each quadrat were tagged and measured. They were identified with the help of the Flora of Jowai (Balakrishnan 1981–1983), the Forest Flora of Meghalaya (Haridasan and

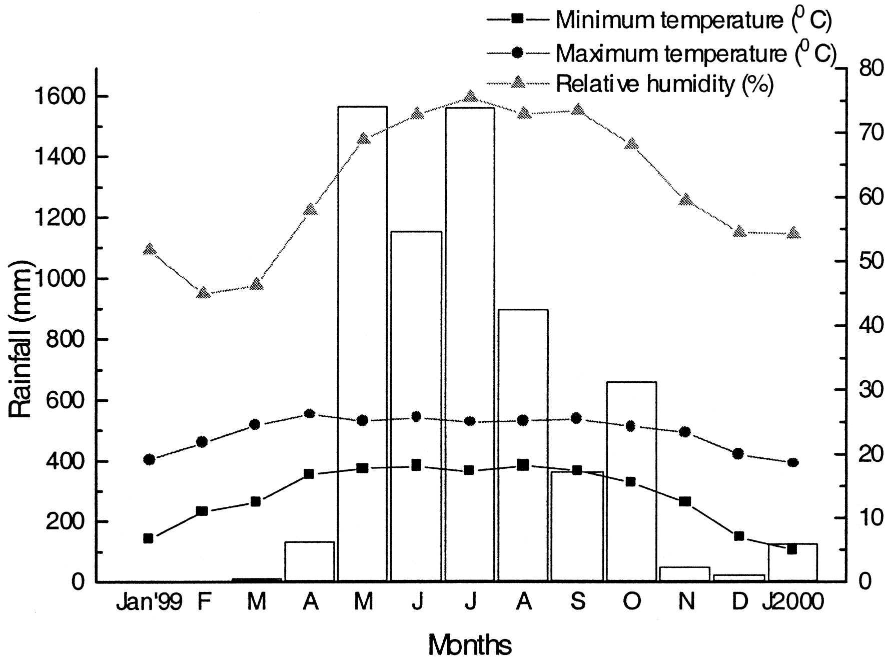


*Figure 1.* Monthly mean temperature (max and min), relative humidity and rainfall at Jowai during January 1999 and 2000.

Rao 1985–1987) and the Flora of Assam (Kanjilal et al. 1934–1940). The Herbaria of Botanical Survey of India, Eastern Circle, Shillong and Botany Department, NEHU, Shillong, were consulted for correct identification of plant specimens. The nomenclature of species follows the regional flora.

Frequency, density, dominance and importance value index (IVI) of all woody species were determined according to Misra (1968) and Muller-Dombois and Ellenberg (1974). The Whitford index was used to study dispersion patterns (Whitford 1948). Shannon's diversity index ($H^{-}$) and Simpson's dominance index ($\lambda$) were calculated according to Magurran (1988). Species richness was studied on the basis of number of species per 100 $m^2$ area.

## Results

### *Species–area curve*

The species–area curves for the two sacred groves were very similar. After a gradual increase in the species number with increase in area, they reached an asymptote at

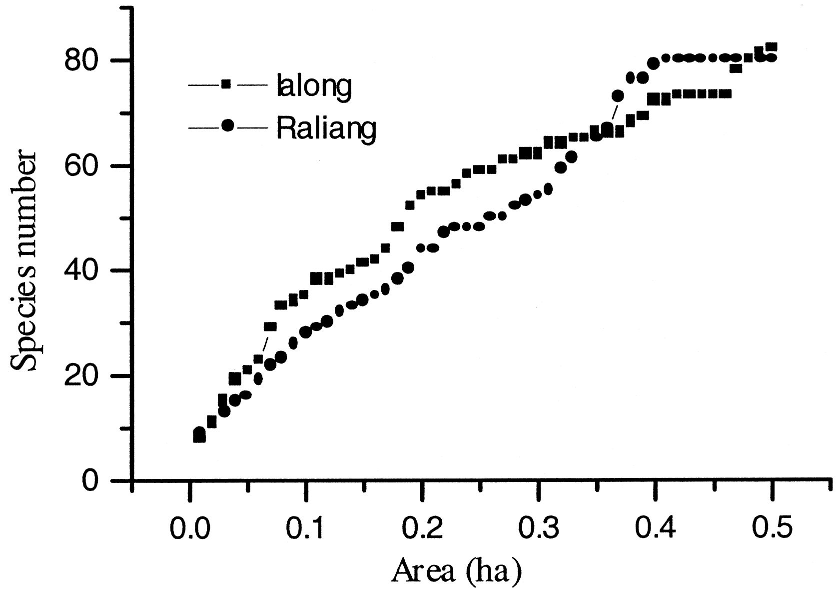


*Figure 2.* Species–area curves of the two sacred groves in the Jaintia hills.

0.35–0.4 ha. About 80% of the species were found in a 0.35 ha area, while 88–99% of the species were encountered in 0.4 ha (Figure 2).

*Species composition and their distribution pattern*

A total of 123 woody species was identified in a 1 ha area of the two sacred groves (Table 1). This included two gymnosperms, viz. *Pinus kesiya* in Ialong and *Podocarpus neriifolia* in Raliang sacred grove. In both groves, trees were distributed in three distinct strata, namely canopy (> 15 m height), subcanopy (8–15 m height) and under canopy (< 8 m height). The canopy layer was composed of *Acer laevigatum*, *Betula alnoides*, *Castanopsis* sp., *Cinnamomum* sp., *Ficus altissima* and *F. virens*, while *Antidesma bunius*, *Diospyros kaki*, *Pithecellobium monodelphum*, *Helicia nilagirica*, and *Schefflera hypoleuca* constituted subcanopy stratum. *Coffea khasiana*, *Erythroxylon kunthianum*, *F. hirta*, *Microtropis discolor*, *Sarcococca pruniformis* and *Wendlandia wallichii* formed the under canopy layer. The subcanopy, with 40 species, was the most species-rich layer in both sacred groves. Species richness (number of species per 100 $m^2$ area) clearly indicated that both the communities were a mosaic of high- and low-diversity patches (Figure 3A).

A total of 82 species belonging to 59 genera and 39 families and 80 species belonging to 62 genera of 41 families were identified in 0.5 ha plots in the Ialong and Raliang sacred groves, respectively. About 32% of the species were common to both groves. Lauraceae with 10 species, Fagaceae and Moraceae (eight species each), Araliaceae, Rubiaceae and Theaceae (five species each), Euphorbiaceae (four

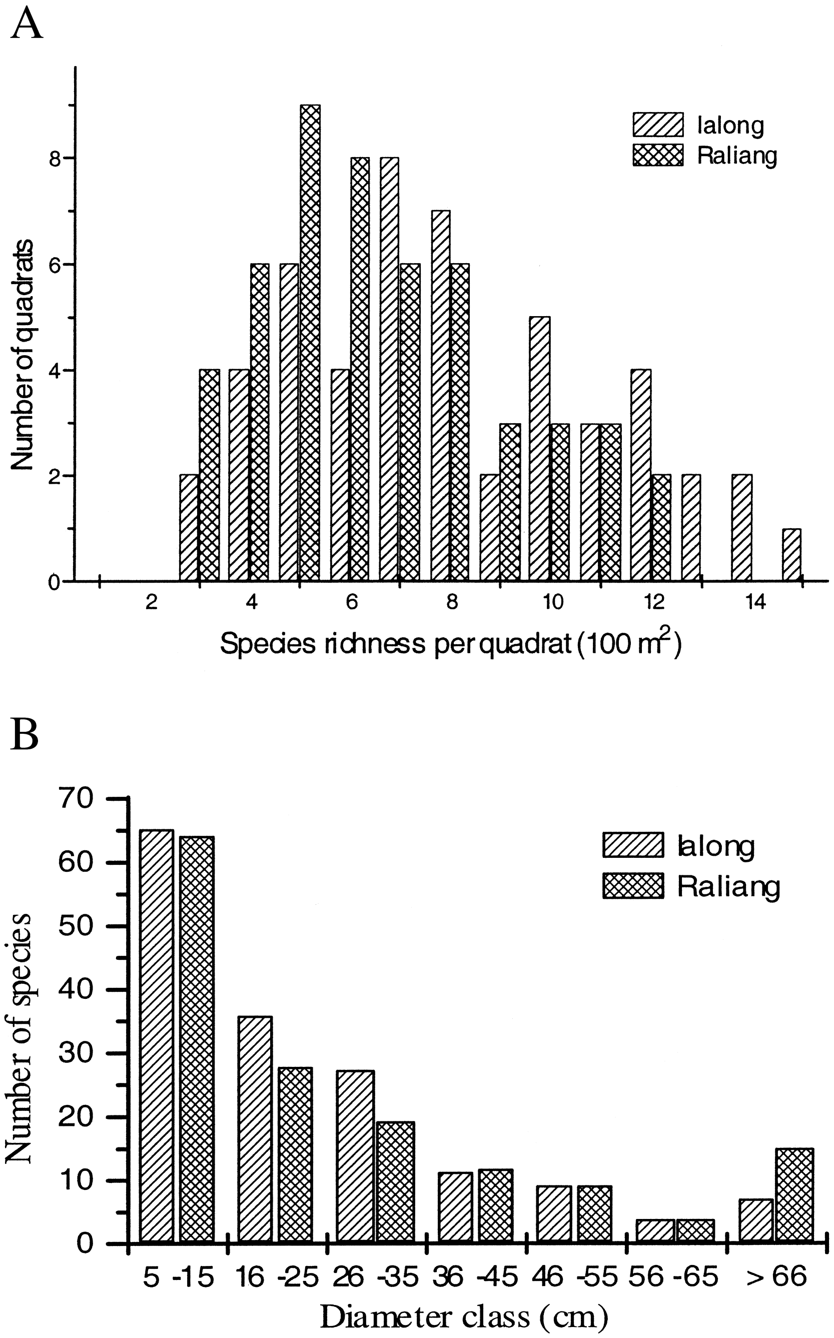


*Figure 3.* (A) Spatial distribution of species richness in the two sacred groves. (B) Distribution of species in different diameter classes in the two sacred groves.

*Table 1.* Frequency (%), density (number of plants per ha) and IVI of woody species (≥ 5 cm dbh) in Ialong and Raliang sacred groves.

| Plant species | Family | Ialong | | | Raliang | | |
|---|---|---|---|---|---|---|---|
| | | Frequency | Density | IVI | Frequency | Density | IVI |
| Canopy layer (15 m height) | | | | | | | |
| *Acer laevigatum* Wall. | Aceraceae | 4 | 6 | 1.48 | 16 | 26 | 11.41 |
| *A. oblongum* Wall. | Aceraceae | – | – | – | 2 | 2 | 0.68 |
| *Actinodaphne obovata* (Nees) Kosterm | Lauraceae | – | – | – | 50 | 108 | 25.59 |
| *Alseodaphne petiolaris* Hk.f. | Lauraceae | 2 | 6 | 1.85 | 6 | 6 | 1.79 |
| *Betula alnoides* Buch-Ham | Betulaceae | 12 | 12 | 16.13 | 2 | 4 | 2.39 |
| *Castanopsis indica* (Roxb) DC | Fagaceae | 10 | 10 | 2.44 | – | – | – |
| *C. purpurella* (Miq.) Balakr. | Fagaceae | 36 | 62 | 14.56 | 8 | 14 | 6.58 |
| *C. tribuloides* (Sm.) DC | Fagaceae | 20 | 30 | 12.9 | – | – | – |
| *Cinnamomum bejolghota* (Buch.-Ham.) Sweet. | Lauraceae | 2 | 2 | 0.58 | 2 | 2 | 2.02 |
| *Ci. glanduliferum* (Wall.) Meissn. | Lauraceae | 16 | 16 | 5.79 | – | – | – |
| *Ci. glaucescens* (Nees) Meissn. | Lauraceae | – | – | – | 2 | 2 | 3.40 |
| *Cryptocarya floribunda* Nees | Lauraceae | – | – | – | 6 | 6 | 2.05 |
| *Drymicarpus racemosus* (Roxb) Hk.f. | Anacardiaceae | – | – | – | 18 | 20 | 5.38 |
| *Elaeocarpus sikkimensis* Mast. | Elaeocarpaceae | – | – | – | 2 | 2 | 0.59 |
| *Engelhardtia spicata* Bl. | Juglandaceae | 28 | 40 | 18.34 | 6 | 8 | 4.81 |
| *Ficus altissima* Bl. | Moraceae | 6 | 8 | 7.40 | 4 | 4 | 12.92 |
| *F. virens* Ait. | Moraceae | 4 | 4 | 6.58 | 8 | 10 | 16.08 |
| *Garcinia tinctoria* (DC.) W.F. Wight | Clusiaceae | 2 | 2 | 0.53 | 4 | 4 | 1.27 |
| *Knema angustifolia* (Roxb.) Warb. | Myristicaceae | – | – | – | 22 | 28 | 7.72 |
| *Lithocarpus elagans* Soepadmo | Fagaceae | 20 | 28 | 3.46 | 14 | 14 | 7.89 |
| *L. fenestrata* (Roxb) Rehder | Fagaceae | 10 | 12 | 2.45 | 2 | 2 | 0.53 |
| *Lithocarpus* sp. | Fagaceae | 6 | 8 | 5.55 | 2 | 2 | 0.52 |
| *Michelia doltsopa* DC. | Magnoliaceae | – | – | – | 2 | 2 | 3.90 |
| *Neolitsea cassia* (L.) Kosterm. | Lauraceae | – | – | – | 32 | 64 | 16.47 |
| *Persea gamblei* (King ex Hk.f.) Kosterm. | Lauraceae | – | – | – | 4 | 4 | 1.82 |
| *Pe. odoratissima* (Nees) Kosterm. | Lauraceae | 14 | 18 | 6.06 | 6 | 10 | 3.76 |
| *Pinus kesiya* Royle ex. G. Don | Pinaceae | 2 | 2 | 1.19 | – | – | – |
| *Podocarpus neriifolia* D. Don | Podocarpaceae | – | – | – | 2 | 2 | 1.01 |
| *Prunus jenkinsii* Hook. f. | Rosaceae | 14 | 20 | 4.06 | 48 | 78 | 19.97 |
| *Pseudostreblus indica* Bureau | Moraceae | 16 | 48 | 14.2 | – | – | – |
| *Quercus serrata* Thunb. | Fagaceae | 2 | 2 | 0.65 | – | – | – |
| *Sarcosperma griffithii* Clarke | Sapotaceae | – | – | – | 72 | 116 | 36.88 |
| *Schima wallichii* Dyer | Theaceae | 14 | 20 | 3.84 | 4 | 4 | 1.50 |
| *Spondias axillaris* Roxb. | Anacardiaceae | – | – | – | 2 | 2 | 2.26 |
| *Syzygium tetragonum* (Wt.) Kurz | Myrtaceae | 38 | 60 | 12.55 | 12 | 14 | 3.74 |
| Subcanopy layer (8–15 m height) | | | | | | | |
| *Alangium chinensis* (Lour) Harms | Cornaceae | 14 | 16 | 4.08 | – | – | – |
| *Antidesma bunius* (L.) Spreng. | Euphorbiaceae | 2 | 2 | 0.4 | 2 | 2 | 0.52 |
| *Beilschmiedia assamica* Meissn | Lauraceae | – | – | – | 8 | 8 | 2.23 |
| *B. roxburghiana* Nees | Lauraceae | 2 | 2 | 0.47 | – | – | – |
| *Caryota urens* Linn. | Arecaceae | – | – | – | 8 | 8 | 2.23 |
| *Ci. tamala* (Spreng.) Nees & Eberm | Lauraceae | – | – | – | 4 | 4 | 1.05 |
| *Citrus latipes* (Swingle) Tanaka | Rutaceae | 8 | 8 | 1.78 | 6 | 6 | 1.56 |
| *Diospyros kaki* L.f. | Ebenaceae | 6 | 8 | 1.40 | 2 | 2 | 0.62 |
| *Dysoxylon gobara* (Buch.-Ham.) Merr. | Meliaceae | – | – | – | 42 | 62 | 14.07 |
| *El. Lancifolius* Roxb. | Elaeocarpaceae | – | – | – | 2 | 2 | 0.55 |

*Table 1.* (*continued*)

| Plant species | Family | Ialong | | | Raliang | | |
|---|---|---|---|---|---|---|---|
| | | Frequency | Density | IVI | Frequency | Density | IVI |
| *Erythrina arborescens* Roxb. | Fabaceae | 2 | 2 | 0.40 | – | – | – |
| *Eurya acuminata* DC. | Theaceae | 2 | 4 | 0.56 | – | – | – |
| *F. concinna* Meq. | Moraceae | 2 | 2 | 0.55 | – | – | – |
| *F. mclelandi* var. *rhododendrifolia* Corn. | Moraceae | 2 | 2 | 0.68 | – | – | – |
| *F. nerifolia* J. E. Sm. | Moraceae | 2 | 2 | 0.43 | 2 | 2 | 0.52 |
| *G. morella* Desr. | Clusiaceae | 2 | 6 | 1.22 | – | – | – |
| *Helecia nilagirica* Bedd. | Proteaceae | 38 | 62 | 9.76 | 10 | 28 | 5.23 |
| *Ilex embeloides* Hook. f. | Aqualifoliaceae | – | – | – | 2 | 4 | 0.75 |
| *Lindera latifolia* Hook. f. | Lauraceae | 16 | 28 | 4.5 | 8 | 10 | 2.45 |
| *Li. nagusa* (D. Don) Merr. | Lauraceae | 2 | 2 | 0.40 | – | – | – |
| *Li. reticulata* Benth. | Lauraceae | – | – | – | 8 | 8 | 3.16 |
| *Litsea semicarpifolia* (Nees) Hook. f. | Lauraceae | – | – | – | 8 | 10 | 2.47 |
| *Macaranga denticulata* (Bl.) Muell-Arg. | Euphorbiaceae | – | – | – | 4 | 4 | 1.47 |
| *Macropanax dispermus* (Bl.) O. Ktze | Araliaceae | 2 | 2 | 0.40 | 20 | 24 | 6.05 |
| *Manglietia insignis* (Wall) Bl. | Magnoliaceae | 2 | 2 | 0.40 | 6 | 8 | 2.87 |
| *Melia azedarach* Linn. | Meliaceae | – | – | – | 2 | 2 | 0.52 |
| *Myrica esculanta* Buch.-Ham. ex D. Don | Myricaceae | 6 | 6 | 2.85 | 2 | 2 | 0.55 |
| *Myrsine semiserrata* Wall. | Myrsinaceae | 10 | 14 | 2.37 | 2 | 2 | 0.52 |
| *Pe. bombocyania* (King ex Hk. f.) Kosterm. | Lauraceae | 2 | 4 | 0.73 | 2 | 2 | 0.52 |
| *Pe. duthiei* (Hook. f.) Kosterm. | Lauraceae | 2 | 4 | 1.03 | – | – | – |
| *Pe. parviflora* Meissn. | Lauraceae | – | – | – | 4 | 4 | 1.27 |
| *Pithecellobium monadelphum* (Roxb.) Kosterm. | Mimosaceae | 34 | 50 | 9.18 | 16 | 18 | 4.44 |
| *P. acuminata* (Wall) Dietr. | Rosaceae | – | – | – | 4 | 6 | 1.26 |
| *Q. griffithii* Hk. f. & Th ex DC. | Fagaceae | 2 | 2 | 0.73 | – | – | – |
| *Rhododendron arboreaum* Sm. | Ericaceae | 2 | 2 | 0.55 | – | – | – |
| *Rhus acuminata* DC. | Anacardiaceae | 28 | 36 | 8.73 | – | – | – |
| *Sapindus rarak* DC. | Sapindaceae | – | – | – | 2 | 2 | 0.52 |
| *Schefflera elata* (Buch.-Ham.) Harms | Araliaceae | 4 | 4 | 0.89 | – | – | – |
| *Sc. Hypoleuca* (Kurz) Harms | Araliaceae | 22 | 22 | 4.63 | 4 | 4 | 1.05 |
| *Vaccinium sprengelii* (G. Don) Rehd. | Vacciniaceae | 2 | 4 | 0.66 | – | – | – |
| Under canopy (< 8 m height) | | | | | | | |
| *Ant. khasiana* Hk. f. | Euphorbiaceae | 2 | 2 | 0.40 | – | – | – |
| *Calophyllum polyanthium* Choisy | Clusiaceae | – | – | – | 2 | 2 | 0.52 |
| *Camellia caudata* Wall. | Theaceae | 30 | 136 | 13.86 | – | – | – |
| *Capparis acutifolia* Sweet | Capparaceae | – | – | – | 24 | 28 | 6.92 |
| *Clerodendron bracteatum* Walp. | Verbenaceae | 2 | 2 | 0.40 | – | – | – |
| *Coffea khasiana* Hook. f. | Rubiaceae | 54 | 100 | 13.96 | 4 | 4 | 1.04 |
| *Croton oblongus* Burm. f | Euphorbiaceae | 4 | 4 | 0.85 | – | – | – |
| *Desmos longiflorus* (Roxb.) Safford | Annonaceae | – | – | – | 6 | 6 | 1.60 |
| *Erythroxylon kunthianum* Kurz. | Erythroxylaceae | 2 | 2 | 0.40 | 2 | 2 | 0.52 |
| *Eu. cerasifolia* (D. Don) Kobuski | Theaceae | 10 | 14 | 2.11 | – | – | – |
| *Eu. japonica* Thunb | Theaceae | 2 | 2 | 0.40 | – | – | – |
| *F. elmerii* Merr. | Moraceae | 2 | 2 | 0.40 | – | – | – |
| *F. hirta* var. *roxburghii* (Mig) King | Moraceae | 8 | 8 | 1.56 | 4 | 4 | 1.05 |
| *Itea chinensis* Hook. & Arn. | Iteaceae | – | – | – | 2 | 2 | 0.52 |
| *I. macrophylla* Wall. | Iteaceace | 2 | 2 | 0.47 | – | – | – |
| *Ixora subsessilis* G. Don. | Rubiaceae | 2 | 2 | 0.70 | 10 | 10 | 3.23 |
| *Li. salicifolia* (Nees) Hook. f. | Lauraceae | – | – | – | 2 | 2 | 0.52 |
| *Maesa indica* (Roxb.) Wall. | Myrsinaceae | 2 | 2 | 0.40 | – | – | – |

*Table 1.* (*continued*)

| Plant species | Family | Ialong | | | Raliang | | |
|---|---|---|---|---|---|---|---|
| | | Frequency | Density | IVI | Frequency | Density | IVI |
| *Mynea spinosa* Link. | Rubiaceae | 4 | 4 | 0.79 | – | – | – |
| *Microtropis discolor* (Wall.) Arn. | Celastraceae | 58 | 298 | 29.49 | – | – | – |
| *Ant. diandrum* (Roxb.) Roth | Euphorbiaceae | 2 | 2 | 0.40 | – | – | – |
| *Paramignya micrantha* Kurz | Rutaceae | – | – | – | 6 | 6 | 1.56 |
| *Phoebe lanceolata* (Nees) Nees | Lauraceae | 16 | 20 | 3.79 | 2 | 2 | 0.52 |
| *Picresema* sp. | Simaroubaceae | 6 | 8 | 1.31 | – | – | – |
| *Pittosporum podocarpum* Gagnep. | Pittosporaceae | – | – | – | 6 | 6 | 1.65 |
| *Pouzolzia frondosa var. fulgens* (Wedd.) Balakr. | Urticaceae | 2 | 2 | 0.42 | – | – | – |
| *Pseudobrassiopsis hispida* (Seem.) R. N. Ban. | Araliaceae | 4 | 4 | 0.78 | – | – | – |
| *Pyrularia edulis* (Wall.) DC. | Santalaceae | 14 | 20 | 3.62 | – | – | – |
| *Randia griffithii* Hook. f. | Rubiaceae | 2 | 2 | 0.40 | – | – | – |
| *Sarcococca pruniformis* Lindl. | Buxaceae | 10 | 10 | 2.22 | 2 | 8 | 1.47 |
| *Stercularia hamiltonii* (O. Ktze.) Adelb. | Sterculiaceae | – | – | – | 4 | 6 | 1.38 |
| *Styrax serrulatum* Roxb. | Styracaceae | 8 | 10 | 1.71 | 6 | 6 | 1.62 |
| *St. hookerii* Cl. | Styracaceae | 2 | 2 | 0.40 | – | – | – |
| *Symplocos pyrifolia* G. Don. | Symplocaceae | – | – | – | 6 | 6 | 1.66 |
| *Sy. spicata* Roxb | Symplocaceae | 8 | 10 | 1.96 | 2 | 2 | 0.52 |
| *Viburnum foetidum* Wall. | Caprifoliaceae | 2 | 2 | 0.40 | – | – | – |
| *Wendlandia wallichii* W. & A. Prodr. | Rubiaceae | 10 | 20 | 3.22 | 4 | 4 | 1.05 |
| Lianas | | | | | | | |
| *Embelia subcoriaceous* (Clarke). Mez. | Myrsinaceae | 4 | 4 | 0.77 | – | – | – |
| *Fissistigma verrucosum* (Hook. f. & Th.) Merr | Annonaceae | – | – | – | 10 | 14 | 3.09 |
| *Melodinus monogynous* Roxb. | Apocynaceae | – | – | – | 2 | 2 | 0.52 |
| *Rourea minor* (Gaertn.) Leenh. | Connanaceae | 24 | 44 | 6.22 | 10 | 12 | 2.92 |
| *Sc. venulosa* (W. & A.) Harms | Araliaceae | – | – | – | 2 | 2 | 0.52 |
| *Sc. wallichiana* (W. & A.) Harms | Araliaceae | 2 | 2 | 0.40 | – | – | – |
| *Tetrastigma leucostaphylum* (Dennest.) Balakr. | Vitaceae | – | – | – | 2 | 2 | 0.53 |
| *T. serullatum* (Roxb.) Planch. | Vitaceae | 12 | 14 | 2.49 | – | – | – |
| *Todallia asiatica* (L.) Lamk. | Rutaceae | 4 | 6 | 0.93 | – | – | – |
| *Tupidanthus calyptratus* Hook. f. & Thoms. | Araliaceae | – | – | – | 4 | 4 | 1.17 |
| Unidentified sp. | – | – | – | – | 2 | 2 | 0.52 |
| Total | | | 1476 | 300 | | 938 | 300 |

species) and Myrsinaceae (three species) were well represented in the Ialong sacred grove. Three families, Clusiaceae, Rutaceae and Styracaceae, were represented by two species each, whereas 28 families were monospecific. Similarly, in the Raliang sacred grove, Lauraceae with 17 species was the dominant family followed by Araliaceae, Fagaceae and Moraceae (four species each) and Rubiaceae (three species). Eleven families had two species each and 25 families were represented by only one species.

In both groves, the majority of species (65) were represented by young individuals (5–15 cm dbh) and species richness decreased with increase in dbh class, except in the case of mature trees beyond 66 cm dbh (Figure 3B). In both groves 87–91% of the species belonged to Raunkiaer's frequency class A and the rest were distributed in the B, C and D classes; class E was completely absent (Table 2). Similarly, the majority of species (90–92%) showed a contagious distribution

*Table 2.* Percentage distribution of species in Raunkiaer's frequency classes in the two sacred groves.

| Sacred grove | Raunkiaer's frequency class | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| Ialong | 86.6 | 11.0 | 2.4 | – | – |
| Raliang | 91.2 | 3.8 | 3.8 | 1.2 | – |

*Table 3.* Percentage of species showing different dispersion patterns (based on Whitford's index) in the two sacred groves.

| Sacred grove | Whitford's index | | |
|---|---|---|---|
| | Regular | Random | Contagious |
| Ialong | – | 9.8 | 90.2 |
| Raliang | 1.2 | 6.3 | 92.5 |

pattern and only 6–10% of the species were randomly distributed in the forest (Table 3). Regular dispersion was seen only in case of *S. griffithii*.

### *Density and basal cover*

Distribution of density in different dbh classes is shown in Figure 4. In Ialong and Raliang, 74% and 54%, respectively of the stems were in the 5–15 cm dbh class and only 2–5% of the individuals were present in the > 66 cm dbh class. The tree density varied from 938 to 1476 $ha^{-1}$ in the two groves (Table 4). In Ialong, 738 individuals encountered in a 0.5 ha area belonged to as many as 82 species. Most of these species (48%) were represented by one or two stems. *Microtropis discolor* had the maximum number of individuals (149 stems), followed by *Camellia caudata* with 68 stems (Figure 5). These species together constituted 29% of the tree density in the forest. In Raliang 469 individuals belonging to 80 species were present in a 0.5 ha area. One or two stems represented 53% of the species. *S. griffithii* had the highest number (58 stems), followed by *Actinodaphne obovata*, which had 54 stems. Together they constituted about 23% of the stand density. In both sacred groves, the density of young trees (5–15 cm dbh) was much greater compared to the mature trees (> 66 cm dbh). However, despite this, the basal cover of young trees was much lower than that of mature trees (2.72 versus 37.78 $m^2$ $ha^{-1}$; Figure 6).

### *Dominance distribution pattern*

The dominance distribution yielded log-normal curves showing a high equitability and low dominance in both groves (Figure 7). *Microtropis discolor* (IVI = 29.49) and *E. spicata* (IVI = 18.34) in Ialong and *S. griffithii* (IVI = 36.88) and *Ac. obovata* (IVI = 25.59) in Raliang were dominant and co-dominant species, respectively (Table 1).

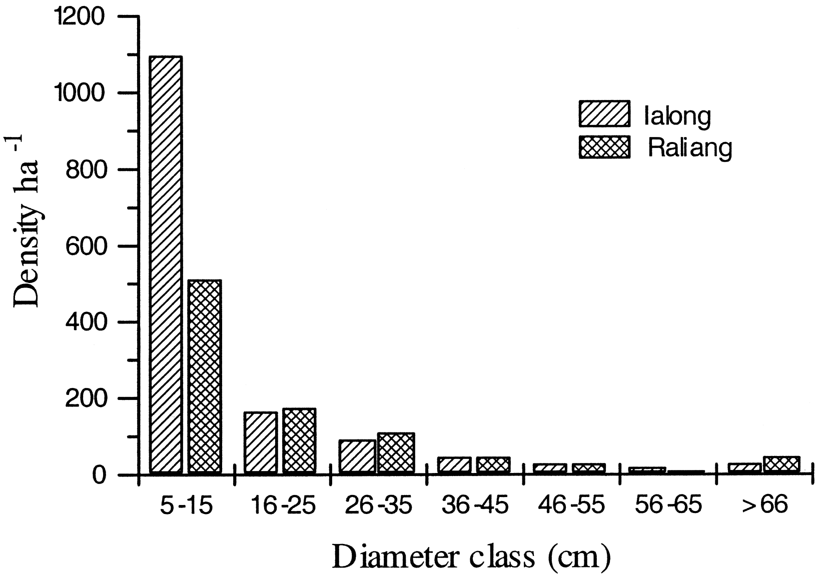


*Figure 4.* Distribution of density in different diameter classes in the two sacred groves.

## Discussion

It has been argued by several workers (cf. Brown 1981) that the productivity of the system and structural complexity or heterogeneity determine species richness in the community. Others have argued that neither ecosystem productivity nor structural complexities seem sufficient on their own to explain the observed pattern of species richness (Putman 1994). Slobodkin and Sanders (1969) opined that species richness of any community is a function of severity, variability and predictability of the environment in which it develops. Therefore, diversity tends to increase as the environment becomes more favourable and more predictable (Putman 1994). In the present case it is difficult to pinpoint the exact causes of high species richness in the sacred groves with the available data, but it seems that the favourable climatic conditions of the area and protection over a long period of time have played a major role in making these forest patches highly complex and species-rich. In this respect they are similar to tropical forests at Luquillo Mountains in Puerto Rico (Weaver and Murphy 1990), Papua, New Guinea (Edwards 1977; Edwards and Grubb 1977), and Yanamono, Peru (Gentry 1988). Forests in which only one tree species constitutes 50–80% of the canopy have been considered as low-diversity forests (Connell and Lowman 1989). On the basis of this criterion, the sacred groves may be regarded as high-diversity forest since ca. 28% of the tree species were present in the canopy layer.

Spatial distribution of species richness was not uniform in the forest; rather, both groves were a mosaic of low- and high-diversity patches. This seems to be the result

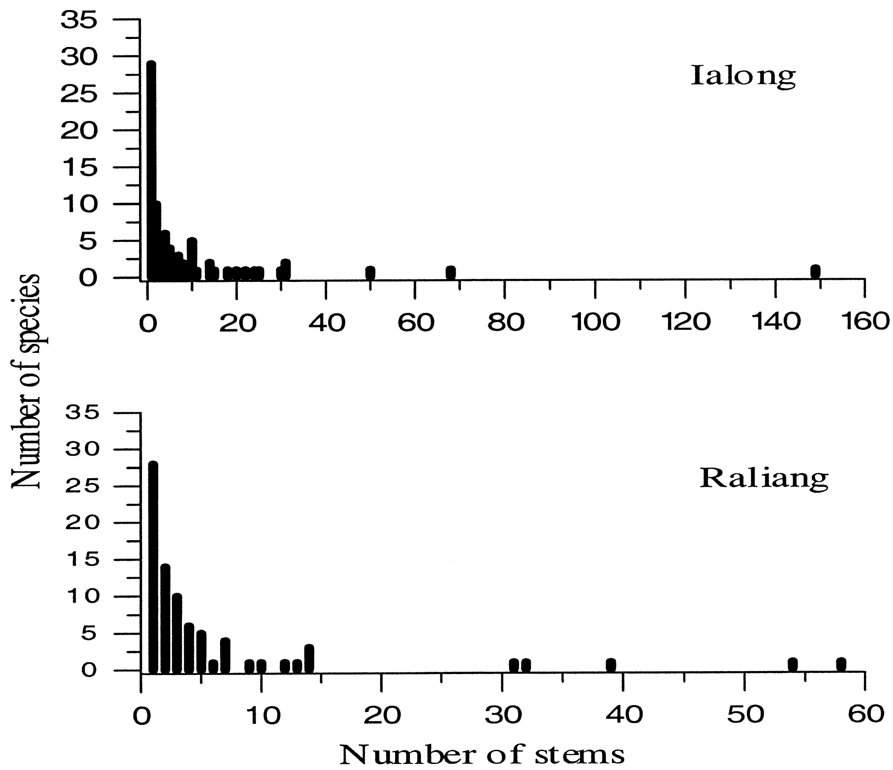


*Figure 5.* Species–stem relationship in a 0.5 ha area of the two sacred groves.

of the combined effect of non-extreme stable environmental conditions and gap-phase dynamics within the forest (Whittaker 1972).

Since the majority of the species was contagiously distributed and frequency class A was dominant, both groves were highly heterogeneous and patchy in terms of species distribution. Poore (1968), Ashton (1969) and Herwitz (1981) have described tropical rain forests as highly patchy communities, primarily due to gap-phase dynamics. Clumping of individuals of the same species is often clearly related to gap formation and dispersal mechanism of the species. Armesto et al. (1986) compared the dispersion pattern of trees in tropical and temperate climates in different parts of the world and concluded that clumping was characteristic of forest in which formation of canopy gaps was the chief source of disturbance. Hubbell (1979), in dry tropical forest, observed that all species were either clumped or randomly dispersed, with rare species more clumped than common species.

The species represented by one or two individuals in the study plot have been considered as rare species. The number of individuals of such species is probably kept low by a combination of unfavourable regeneration conditions, lack of appropriate habitat, or both (Hubbell 1979). Based on this criterion, 48–53% of

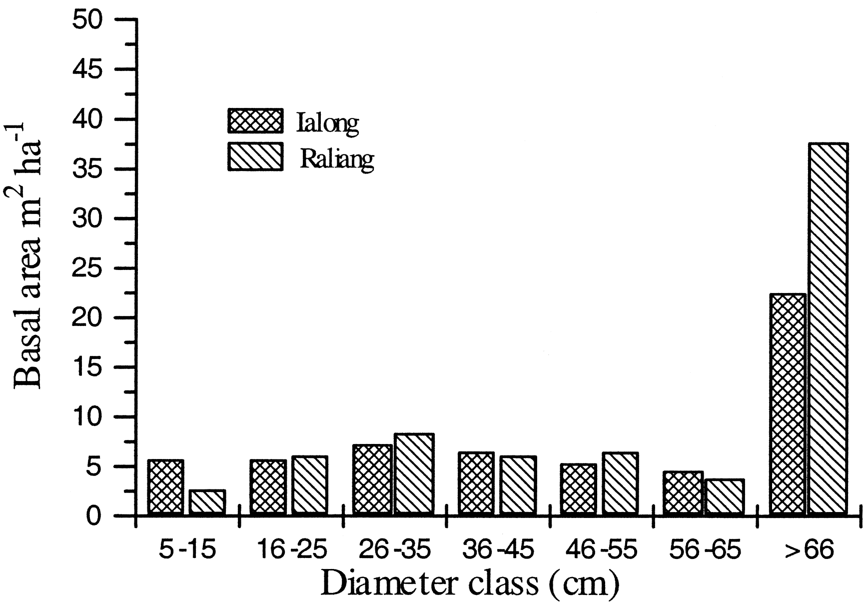


*Figure 6.* Distribution of basal area in different diameter classes in the two sacred groves.

*Table 4.* Density, basal area, dominance, diversity and evenness indices of woody species in two sacred groves in the Jaintia hills, Meghalaya.

| Variable | Ialong | Raliang |
|---|---|---|
| Density ($ha^{-1}$) | 1476 | 938 |
| Basal area ($m^2 ha^{-1}$) | 57.46 | 71.44 |
| Shannon's diversity index | 3.42 | 3.55 |
| Pielou's evenness index | 0.53 | 0.56 |
| Simpson's dominance index | 0.067 | 0.052 |

species may be termed as rare in the two groves. In this respect too, the two sacred groves are similar to tropical forests, which are known to possess large numbers of rare tree species. For example, Paijmans (1970), Thorington et al. (1982) and Parthasarathy and Karthikeyan (1997) reported that 50% of species in New Guinea, 40% on Barro Colorado Island, Panama, and 47% in the Western Ghats forests were rare.

Abundance of young individuals in both groves, a characteristic feature of vegetation on moist and infertile soil (Coomes and Grubb 2000), indicates a slow rate of seedling and sapling growth in the understorey and a relatively low rate of seedling mortality. This may also be due to tree-fall gaps having a varied microenvironmental variability (Rao et al. 1997), which might have favoured the tree species having different regeneration requirements (Phillips et al. 1994). The preponderance of young individuals in the mature forest has also been reported from

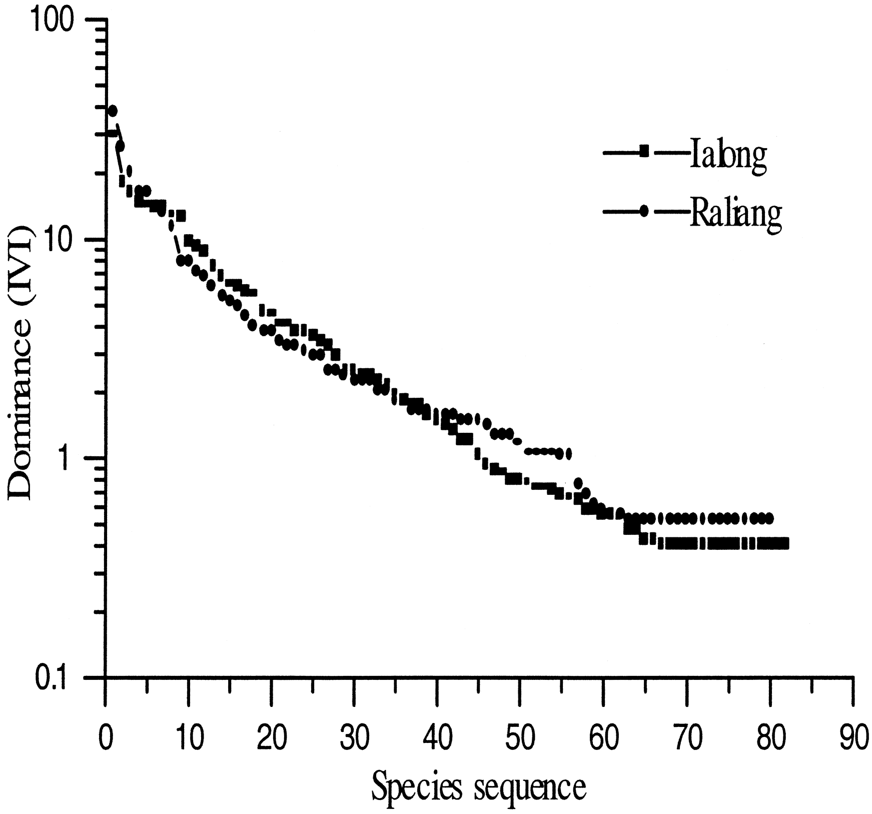


*Figure 7.* Dominance–diversity curves of woody species in the two sacred groves.

the Brazilian Amazon (Campbell et al. 1992), Costa Rica (Nadkarni et al. 1995) and the Western Ghats (Parthasarathy 2001).

The basal cover (57.46 and 77.44 $m^2 ha^{-1}$) in both the sacred groves is close to that of other tropical forests, such as equatorial forest (10–45 $m^2 ha^{-1}$) in Kongo Island, Zaire (Mosango 1991), tropical rain forest (78 $m^2$ $ha^{-1}$) in Amazonia (Campbell et al. 1992), lower montane forest (62 $m^2$ $ha^{-1}$) in Costa Rica (Nadkarni et al. 1995), evergreen forest (55.3–78.3 $m^2 ha^{-1}$) around Sengattheri in the Western Ghats (Parthasarathy 2001), and in the dry evergreen forest (32.8 $m^2 ha^{-1}$) of Puthupet, South India (Parthasarathy and Sethi 1997).

The dominance–distribution curve showed a log-normal distribution. A logarithmic or broken-stick distribution reflects that the community is primarily ordered with respect to one dominating factor, while a log-normal distribution represents a more complex community, ordered by a multiplicity of interactions (May 1975). The latter appears to be the case for the sacred groves under study.

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**References**

Armesto J.J., Mitchell J.D. and Villogram C. 1986. A comparison of spatial patterns of trees in tropical and temperate forests. Biotropica 18: 1–11.

Ashton P.S. 1969. Speciation among tropical forest trees: some deductions in the light of recent evidence. Biological Journal of the Linnaean Society London 1: 155–196.

Ayyappan N. and Parthasarathy N. 1999. Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. Biodiversity and Conservation 8: 1533–1554.

Balakrishnan N.P. 1981–1983. Flora of Jowai and Vicinity, Meghalaya, 2 Vols. BSI, Howrah, India.

Barik S.K., Pandey H.N., Tripathi R.S. and Rao P. 1992. Microenvironmental variability and species diversity in treefall gaps in a sub-tropical broad-leaved forest. Vegetatio 103: 31–40.

Brown J.H. 1981. Two decades of homage to Santa Roselia: towards a general theory of diversity. American Zoologist 21: 877–888.

Campbell D.G., Stone J.L. and Rosas A. Jr. 1992. A comparision of the phytosociology and dynamics of three flood plain (Varzae) forests of known ages, Rio Jurua, Western Brazalian Amazon. Botanical Journal of the Linnaean Society 108: 213–237.

Champion H.G. and Seth S.K. 1968. A Revised Survey of Forest Types of India. Government of India Press, Delhi, India.

Chandrashekara U.M. and Sankar S. 1998. Ecology and management of sacred groves in Kerala, India. Forest Ecology and Management 112: 165–177.

Connell J.H. and Lowman M.D. 1989. Low-diversity tropical rain forests: some possible mechanisms for their existence. The American Naturalist 134: 89–119.

Coomes D.A. and Grubb P.J. 2000. Impacts of root competition in forests and woodlands: a theoretical framework and review of experiments. Ecological Monographs 70: 171–207.

Edwards P.J. 1977. Studies in montane rain forest in New Guinea. II. The production and disappearance of litter. Journal of Ecology 65: 971–1022.

Edwards P.J. and Grubb P.J. 1977. Studies of mineral cycling in a montane rain forest in New Guinea. I. The distribution of organic matter in the vegetation and soil. Journal of Ecology 65: 943–969.

Gentry H.A. 1988. Tree species richness of upper Amazon forests. Proceedings of the National Academy of Sciences USA 85: 156–159.

Haridasan K. and Rao R.R. 1985–1987. Forest Flora of Meghalaya, 2 Vols. Bishen Singh Mahendrapal Singh, DehraDun, India.

Herwitz S.R. 1981. Regeneration of selected tropical tree species in Corcovado National Park, Costa Rica. Publication in Geography 24. University of California, Berkeley, California.

Hooker J.D. 1872–1897. Flora of British India. Vols. 1–7. L. Reeve & Co., Ashford, Kent, UK.

Hubbell S.P. 1979. Tree dispersion, abundance and diversity in a tropical dry forest. Science 203: 1299–1309.

Jamir S.A. 2000. Studies on plant biodiversity, community structure and population behaviour of dominant tree species of some sacred groves of Jaintia hills, Meghalaya, Ph.D. Thesis, North-Eastern Hill University, Shillong, India.

Kanjilal V.N., Kanjilal P.C., Das A., De R.N. and Bor N.L. 1934–1940. Flora of Assam, 5 Vols. Government Press, Shillong, India.

Khan M.L., Rai J.P.N. and Tripathi R.S. 1987. Population structure of some tree species in disturbed and protected subtropical forests of north-east India. Acta Oecologia 8: 247–255.

Khan M.L., Shaily M. and Bawa K.S. 1997. Effectiveness of the protected area network in biodiversity conservation, a case study of Meghalaya state. Biodiversity and Conservation 6: 853–868.

Khiewtam R.S. and Ramakrishnan P.S. 1993. Litter and fine root dynamics of relic sacred grove forest of Cherrapunjee in northeastern India. Forest Ecology and Management 60: 327–344.

Magurran A. 1988. Ecological Diversity and its Measurement. Princeton University Press, Princeton, New Jersey.

May R.M. 1975. Patterns of species abundance and diversity. In: Cody M.L. and Diamond J.M. (eds), Evolution of Communities. Belknap Press, Harvard, Massachusetts, pp. 81–120.

Misra R. 1968. Ecology Work Book. Oxford & IBH Publishing Co., Calcutta, India.

Mosango M. 1991. Contribution 'AI' etude botanique biogeochemique de I ecosystem forest region equatoriale (IFBe Kongalo, Zaire). Belgian Journal of Botany 124: 167–194.

Muller-Dombois D.D. and Ellenberg H. 1974. Aims and Methods of Vegetation Analysis. John Wiley and Sons, New York.

Nadkarni N.M., Matelson T.J. and Haber W.A. 1995. Structural characteristics and floristic composition of neotropical cloud forest, Monteverde, Costa Rica. Journal of Tropical Ecology 11: 482–495.

Olson M.D., Dinerstein E., Mittermeier R.A., Myers N., Thomsen J.B. and da Fonseca G.A.B. 1998. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conservation Biology 12: 516–520.

Paijmans K. 1970. An analysis of four tropical rain forest sites in New Guinea. Journal of Ecology 58: 77–101.

Parthasarathy N. 2001. Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. Current Science 80: 389–393.

Parthasarathy N. and Karthikeyan R. 1997. Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandal Coast, South India. Biodiversity and Conservation 6: 1063–1083.

Parthasarathy N. and Sethi P. 1997. Trees and liana species and population structure in a tropical dry evergreen forest in south India. Tropical Ecology 38: 19–30.

Pascal J.P. and Pelissier R. 1996. Structure and floristic composition of a tropical rain forest in south-west India. Journal of Tropical Ecology 12: 191–214.

Phillips O.L., Hall P., Gentry A.H., Sawyer S.A. and Vasquez R. 1994. Dynamics and species richness of tropical rain forest. Proceedings of the National Academy of Science USA 91: 2805–2809.

Poore M.E.D. 1968. Studies in Malaysian rain forest. I. The forest on Triassic sediments in Jengka forest reserve. Journal of Ecology 56: 143–196.

Putman R.J. 1994. Community Ecology. Chapman & Hall, London.

Ramakrishnan P.S., Saxena K.G. and Chandrashekara U.M. 1998. Conserving the Sacred for Biodiversity Management. Oxford and IBH publication Co Pvt Ltd, New Delhi, India.

Rao A.S. 1969. Orchids of Khasi and Jaintia Hills. Bulletin of Botanical Survey of India 11: 115–123.

Rao A.S. 1974. The vegetation and phytogeography of Assam–Burma. In: Mani M.S. (ed.), Ecology and Biogeography in India. W. Junk, The Hague, the Netherlands, pp. 204–205.

Rao A.S. 1977. Floristic studies in north-eastern India (Old Assam Region). Bulletin Botanical Survey of India 19: 56–60.

Rao R.S. and Panigrahi G. 1961. Distribution of vegetational types and their dominant species in Eastern India. Journal of the Indian Botanical Society 40: 274–285.

Rao P., Barik S.K., Pandey H.N. and Tripathi R.S. 1997. Tree seed germination and seedling establishment in tree-fall gaps and understorey in a sub-tropical forest of northeast India. Australian Journal of Ecology 22: 136–145.

Slobodkin L.B. and Sanders H.L. 1969. On the contribution of environmental predictability to species diversity. Brookhaven Symposia in Biology 22: 82–95.

Thorington R.W. Jr., Tannenbaum B., Tarak A. and Rudran R. 1982. Distribution of trees on Barro Colorado Island: a five hectare sample. In: Leigh E.G., Rand A.S. Jr. and Windror D.M. (eds), The Ecology of Tropical Forest – Seasonal Rhythms and Long-term Changes. Smithsonian Institution Press, Washington, DC.

Weaver P.L. and Murphy P.G. 1990. Forest structure and productivity in Puerto Rico's Luquillo mountains. Biotropica 22: 69–82.

Whitford P.B. 1948. Distribution of woodland plants in relation to succession and clonal growth. Ecology 30: 199–208.

Whittaker R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 213–251.