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Received 28 February 2005; revised accepted 7 November 2005

Status of medicinal plants in the disturbed and the undisturbed sacred forests of Meghalaya, northeast India: population structure and regeneration efficacy of some important species

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Plants used by indigenous people as traditional medicine were identified from a disturbed (Swer) and undisturbed (Mairang) sacred grove of Meghalaya. Medicinal flora of the two sacred groves consists of 80 woody species. Species richness was adversely affected by anthropogenic activities and it decreased from 57 in the undisturbed to 41 in the disturbed sacred grove. Distribution of important value index was more among species in the Mairang sacred grove. The position of common species was changed from undisturbed to disturbed forests. The population structure and regeneration potential of *Camellia caduca* (endemic and less frequent), *Cinnamomum pauciflorum* (endemic and rare), *Erithroxylum kunthianum* (endemic) and *Picrasma javanica* (rare) were studied. Seedling recruitment of all four species was higher in the disturbed condition. However, per cent conversion of seedlings into saplings was more in the undisturbed forest, except in the case of *E. kunthianum*. The gaps facilitated per cent conversion of saplings into trees in the first three species. Regeneration efficiency of these species was higher in the Swer than the Mairang sacred grove.

Keywords: Anthropogenic disturbance, population structure, regeneration efficacy, sacred groves, traditional healthcare system.

PLANTS have been used in the traditional healthcare system from time immemorial, particularly among tribal communities. The World Health Organization (WHO) has listed 20,000 medicinal plants globally[1]; India's contribution[2] is 15–20%. According to the WHO estimate, about 80% of the population in the developing countries depends directly on plants for its medicines[3,4]. In India, about 2000 drugs used are of plant origin[5]. Plant resources are depleting globally at an alarming rate and a number of economically and medicinally important plant species will soon be extinct. In the last few decades over-exploitation of forest resources has led to species loss. As a result, 20–25% of existing plant species in India has become endangered. Medicinal plants are now under great pressure due to their excessive collection or exploitation. The degree of threat to natural populations of medicinal plants

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has increased because more than 90% of medicinal plant raw material for herbal industries in India and also for export is drawn from natural habitat[6].

The sacred groves of Meghalaya are as ancient as the civilization itself. The sacred forests (groves) are traditionally managed by local people and set aside for religious purposes. These groves are a treasure house of plant diversity and harbour a large number of valuable species. Ecologically, these groves are remnant of climax vegetation. Plants used in the primary healthcare are mostly drawn from sacred forests (groves). Some endemic and rare species are confined to these groves only[7]. Past studies on herbal medicines in forests of Meghalaya[8], ethnobotany of Khasi and Garo tribes of Meghalaya[9,10], medicinal plants of Balphakram Wildlife Sanctuary used by local tribes in Garo hills district of Meghalaya[11] and ethnobotany of the Khasi and Garo tribes of Meghalaya[12], provide basic information on distribution of medicinal plants of community forests in Meghalaya, other than sacred groves. Past studies do not provide adequate information on medicinal plant wealth in sacred groves of Meghalaya. Effect of disturbance on conservation status, community organization and population structure of important species is still untouched. There is an urgent need of such type of study that may be helpful in developing an appropriate strategy for conservation of these valuable biological resources on sustained basis.

Thus, the present study was carried out with an objective to explore the medicinal plants in the disturbed and undisturbed sacred groves and to determine the effect of disturbance on community organization, population structure and regeneration efficacy of important species.

The study was conducted in the Swer sacred grove (lat. 25°25′N, long. 91°47′E; altitude 2035 m asl) of the East Khasi hills and the Mairang sacred grove (lat. 25°33′N; long. 91°38′E; altitude 1748 m asl) of the West Khasi hills districts of Meghalaya. The Swer sacred grove is located about 28 km south of Shillong on the way to Cherrapunji and it covers an area of 40 ha on the hill 'Lum Swer'. This grove is characterized by undisturbed (15 ha), mildly/moderately disturbed (15 ha) and highly disturbed (10 ha) patches[13]. The overall disturbance index was estimated as 19.5% (per cent of tree stumps to the total number of trees, including tree stumps in the stand). The Mairang sacred grove is 52 km southwest of Shillong near Mairang town. It covers an area of 80 ha on the hill. This grove is well protected; however, collection of fuel-wood and cattle grazing were seen in buffer zone[14].

The climate of the area is monsoonic with distinct warm–wet and cool–dry seasons. The average annual rainfall is about 2500 mm, more than 85% of which is received during May to September.

Vegetation sampling was done during 2000–02, following the methods outlined by Misra[15], and Mueller-Dombois and Ellenberg[16]. The quadrat method was adopted for recording field data on woody plant species of the sacred forests. Thirty quadrats each for trees (10 m × 10 m size) and saplings (5 m × 5 m size) were laid in both the forests. The seedlings were observed in 120 quadrats of 1 m × 1 m size in each forest. National and regional floras[7,17] were used for plant identification. Plant specimens collected during the field study were counterchecked with the herbarium of the Botanical Survey of India, Eastern Circle, Shillong for confirmation of species identified. The importance value index (IVI) of species was computed to determine species rank[18].

Indigenous people actively engaged in traditional healthcare practice were interviewed for recording their unique knowledge about medicinal values of different plant species. Information on medicinal value of plants was counterchecked from the available literature[19–22]. The endemicity and rarity of plant species were ascertained with the help of the *Red Data Book*[23–25] and an elaborated review by Balakrishnan and Vasudeva[26].

Four medicinally important woody species present in both the groves, namely *Camellia caduca*, *Cinnamomum pauciflorum*, *Erythroxylum kunthianum* and *Picrasma javanica* were considered to determine their population structure by adopting girth-distribution method. The first three species are endemic to Meghalaya. *C. caduca* is less frequent and two species, namely *C. pauciflorum* and *Picrasma javanica* are rare. The individuals were grouped into seven girth classes, viz. 0–5, 5–20, 20–40, 40–60, 60–80, 80–100 cm and above 100 cm. The regeneration efficacy of the above species was determined by studying relative size of seedling (gbh 0–5 cm), sapling (gbh 5–20 cm) and tree (gbh > 20 cm) populations.

The medicinal use of different plant species is given in Table 1. Altogether, 80 medicinally important woody species were identified from the two sacred groves. Anthropogenic activities resulted in low species content (41 species) in the Swer sacred grove. However, the Mairang sacred grove had high species richness (57 species). Seventeen species were common in both the groves. The cutting of mature trees was responsible for change in community organization and altering the botanical composition[13]. Terborgh[27] has reported that anthropogenic activities often accelerate species loss than operations of internal biological processes. Forty families of angiosperms were recorded from both the groves. Lauraceae was the dominant and most specious (11 species) family followed by Euphorbiaceae (5 species). Disturbance was directly linked with loss of species. Lauraceae had ten species in the undisturbed Mairang sacred grove and five species in the disturbed Swer sacred grove. Majority of families (22) had single species. Change in microenvironment had resulted in elimination of some single-species families. As a result, the Swer sacred grove showed reduced number of monospecific families.

Out of seven endemics in two groves, three species, namely *C. caduca*, *C. pauciflorum* and *E. kunthianum* were present in both the groves. However, *E. lawsonii* and *I. embeloides* were present in the Swer sacred grove only, and *L. latifolia*, and *S. khasiana* in the Mairang sacred

Table 1. Medicinal use, importance (species ranked based on IVI of respective species) and conservation status of woody species of the Swer and Mairang sacred groves

Species (vernacular name)	Family	Medicinal use	Species rank: SSG/MSG (conservation status)
Aesculus assamica Griff. (Dieng-sangkenrop)	Sapindaceae	Leaf and bark in fever, fish poisoning	0/4
Alangium chinense (Lour.) Harms (Diengsohkympel)	Cornaceae	Root astringent, anthelmintic	0/57
Antidesma diandrum (Roxb.) Roth. (Dieng-japew)	Euphorbiaceae	Leaf diphoretic	0/27
Ardisia paniculata Roxb.	Myrsinaceae	Root used in haemorhoea,	25/0
Berberis wallichiana DC. (Dieng-mat-shynrang)	Berberidaceae	bark and roots are medicinal	10/0
Callicarpa arborea Roxb. (Dieng-lakhiot)	Verbenaceae	Leaf, stem and bark medicinal; leaf juice in fever, gastric diseases, giddiness, headache; bark in skin diseases and scorpion sting, carminative and used in cutaneous diseases	0/14
Camellia caduca Cl. ex Brandis (Dieng-tyrnem)	Theaceae	Leaves astringent, digestive, carminative, diuretic	4/50 (endemic, less frequent)
Canna indica Linn.	Cannaceae	Rhizome in tumour	0/28
Casearia vareca Roxb. (Dieng-soh-rang)	Flacourtiaceae	Fruit juice anthelmintic and in ear ache; anticancer and anti-vermicidal properties	5/0
Celtis cinnamomea Lindl ex Planch	Ulmaceae	Wood as blood purifier	0/40
Celtis tetranda Roxb.	Ulmaceae	Fruit in amenorrhoea and colic diseases	0/11
Cinnamomum granduliferum (Wall.) Meissn. (Dieng-pingwail)	Lauraceae	Contains d-camphor good substitute for Sassafras	0/53
Cinnamomum pauciflorum Nees. (Dieng-lorthia)	Lauraceae	Bark expectorant, deodorant, diuretic, carminative and used in bronchitis, asthma, diarrhoea, nausea	13/12 (endemic, rare)
Cinnamomum tamala Fr. Nees. (Dieng-sia-sia)	Lauraceae	Aromatic; leaf in diarrhoea, colic pain (carminative); bark in cold and cough	31/0
Citrus medica Linn. (Sohkwit)	Rutaceae	Root laxative, anthelmintic, diuretic; fruit astringent, stimulant, anthelmintic, carminative, digestive; preserved rind used in dysentery	0/1
Clerodendrum infortunatum Auct non Linn. (Dieng-kylasla)	Verbenaceae	Root astringent, decoction used as a demulcent in gonorrhoea	0/55
Combretum pilosum Roxb.	Combretaceae	Stem medicinal	0/30
Cordia fragrantissima Kurz. (Bahari)	Boraginaceae	Bark astringent, anthelmintic and used in fever, diarrhoea, skin diseases; fruit astringent, anthelmintic, diuretic, expectorant and used in lung and spleen diseases	0/15
Croton caudatus Geisel. (Soh-lambrang)	Euphorbiaceae	Leaf, stem and root medicinal; leaf and shoot extract used for malaria and cholera	0/51
Cryptocarya amygdalina Nees. (Dalgappa)	Lauraceae	Leaf and bark medicinal	0/2 (rare)
Diospyros pilosula (DC.) Hiem.	Ebenaceae	All parts are medicinal and used for stomach disorder, piles, kidney stone, diarrhoea, and dysentery	28/0
Dysoxylum binectariferum Hk.f. et Bedd. (Bol-narang)	Meliaceae	Wood and seeds are medicinal	24/10
Embelia ribes Burm. F. (Bakul lata)	Myrsinaceae	Bark, root, fruit and seeds are medicinal; root acrid, astringent, stomachic and used in skin diseases, leprosy, nervous debility; leaf astringent in skin diseases and leprosy	0/46
Engelhardtia spicata Leschn ex Bl. (Dieng-lamba)	Juglandaceae	Bark contains a resin used in medicine	19/7
Erythrina stricta Linn. (Dieng-songdkhar)	Fabaceae	Bark sedative, carminative, digestive, anthelmintic, expectorant, diuretic; leaf anthelmintic, diuretic, stomachic; used in rheumatism, itching, burning, fever, fainting, asthma, leprosy, epilepsy	0/41
Erythroxylum kunthianum Wall ex Kurz. (Dieng-painkhar)	Erythroxylaceae	Bark chewed with betel leaf as a stimulant.	7/24 (endemic)
Euonymus lawsonii Cl. & Pr.	Celastraceae	Bark in syphilis, indigestion, liver disorder; seed oil for lice	35/0 (endemic)
Eurya acuminata DC. (Dieng-shit)	Theaceae	Leaf medicinal	3/13
Eurya japonica Thunb. (Dieng-pyrshit)	Theaceae	Leaf used for poulticing skin eruption	2/21

(*Contd...*)

Table 1. (*Contd…*)

Species (vernacular name)	Family	Medicinal use	Species rank: SSG/MSG (conservation status)
Ficus hispida Linn. f. (Dieng-lapong)	Moraceae	Bark, fruit and seeds are emetic and purgative and used in anaemia, jaundice, fever, ulcer	0/34
Garcinia cowa Roxb. ex DC. (Rengran)	Clusiaceae	Plant cathartic; leaf and fruit acidic and used to cure dysentery, stomach trouble	32/52
Gaultheria fragrantissima Wall. (Jirhap)	Ericaceae	Plant stimulant, carminative used in rheumatism, neuralgia as an antiseptic; wormicidal action against hookworm; root used in menstrual disorder	23/0
Glochidion lanceolarium (Roxb) Voight	Euphorbiaceae	Bark in stomach ailments	22/0
Grewia multiflora Juss. (Dieng-tyrbhong)	Tiliaceae	Bark astringent, expectorant and used in cough, skin diseases, clearing hair	0/35
Helicia excelsa Bl.	Proteaceae	Bark colic	30/0
Ilex khasiana Purk.	Aquifoliaceae	Bark and root decoction in cold and cough, tuberculosis	36/0 (rare)
Ilex embelioides Hk.f.	Aquifoliaceae	Bark and root decoction in cold and cough, tuberculosis	33/0 (endemic/rare)
Ixora acuminata Roxb.	Rubiaceae	Leaf and roots are medicinal	0/56
Kydia calycina Roxb. (Dieng-misiri)	Malvaceae	Leaf, bark, roots are medicinal; root paste with oil used as an embrocation in rheumatism and lumbago, also as febrifuge	27/0
Lindera latifolia Hk.f. (Dieng-jalang)	Lauraceae	Aerial part medicinal	0/42 (endemic/rare)
Lindera pulcherrima (Nees) Benth. (Dieng-jaburit)	Lauraceae	Bark used in cold, cough, worm	0/9
Litsea citrata Bl. (Dieng-sying)	Lauraceae	Fruit medicinal perfume deodorant, insect repellent	11/22
Litsea salicifolia Roxb. ex Nees. (Dieng-lali)	Lauraceae	Aerial part medicinal	14/39
Lonicera japonica Thunb. (Jermei-ren)	Caprifoliaceae	Leaves astringent used for gargles; flower used for pulmonary diseases	21/0
Lyonia ovalifolia (Wall) Druce. (Diengla-samiang)	Ericaceae	Root used for rheumatism, sprain, scabies, eczema, cut-wounds	17/0
Macropanax undulatus (Wall. ex D.Don.) Seem. (Dieng-jarasi)	Araliaceae	Leaf medicinal	40/8
Mahonia nepalensis DC. (Dieng-niangmat)	Berberidaceae	Bark medicinal	38/0
Michelia champaca Linn. (Shap)	Magnoliaceae	Bark stimulant, purgative; seed, bark, root and flower medicinal	0/31
Micromelum pubescens non Bl. (Dieng-sohsat)	Rutaceae	Root used with betel leaf in cough	0/23
Myrica esculenta Buch-Ham ex D. Don. (Sohphie)	Myricaceae	Bark astringent, carminative, antiseptic and decoction used in asthma, fever, chronic bronchitis, lung infections, dysentery, toothache; leaf, fruit, root and bark for worms, jaundice, dysentery	18/47
Olax acuminata Benth.	Olacaceae	Leaf medicinal and used as cathartic	34/0
Olea dioica Roxb. (Poreng)	Olacaceae	Bark febrifuge	0/48
Persea bombycina (King ex Hk.f.) Koster. (Som)	Lauraceae	Leaf in falling of hair	39/19
Persea gamblei (King ex Hk.f.) Koster. (Omgthat)	Lauraceae	Plant juice in muscular pain	0/17
Phoebe attenuata (Nees) Nees. (Bonsum)	Lauraceae	Ash of berries cures sores	0/3
Phyllanthus parbifolius Ham.	Euphorbiaceae	Plant astringent, diuretic, stomachic and used in jaundice, diarrhoea, dysentery, fever	6/0
Phyllanthus retusus Dennst.	Euphorbiaceae	Leaf diuretic; bark astringent, diuretic	0/37
Picrasma javanica Bl. (Bor-jagreng)	Simaraubaceae	Bark as febrifuge; leaves applied to sores; used as anaema to expel throat worm and as tonic	41/18 (rare)
Polyalthia longifolia Benth & Hk.f. (Diengther)	Annonaceae	Bark febrifuge	0/20
Pongamia glabra Vent.	Fabaceae	Leaf and root juice in cough, leprosy	0/43
Prunus nepaulensis (Ser.) Steud. (Soh-iong)	Rosaceae	Fruit astringent; leaf diuretic and used in dropsy; hardwood astringent, acrid, refrigerant	0/38

(*Contd...*)

Table 1. (*Contd…*)

Species (vernacular name)	Family	Medicinal use	Species rank: SSG/MSG (conservation status)
Pyrus pashia D.Don. (Soh-shur)	Rosaceae	Leaf medicinal	26/54
Randia longiflora Lamk. (Jyrmishiah-tiewkrot)	Rubiaceae	Fruit extract insecticidal and insect repellant and used in insecticidal preparation	0/36
Rhododendron arboreum Sm. (Tiewsaw)	Ericaceae	Bark in preparation of snuff; tender leaf for relief from headache, in diarrhoea, dysentery; dried flower fried with ghee to check blood dysentery	1/0
Rhus javanica (Dieng-sohma)	Anacardiaceae	Fruit in stomach pain, skin trouble, treatment of papyloma; root in rheumatism	0/8
Rhus succedaenia (non L.) Gamble (Dieng-khlaw)	Anacardiaceae	Fruit in phthasis; galls on branches astringent, tonic, expectorant, stimulant and used in diarrhoea and dysentery	20/25
Salix tetrasperma Roxb. (Jamynrei)	Salicaceae	Bark febrifuge; dried and powdered leaves with sugar in rheumatism, epilepsy, piles, swellings, stones in bladder	37/0
Sapindus attenuatus Wall. ex Hiern. Rarak DC.	Sapindaceae	Fruit to remove pimples	0/44
Saprosma ternatum Hk.f.	Rubiaceae	Leaf to relieve flatulence and stomach ache; bark juice in indigestion	9/0
Schima khasiana Dyer. (Dieng-ngan)	Theaceae	Bark irritates skin, anthelmintic, rubefacient	0/29 (endemic, rare)
Schima wallichii (DC.) Korth. (Dieng-nganbuit)	Theaceae	Bark, leaf medicinal; leaf paste on cuts and wounds; leaf decoction to cure flatulence; powdered bark to cattle to kill intestinal worms	15/5
Skimmia laureola (DC.) Sieb. & Zucc. Ex Walp.	Rutaceae	Leaf medicinal	0/32
Spondias pinnata (Linn f.) Kurz. (Dieng-sohpier)	Anacardiaceae	Bark refrigerant and used in dysentery, rheumatism; fruit in dyspepsia	29/0
Sterculia coccinea Roxb. (Nok-chepeta)	Sterculiaceae	Bark in veterinary medicines	0/26
Symplocos racemosa Roxb. (Bolimitap)	Symplocaceae	Bark in diarrhoea, menstrual disorder, indigestion, ulcer, eye diseases, tonic	12/0
Symplocos theaefolia D.Don. (Dieng-pei)	Symplocaceae	Extract of leaf and twig shows activity against human epidermoid carcinoma of the naso-pharynx in tissue culture	0/49
Trevesia palmata (Roxb.) Vis. (Dieng-lakor)	Araliaceae	Leaf, root used in stomach ache	0/16
Viburnum foetidum Wall. (Dieng-sohlang)	Caprifoliaceae	Plant astringent, emmenetic; leaf juice used in haemorrhage	8/45
Vitex negundo Linn. (Pasutia)	Verbenaceae	Entire plant medicinal; decoction in cough, fever, malaria, chicken pox, pneumonia; leaf vermifuge, used in headache, tonic; flower astringent	0/33
Zanthoxylum khasianum Hk.f. (Soh-tiewshiah)	Rutaceae	Bark, fruit, seed – carminative, stomachic, anthelmintic	16/0

SSG, Swer sacred grove; MSG, Mairang sacred grove; 0, absent.

grove only. Eight species were found rare, including *C. caduca* (less frequent). *C. caduca* and *P. javanica* and were represented in both the groves. However, *I. khasiana* was present in the Swer sacred grove only, and *C. amygdalina* in the Mairang sacred grove only. *C. caduca*, *I. embelioides*, *L. latifolia* and *S. khasiana* were rare as well as endemic species. The IVI of species was more evenly distributed in the Mairang sacred grove that indicated greater level of stability of community. The IVI of *R. arboreum* (33.2), the dominant species in the Swer sacred grove was two and half times greater than *C. medica* (14.3), the dominant species in the Mairang sacred grove. This depicts that disturbance-favoured growth of *R. arboreum* and it also suppresses survival of other species in the Swer sacred grove. The shift in the position of the common species seems to be linked with disturbance (Table 1)[13].

The density–distribution (Figure 1) of four important species (*C. caduca*, *C. pauciflorum*, *E. kunthianum* and *P. javanica*) indicated sufficient recruitment of seedlings (gbh 0–5 cm) and it was markedly high in *E. kunthianum*. A similar result with greater number of individuals in lower girth class was also reported[14] in a subtropical humid forest of Meghalaya. Increased seedling density of all four species in the Swer sacred grove was mainly due to gaps. The disturbance provides a chance of gap formation in this grove that facilitates germination of seeds and growth of plants in early stage. Increased grazing pressure may have been a contributory factor for low sapling density of

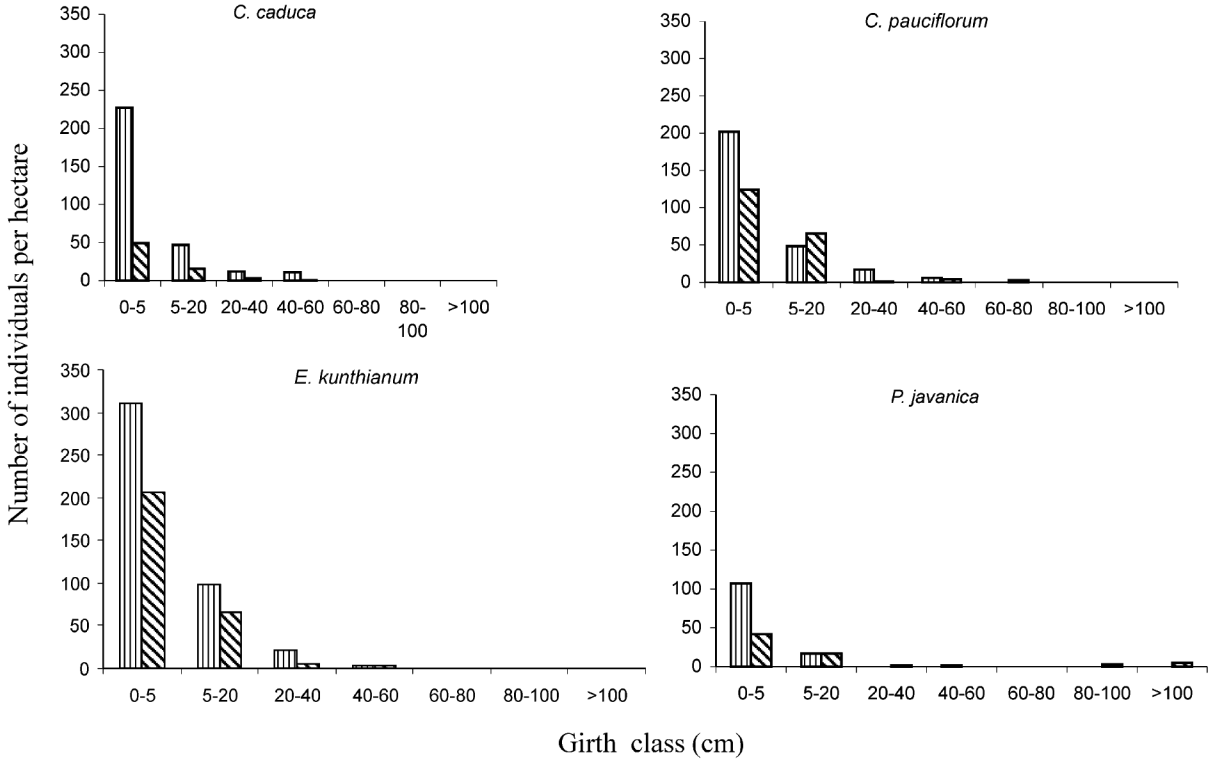

Figure 1. Population structure of four important species in the Swer and Mairang sacred groves.

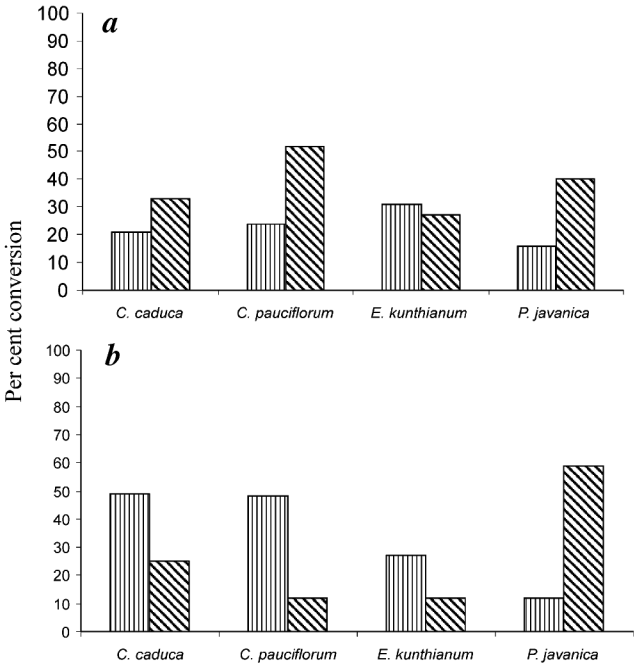

Figure 2. Regeneration efficiency of four important species in terms of per cent conversion of (***a***) seedlings into saplings and (***b***) saplings into trees in the Swer and Mairang sacred groves.

C. pauciflorum in the Swer sacred grove[28]. On the other hand, arrested growth of saplings under close canopy could be one of the reasons for low sapling density of *C. caduca* and *E. kunthianum* in the Mairang sacred grove[14].

The overall population structure of all four species was similar, as they showed a successive decrease in population density from seedling to tree stage. There was a gradual decrease in density with increase in girth size. Individuals of *C. caduca* and *E. kunthianum* were present up to girth class 40–60 cm, and of *C. pauciflorum* up to 60–80 cm girth, as they are small trees. However, *P. javanica* had trees beyond 100 cm girth in the Mairang sacred grove. Trees of this species were absent in some intermediate girth classes. This may be due to cutting of mature trees of this species, with greater degree of exploitation in the Swer sacred grove[13]. The distribution of plants of different age groups in the tree population depicts that these sacred groves are stable forests. In respect of density–distribution of trees, these forests are similar to the tropical dry evergreen forests of southern India[29,30].

The regeneration potential of the above four species was highly influenced by disturbance (Figure 2 *a*, *b*). The percentage of seedlings that grew into saplings varied from 16 (*P. javanica*) to 31 (*E. kunthianum*) in the Swer sacred grove, and 27 (*E. kunthianum*) to 52 (*C. pauciflorum*) in the Mairang sacred grove. The per cent conversion of saplings into trees ranged from 12 (*P. javanica*) to 49 (*C. caduca*) in the Swer sacred grove. However, the percentage of saplings that grew into trees was 12 (*C. pauciflorum* and *E. kunthianum*) to 59 (*P. javanica*) in the Mairang sacred grove. The per cent conversion of seedlings to saplings was more in the Mairang sacred grove, except *E. kunthianum*. *C. caduca* showed a marked variation in per

cent conversion of seedlings into saplings from the Swer (24) to the Mairang (52) sacred groves. The disturbance adversely affected growth and survival of plants at juvenile stage[28]. The percentage of saplings that attained tree stage was greater in the Mairang sacred grove only in *P. javanica*. The gaps facilitated conversion of saplings into trees and the first three species showed greater values in the Swer sacred grove.

The disturbance adversely affected regeneration of *P. javanica* and *E. kunthianum*, which showed a positive response to disturbance. In the first two species, disturbance favoured conversion of saplings into trees. On the contrary, percentage of seedlings that grew into saplings was more in the Mairang sacred grove. The first three species showed better regeneration in the disturbed condition in terms of conversion of saplings into trees. This could be due to their shrubby habit[28].

The study revealed that change in community organization and loss of species were closely linked with disturbance. Study of population structure and regeneration potential of endemic and/or rare species depicts that disturbance favoured seedling recruitment, but its conversion into saplings was adversely affected. Low conversion of saplings into trees in the Mairang sacred grove could be enhanced by formation of gaps within the forest. To ensure sustainable utilization, there is an obvious need of proper conservation strategy. Priority should be given to rare endemics. Intellectual Property Rights, patent laws and other related issues would contribute much towards conservation of such rare endemics.

Moreover, the traditional healthcare system is an age-old practice in Meghalaya. This system of ethnic communities is conservation-oriented and has great potential. About 90% of the rural population in hilly terrain depends on traditional healthcare system. Traditional knowledge is transmitted from one generation to another. This is a secret confined to a few persons living in and around the forests. This system needs to be studied, documented and used. This study suggests a coordinated effort for strengthening the medicinal plant sector in Meghalaya. This could only be achieved by pooling conservation, biodiversity and healthcare system together by involving the Government, NGOs and research institutions. Collaborative research and integrated efforts are necessary to preserve the knowledge of indigenous people on traditional healthcare. Mass awareness programmes on usefulness of plants will be a basic tool for conservation and sustainable utilization of medicinal plants. These efforts may help in upliftment of the state economy as well as long-term security of the traditional healthcare system.

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ACKNOWLEDGEMENTS. We thank the University Grants Commission, New Delhi for financial support under UGC–DSA programme. We are also grateful to the Head, Department of Botany, NEHU, Shillong for extending basic facilities to complete this work.

Received 18 May 2005; revised accepted 10 October 2005

Pollination by bees and passerine birds and seed dispersal by monkeys in the white teak *Gmelina arborea* Roxb., a commercially important timber tree species in the Eastern Ghats

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***Gmelina arborea* is a dry season bloomer. It produces large, brownish-yellow, bisexual and zygomorphic nectariferous flowers. The breeding system involves both self- and cross-pollination, but most of the self-pollinated flowers abort after two weeks of growth. The floral characteristics suggest bee-floral syndrome, but bees, especially *Xylocopa* bees and passerine birds, pollinated the flowers. The natural fruit set rate is low and it is attributed to selective elimination of self-pollinated fruits, removal of numerous flowers by lorikeets in quest of nectar, large amounts of pollen collection by *Amegilla* and *Apis* bees, and availability of low maternal resources during dry season for the growing fruits. The yellow, fleshy fruits are single-seeded. Monkeys ingest and excrete the seeds unaffected; in this manner they contribute to seed dispersal.**

Keywords: Bees, *Gmelina arborea*, monkeys, passerine birds, pollination, seed dispersal.

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GMELINA ARBOREA is native to India and other Asian countries. It was introduced into many tropical countries such as Brazil, Costa Rica and Ivory Coast. This species is commercially important for its timber and is often called 'white teak'. In Brazil, it is cultivated for its timber, which is used for furniture and as raw material for pulp and paper industries[1]. In India, *G. arborea* is widely used as one of the most important timbers and is commonly available in timber stores. Despite its importance as a timber source, *G. arborea* has not been studied for its floral biology, breeding systems, pollinators and seed dispersers in its native geographic regions. In this context, these aspects have been studied for *G. arborea* in its natural areas and discussed in the light of relevant information.

The study was conducted during February–May 2003 and 2004 for *G. arborea* occurring in the Eastern Ghats forests, Visakhapatnam district (Lotugedda, Chintapalli and Paderu), Andhra Pradesh, India. Fifty tagged mature buds on ten different trees were followed for anthesis, anther dehiscence, and stigma receptivity and flower life. Stigma receptivity was tested with hydrogen peroxide according to Dafni[2]. Ten mature buds were bagged and used after anthesis to measure the volume of nectar per flower. The nectar sugar concentration was also noted using a Hand Sugar Refractometer (Erma, Japan). Hand-pollination tests were conducted for autogamy (bagged, and hand-manipulated and bagged), geitonogamy and xenogamy. For each mode, fifty flowers, ten each from five different trees were used. For geitonogamy and xenogamy, anthers were removed at mature bud stage and bagged immediately. The bags were removed from these flowers at 1100 h on the following day and the stigmas were pollinated with pollen from different flowers from the same tree for geitonogamy and with the pollen from different trees located at a different place for xenogamy. These flowers were again closed with bags and followed for fruit set. For natural fruit set, two hundred flowers on 16 inflorescences were tagged and followed until fruit maturation. As the initial (and young) and final fruit set rates were different, the fruit set rate was separately calculated for the initial stage and ripened stage of fruits. Ripe fruits were used to calculate seed set rate. Flower visitors included bees and birds and their foraging activities in relation to pollination were observed during daytime. Frugivores included monkeys only, and they were observed for their role in seed dispersal. The observations were confirmed by examining the excreta of monkeys for *G. arborea* seeds.

G. arborea is a deciduous tree species. It is leafless during flowering period (Figure 1 *a*) and flowers during