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C O N T E N T S

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Palynological investigation of subsurface Lower Gondwana sediments in Gundala area, Lingala-Koyagudem Coalbelt, Godavari Graben, Andhra Pradesh, India

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ABSTRACT

Jha N., Saleem M. & Aggarwal N. 2013. Palynological investigation of subsurface Lower Gondwana sediments in Gundala area, Lingala-Koyagudem Coalbelt, Godavari Graben, Andhra Pradesh, India. Geophytology 42(2): 85-92.

Qualitative and Quantitative analyses of the palynoflora obtained from borecores, SGK-2, SGK-3 and SGK-4, drilled near Gundala, Godavari Graben, Andhra Pradesh, have been carried out. The palynoassemblage, containing 23 genera and 38 species, is characterized by dominance of radial monosaccates (chiefly *Parasaccites*) and subdominance of non-striate disaccates (chiefly *Scheuringipollenites*). This association, along with presence of *Crucisaccites* and few striate disaccates, suggests its resemblance with palynofloras obtained from the Upper Karharbari Formation of other basins (Late Sakmarian - Early Artinskian). Presence of Upper Karharbari palynoflora has been demarcated in lithologically designated Lower Barakar Formation.

Key-words: Palynology, Upper Karharbari, Lower Gondwana, Permian, Godavari Graben. Andhra Pradesh, India.

INTRODUCTION

The Lingala-Koyagudem coalbelt, situated in the south-western part of Godavari sub-basin, comprises Gundala block, which contains varied number of carbonaceous horizons (Text-figure 1). The palynological investigation carried out on three borecores near Gundala (SGK-2, SGK-3 and SGK-4), drilled by Singareni Collieries Company Limited, is presented here.

MATERIAL AND METHOD

Altogether, 70 samples (30 from SGK-2, 20 from SGK-3 and 20 from SGK-4) were collected. Of these, 20 samples (12 from SGK-2, 4 from SGK-3 and 4 from SGK-4) yielded palynofossils. About 20 gm of the material from each sample was first treated with conc. hydrofluoric acid (HF) for two days and then with commercial nitric acid (HNO_3) for 3-4 days followed by treatment with 10% potassium hydroxide (KOH) after thorough washing with water. The macerates were then mounted in canada balsam with the help of polyvinyl chloride (PVC) and slides were prepared. The slides are stored in the museum of the Birbal Sahni Institute of Palaeobotany, Lucknow. Two hundred specimens per sample were counted for palynofloral analysis.

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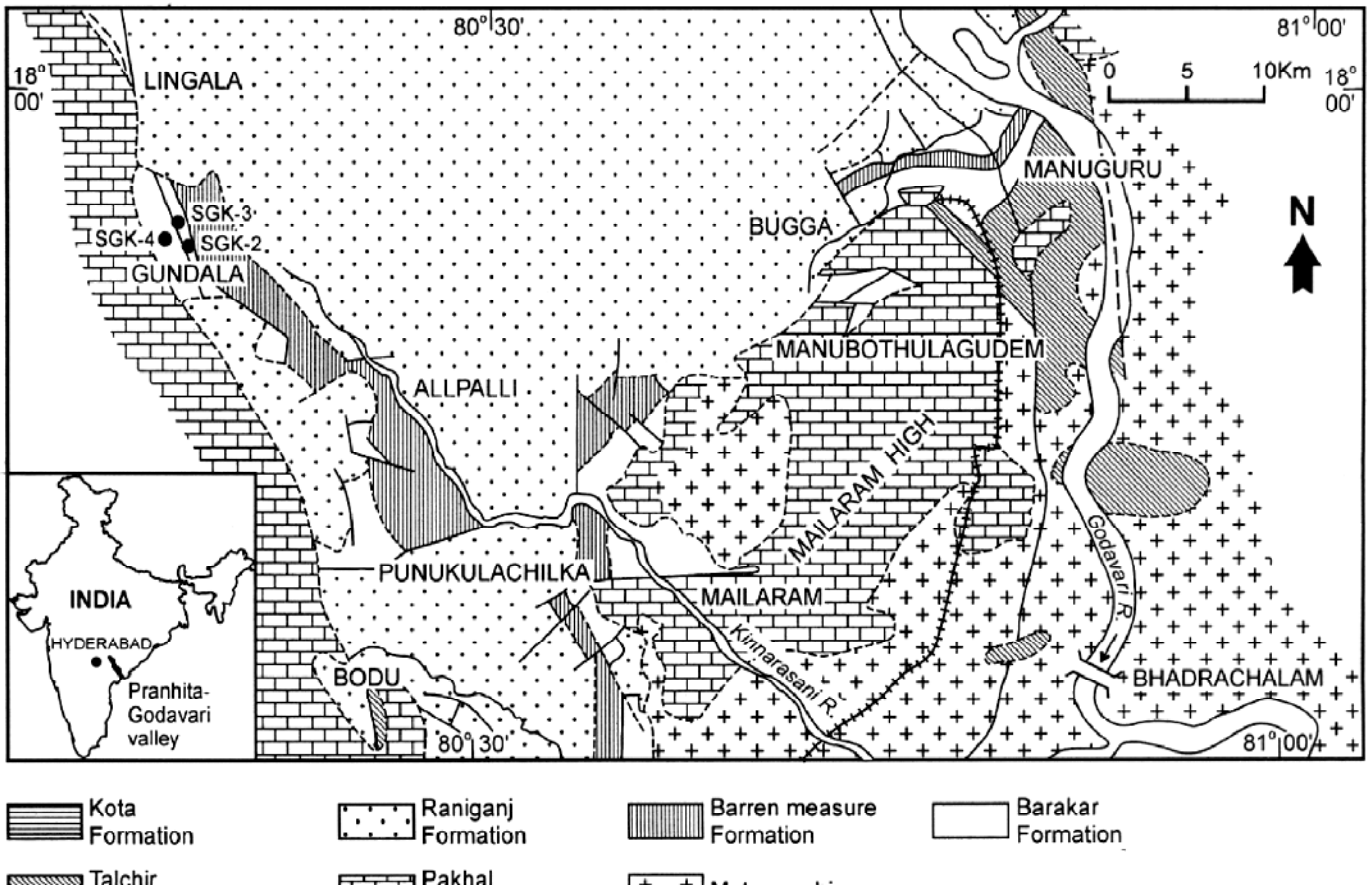


Text-figure 1. Geological map of the Gundala area showing location of borecores SGK-2, SGK-3 and SGK-4

Table 1. Stratigraphic succession in Gundala block

Age	Group	Formation	Lithology
Recent	-	-	Soil Cover
Permian	Lower Gondwana	Kamthi	Sandstone with subordinate shales and coal seams
		Barren Measures	Grey to greenish grey, coarse to pebbly felspathic sandstone with shale bands
		Barakar	Predominantly medium to coarse grained, grey white sandstones, altered feldspars with subordinate clays/shales and persistent coal seams
		Talchir	Fine to medium grained, pale green sandstone with occasionally olive green shales
----------Unconformity----------			
Proterozoic		Pakhal	Quartzites, Phyllites and Dolomites

→

Plate 1

1. *Callumispora gretensis* (Balme & Hennelly) Bharadawj & Srivastava, BSIP slide no. 13939, R50-2. 2. *Microfoveolatispora foveolata* (Tiwari) Tiwari & Singh, BSIP slide no. 14228, K59-2. 3. *Parasaccites korbaensis* Bharadwaj & Tiwari, BSIP slide no. 13977, S41-2. 4. *Parasaccites distinctus* Tiwari, BSIP slide no. 13815, O60-4. 5. *Parasaccites* sp., BSIP. slide no. 13886, S52-2. 6. *Crucisaccites indicus* Srivastava, BSIP slide no. 14140, O68-3. 7. *Potonieisporites concinnus* Tiwari, BSIP slide no. 14229, E51-3. 8. *Scheuringipollenites barakarensis* (Tiwari) Tiwari, BSIP slide no. 13982, P53-3. 9. *Scheuringipollenites maximus* (Hart) Tiwari, BSIP slide no. 14227, Q41-3. 10. *Ibisporites diplosaccus* Tiwari, BSIP slide no. 13806, N65-2. 11. *Platysaccus densicorpus* Anand-Prakash, BSIP slide no. 14224, O48-4. 12. *Striatopodocarpites tiwarii* Bharadwaj & Dwivedi, BSIP slide no. 14226, S38-4. 13. *Striatites communis* Bharadwaj & Tiwari, BSIP slide no. 13806, J63-1. 14. *Striatopodocarpites subcircularis* Sinha, BSIP slide no. 14225, K55-1. 15. *Tiwariasporis simplex* (Tiwari) Maheshwari & Kar, BSIP slide no. 13846, H35-3.

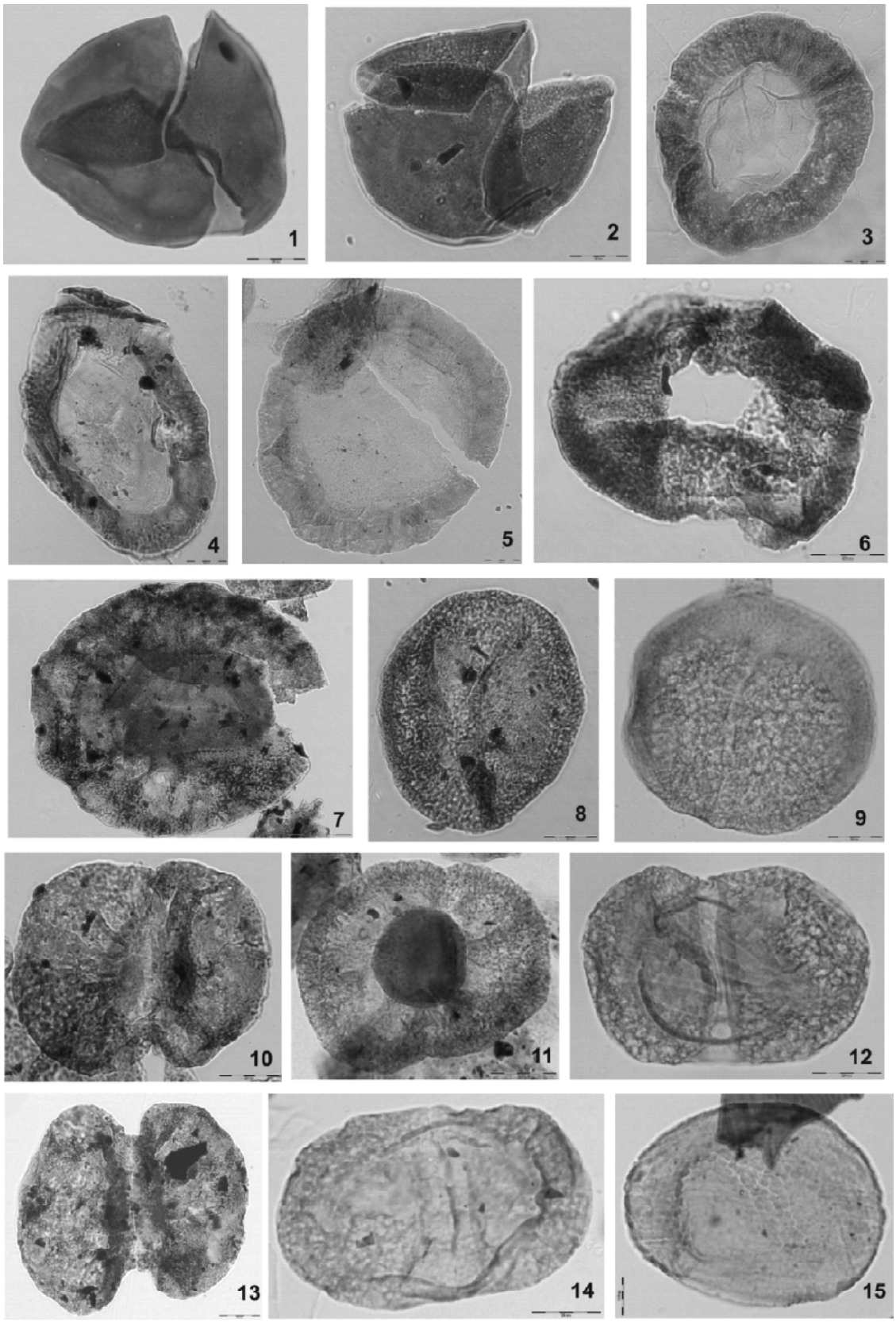


Plate 1

PALYNOFLORA

The palynoflora obtained from the carbonaceous horizons of the borecores of Gundala block comprises 23 genera and 38 species of palynofossils (Text-figure 2, Plate 1). The following spore pollen species have been recorded.

Trilete spores: *Brevitriletes communis* (Bharadwaj & Srivastava) Tiwari & Singh, *B. unicus* (Bharadwaj & Srivastava) Tiwari & Singh, *Callumispora barakarensis* (Bharadwaj & Srivastava) Tiwari et al., *C. gretensis* (Balme & Hennelly) Bharadwaj & Srivastava, *C. tenuis* Bharadwaj & Srivastava, *Horriditriletes rampurensis* Tiwari, *H. ramosus* (Balme & Hennelly) Bharadwaj & Salujha, *Leiotriletes rectus* Bharadwaj & Salujha, *Lophotriletes rectus* Bharadwaj & Salujha, *Microbaculispora barakarensis* (Tiwari) Tiwari & Singh, *M. tentula* Tiwari, *Microfoveolatispora foveolata* (Tiwari) Tiwari & Singh.

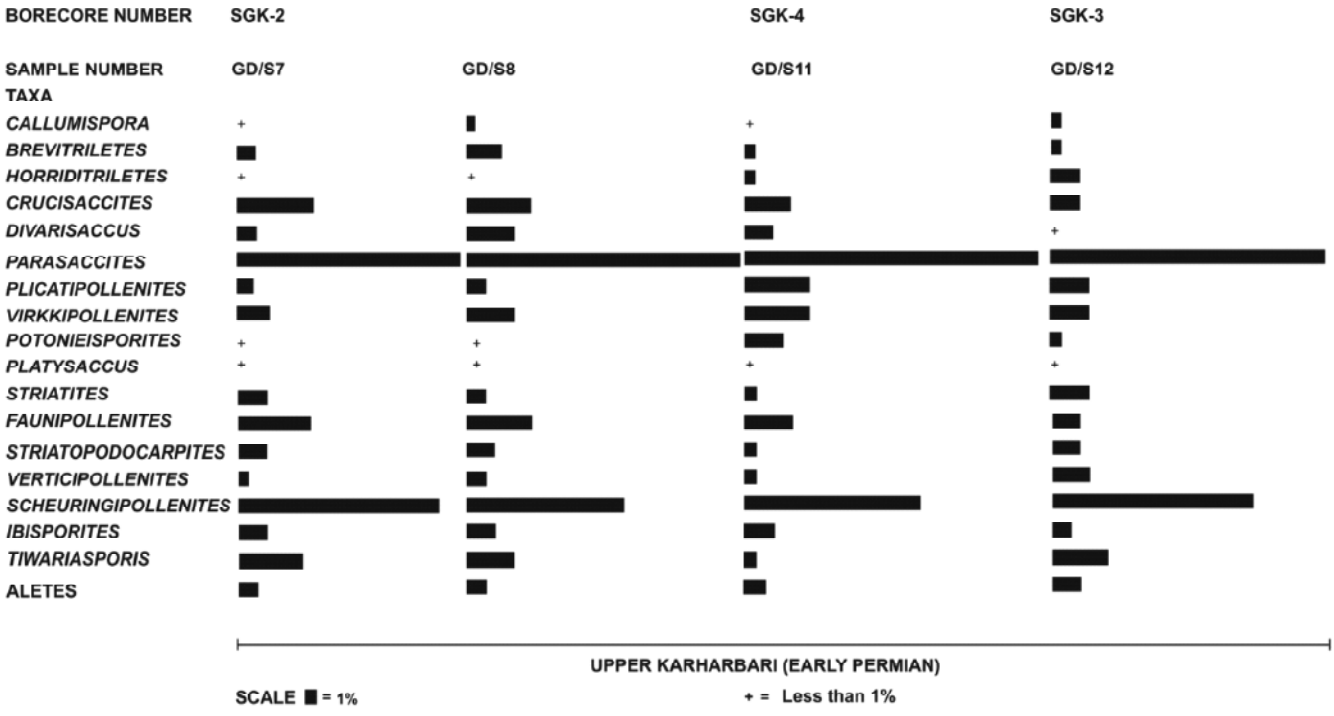
Monosaccate pollen: *Crucisaccites indicus* Srivastava, *C. monoletus* Maithy, *Divarisaccus lelei* Venkatachala & Kar, *Divarisaccus*. sp., *Parasaccites diffusus* Tiwari, *P. distinctus* Tiwari, *P. korbaensis* Bharadwaj & Tiwari, *P. obscurus* Tiwari, *Parasaccites* sp., *Plicatipollenites indicus* Lele, *Potonieisporites concinnus* Tiwari, *Virkkipollenites orientalis* Tiwari.

Striate disaccate pollen: *Faunipollenites bharadwajii* Maheshwari, *F. parvus* Tiwari, *F. varius* Bharadwaj, *Striatites communis* Bharadwaj & Tiwari, *Striatopodocarpites decorus* Bharadwaj & Salujha, *S. diffusus* Bharadwaj & Salujha, *S. subcircularis* Sinha, *S. tiwarii* Bharadwaj & Dwivedi, *Verticipollenites crassus* Bharadwaj & Salujha.

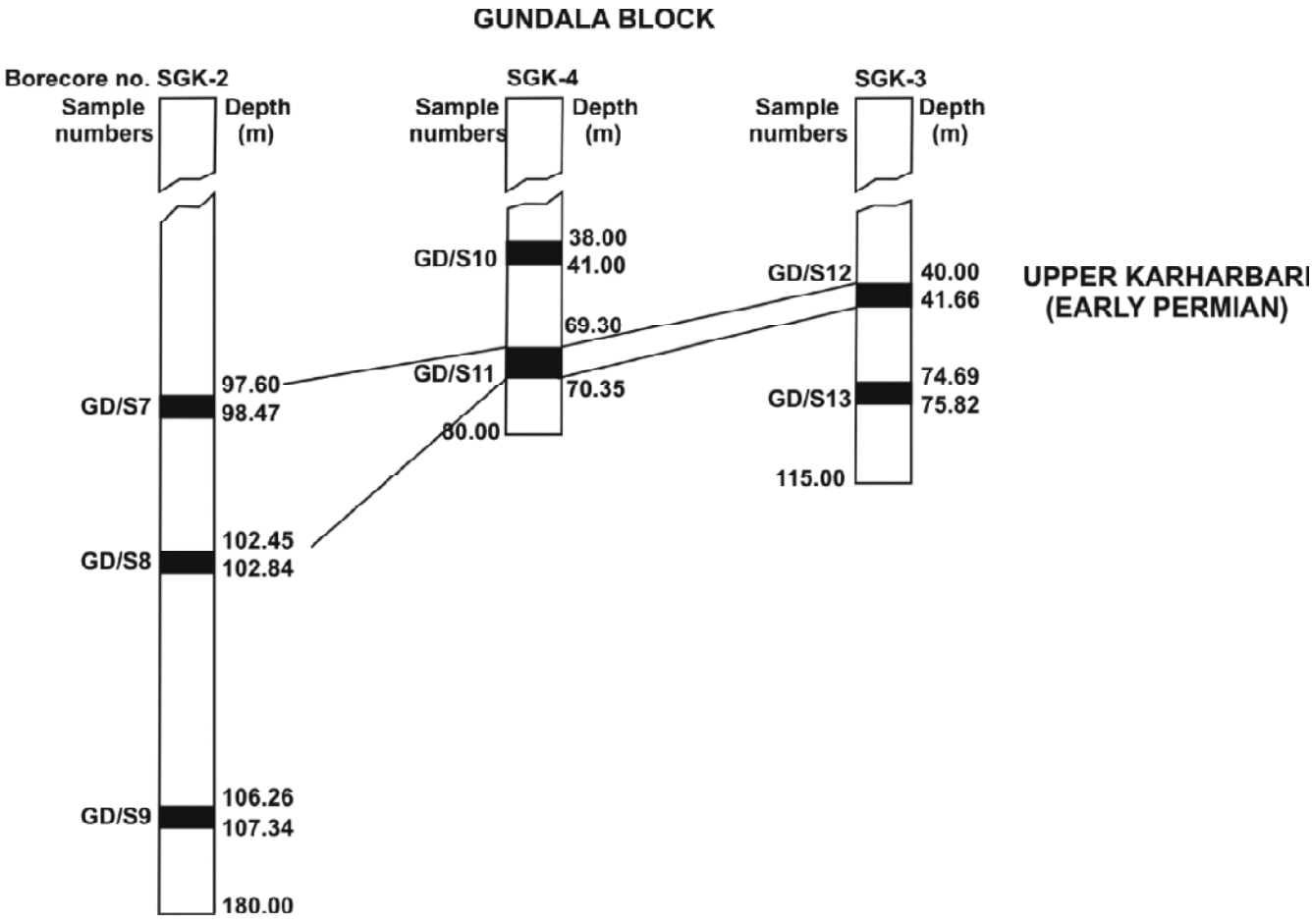
Non-striate disaccate pollen: *Ibisporites diplosaccus* Tiwari, *Platysaccus densicorpus* Anand-Prakash, *Scheuringipollenites barakarensis* (Tiwari) Tiwari, *S. maximus* (Hart) Tiwari, *S. tentulus* (Tiwari) Tiwari.

Others: *Balmella* sp., *Leiosphaeridia* sp., *Tiwariasporis gondwanensis* (Tiwari) Maheshwari & Kar, *T. simplex* (Tiwari) Maheshwari & Kar.

Earlier, a megaspore assemblage was recorded from borecore SGK-2 by Jha et al. (2006).



Text-figure 2. Histogram showing percentage frequency of palynofossils in borecores SGK-2, SGK-3 and SGK-4 of Gundala area



Text-figure 3. Diagrammatic representation of palynological correlation of borecores SGK-2, SGK-4 and SGK-3 from Gundala area of Lingala-Koyagudem coalbelt

QUANTITATIVE ANALYSIS

The present palynoassemblage is characterized by dominance of radial monosaccates chiefly *Parasaccites* (23-32%) and subdominance of non-striate disaccates chiefly *Scheuringipollenites* (17-22%). The other taxa are: triletes: *Horriditriletes* (0.2-1.5%), *Callumispora* (0.5-1.7%), *Microbaculispora* (0.5%), *Leiotriletes* (0.5%), *Brevitriletes* (1.5-4.3%), *Lophotriletes* (0.5%), *Microfoveolatispora* (0.5%); monosaccates: *Virkkipollenites* (2.7-7.2%), *Plicatipollenites* (1.7-7.2%), *Potonieisporites* (0.6-4.1%), *Crucisaccites* (3-12.3%), *Divarisaccus* (2.6-4%); non-striate disaccates: *Ibisporites* (2.8-3.6%), *Platysaccus* (0.4-0.8%); striate disaccates: *Faunipollenites* (3.4-8.1%), *Striatopodocarpites* (1.5-3.7%), *Striatites* (1.5-4%) and *Verticipollenites* (1.5-4.6%). *Crucisaccites* (3-12.3%) and *Tiwariasporis* (1.5-7.6%) have been recorded in all the samples. Besides, aletes have also been marked in low amount (2-3%). Diagrammatic representation of palynological correlation of borecores SGK-2, SGK-4 and SGK-3 from Gundala area of Lingala-Koyagudem coalbelt is shown in Text-figure 3.

COMPARISON AND DISCUSSION

The present palynoassemblage compares well with Upper Karharbari palynoassemblages of different Gondwana basins of India, viz. Damodar (Korba Coalfield-Bharadwaj & Srivastava 1973, Raniganj Coalfield-Tiwari 1973), Wardha (Bharadwaj & Anand-Prakash 1974, Sarate 1985, Bhattacharyya 1997, Katol area-Kumar & Jha 2000), Satpura (Trivedi &

Ambwani 1984, Sarate 1986) and Godavari (Srivastava 1987, Srivastava & Jha 1989, 1992a, b, 1993, 1995a, b, 1996). It closely resembles with the palynoassemblage of type area of Karharbari Formation, i.e. Giridih Coalfield (Maithy 1965, Srivastava 1973) in dominance of radial monosaccates and subdominance of non-striate disaccates. Bharadwaj and Anand-Prakash (1974) recorded a rich palynoflora in coal deposits of Umrer Coalfield and established 3 biozones. The present assemblage compares with biozone III in having dominance of *Parasaccites* and subdominance of *Scheuringipollenites*.

The dominance of monosaccates during Early Permian has also been recorded from all other Gondwana continents, i.e. Africa (Dwyka Tillite - Anderson 1970, Falcon 1975, Utting 1978), Australia (Baccus Marsh Tillite - Truswell 1980), Antarctica (Darwin Tillite - Barrett & Kyle 1975, Victoria Group - Roaring Formation - Kyle & Schopf 1982, Mackellar Formation - Masood et al. 1994), South America (Lower Itararé Formation of Brazil - Bharadwaj et al. 1976) and Salt Range (Tobra Formation - Masood et al. 1992).

The dominance of *Parasaccites* has been recorded from Early Permian sediments of India (Talchir and Karharbari) but the association of *Scheuringipollenites* and few striate disaccates distinguish the present assemblage from palynoflora of Talchir Formation. Palynoflora of Barakar Formation of India is characterized by dominance of *Scheuringipollenites* and subdominance of striate disaccates, viz. *Faunipollenites*, *Striatopodocarpites*. High frequency of monosaccate, viz. *Parasaccites* and very low percentage of striate disaccates in the present palynoassemblage indicate that this is older than palynoflora of Barakar Formation. Moreover, presence of triletes in good amount and occurrence of *Crucisaccites* also indicate Karharbari affinity.

On the basis of lithological attributes, the coal seams have so far been considered to be of Barakar Formation but present palynological analysis provides evidence for the presence of Upper Karharbari sediments (Late Sakmarian-Early Artinskian) in Gundala area. However, the coal seam has not attained workable thickness in this borecore but it opens up new possibility for search of Karharbari coals in Gundala area. The megaflora, too, exemplifies floristic differences in both the formations, i.e. Karharbari and Barakar formations (Maheshwari 1992). On the basis of present palynological investigation, it can be established that rich Karharbari flora existed during Early Permian in Godavari Valley.

Spore/pollen from various coalfields of India have been extensively worked out and many biozones have been proposed (Tiwari 1995). Stratigraphic significance of spore-pollen, in resolving time boundaries, has been consistently emphasized (Tiwari & Kumar 2002). The distinction between Karharbari and Barakar formations is primarily based on megafloral (Maithy 1966, 1969, Banerjee 1988, Maheshwari 1992) and spore/pollen (Maithy 1965, Srivastava 1973, Bharadwaj 1974, 1975) studies. Unlike other basins, Wardha-Godavari Basin is deprived of well established megafloristic zones distinguishing Karharbari and Barakar sequences. It is also noteworthy that lithological characters did not help their categorization. But the Karharbari palynoflora has been recorded in many areas in Godavari Graben (Jha 2006, Jha & Aggarwal 2010a, b). This necessitates a thorough search for plant fossil evidences in Godavari Graben in order to understand floristic differentiation, if any.

CONCLUSION

The palynoassemblage encountered in borecores of Gundala block of Lingala-Koyagudem coalbelt compares with palynoassemblage of Karharbari Formation described from Giridih Coalfield, Bihar (Maithy 1965). It shows that diversified vegetation was growing in Gundala area comprising 23 genera and 38 species of palynofossils. It is concluded that the assemblage encountered in the carbonaceous horizons of Gundala block belongs to Karharbari and is Early Permian in age.

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February 2013

Pollen analysis in understanding the foraging behaviour of *Apis mellifera* in Gangetic West Bengal

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ABSTRACT

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Forage patterns, with respect to pollen as well as nectar, of *Apis mellifera* in Gangetic West Bengal throughout the year have been worked out in detail. The results are based on the pollen analysis of 1443 pollen pellets and 61 honey samples collected systematically in different months throughout the calendar year. The work reveals that the forage spectrum of *A. mellifera* in the region is constituted by altogether 77 species of flowering plants. Among those, *Cocos nucifera*, *Phoenix sylvestris*, *Borassus flabellifer, Citrus maxima, Carica papaya*, *Pongamia pinnata, Luffa acutangula, Croton bonplandianum, Terminalia arjuna*, *Bauhinia malabarica, Averrhoa carambola, Chrozophora rottleri*, *Monochoria hastata, Anthocephalus cadamba, Acacia auriculiformis, Murraya paniculata, Cleome viscosa, Eucalyptus globulus* and *Xanthium strumarium* serve as the predominant pollen source. *Brassica nigra*, *Moringa oleifera*, *Borassus flabellifer, Syzygium cumini, Sesamum indicum*, *Anthocephalus cadamba*, *Impatiens balsamina*, *Eucalyptus globulus*, *Acacia auriculiformis* and *Mikania scandens* constitute the important nectar source. For the major part of the year, *A. mellifera* produces multifloral honeys, except in September when it yields *Eucalyptus* type unifloral ones.

Key- words: Melissopalynology, nectar forage, pollen forage, unifloral honey, multifloral honey, *Apis mellifera*, Gangetic West Bengal, India

INTRODUCTION

Honey, the splendid sweet substance obtained from honeycomb, is primarily a viscous supersaturated solution of sugars. In addition, honey also contains minor amounts of insoluble carbohydrates called 'honey dextrins' (analogous to starch), enzymes, amino acids, organic acids, vitamins, minerals and water. From ancient time, use of honey for various purposes, viz. as food, medicine and in rituals, is a traditional practice. The importance of honey has been mentioned in the ancient Indian Vedas. Wide variation in constituents of different samples of honey has been noticed. It is largely influenced by the plant source together with the environmental factors like weather, soil, etc. Besides honey, other commercially important products obtained from bees are royal jelly, propolis and bee venom. Also, during the course of their foraging activities, bees act as pollinators and help in increasing the yield of many economically important plants (Free 1993). In view of the environmental onslaught on insect pollinators, beekeeping is nowadays used as an effective means to overcome the pollination crisis of bee-pollinated crops (Goyal 1993, Kumar et al. 1998).

Honeybees forage on flowering plants for collecting pollen grains and nectar for making beebread. The plants that yield these two substances collectively constitute the bee pasturage. Vegetation in the area is therefore of immense importance for establishment, maintenance and yield, i.e. all round development, of a bee colony. The forage pattern of bees varies from species to species, sometimes among varieties. In a colony, there exists a distinctive division of labour among the worker-bees

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with respect to the collection of nectar and pollen grains and also for other purposes. Distinction between the nectar and pollen-collecting bees was recognized as early as in 1623 (Butler 1954). Pollen grains from anthers of flowers are carried by the designated worker bees in the form of pellets packed onto the concavities of their hind limbs referred to as the 'corbiculae' or 'pollen baskets' and are stored in the pollen-cells of the hive. Nectar from flowers is collected by a bee into its honey stomach by repeated sucking through the proboscis. The bee regurgitates the nectar in the form of a suspended drop onto the upper wall of an empty honey-cell in the comb which, in course of time, is turned into honey by the complex work of other worker bees. While collecting nectar, various parts of a bee's body incidentally get smeared with the pollen grains of flowers they visit. Eventually, honey contains pollen grains as contaminants with the collected nectar of the plants visited by bees.

Pollen analyses of honey and pollen pellets are considered to be the most suitable and widely used means to understand the forage pattern of a bee species. To decipher the details of pollen forage as well as nectar forage in an area by any particular bee species/variety, pollen analyses of both pollen pellets and honey samples are to be done simultaneously.

Melissopalynological research can be traced back to the end of the nineteenth century, when Pfister (1895) examined the pollen contents of various honey samples from different parts of Europe. In India, pollen analysis of honey was initiated by Sen and Banerjee (1956) while working on the samples collected from a small private garden of Kolkata. Subsequently, a number of workers made significant contributions in this field of knowledge. Mention may be made of Deodikar and Thakar (1953), Vishnu-Mittre (1957), Chaubal and Deodikar (1963, 1965), Nair (1964), Deodikar (1965), Sharma and Nair (1965), Sharma (1970), Chaturvedi (1973, 1977, 1983), Chaudhari (1977, 1978), Seethalakshmi and Percy (1979), Seethalakshmi (1980), Chaubal (1980), Mondal and Mitra (1980), Chanda and Ganguly (1981), Bhattacharya et al. (1983), Chakrabarti (1987), Jhansi and Ramanujam (1987, 1990), Kalpana et al. (1990), Ramanujam (1994), Ramanujam and Kalpana (1995), Kalpana and Ramanujam (1995, 1998), Malakar et al. (1995), Bera et al. (1997), Lakshmi and Suryanarayana (1997), Jana and Bera (2004), Ramakrishna and Bushan (2004), Chaya and Verma (2004) and Chauhan and Murthy (2010). However, all of the previous works were based on isolated samples and the forage pattern of any of the bee species in an area throughout the year has not yet been done.

Nine species of honeybees, viz. *Apis mellifera* L., *A. florea* Fabricus, *A. cerana* Fabricus, *A. andreniformis* Smith, *A. dorsata* Fabricus, *A. nigrocincta* Smith, *A. laboriosa* Smith, *A. koschevnikovi* Enderlein and *A. nuluensis* Tingek et al., are known to occur globally (Oldroyd & Wongsiri 2006). Among those, *A. mellifera* and *A. cerana* have been hived successfully for commercial purposes (Gotaria et al. 1998). Modern beekeeping is a recent development in India, which started with the hiving of indigenous *Apis cerana* for honey production as a hobby (Holmes 1965). Until 1960, beekeeping in the country remained confined only to this particular species. However, domestication of *Apis cerana* was found to be less fruitful because of low productivity of honey and its susceptibility to the 'Thai sac brood' disease. To solve the problem the European bee species, *Apis mellifera*, was introduced in India during mid 1960s (Goyal & Gupta 1994). The species has been preferred by Indian beekeepers and farmers because of its better yield, resistance to various diseases and easy domestication (Phadke & Wakhle 1996). Apiculture is rapidly becoming popular nowadays in West Bengal and the high yielding introduced European honeybee, *Apis mellifera*, is almost exclusively employed for the purpose. Gangetic West Bengal is characterized by a tropical monsoon climatic set-up that supports a diversified flora. About 1500 species of flowering plants are known to grow in the region. Agriculture is the prime economy of the area and it is famous for a high crop yield. The present work was undertaken to work out the month-wise nectar and pollen forage calendar of the aforesaid introduced bee species in Gangetic West Bengal. Honey samples and pollen pellets collected systematically from different parts of the region were

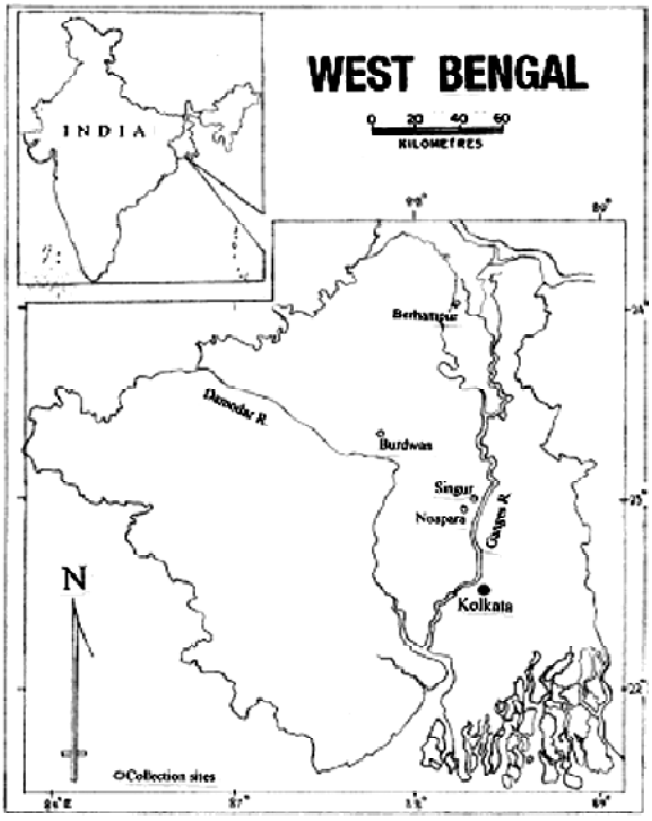
palynologically analyzed. Both qualitative and quantitative analyses were undertaken. Qualitative analysis was done to work out the plant species in the region foraged by *A. mellifera*, either for pollen or nectar or both. Quantitative analysis reveals the relative importance of the taxa in forage. A thorough survey of previously published works reveals that this sort of comprehensive approach is being made for the first time in the country.

MATERIAL AND METHOD

The present work is based on the month-wise collection of pollen pellets and honey samples of *Apis mellifera* in Gangetic West Bengal. Altogether, 1443 samples of pollen-pellets and 61 samples of honey have been collected from four localities in the region, viz. Burdwan, Noapara, Singur and Berhampur (Text-figure 1). For the purpose, six beehives of *Apis mellifera* have been maintained for more than two years (2002-2004) at Golapbag, Krishnapur and Tejgunj localities of Burdwan. Samples from other three localities were collected from the hives maintained by the professional apiculturists.

Majority of the pollen pellets were collected directly from the pollen baskets of the bees. Some pollen pellets were also recovered from the brood frames where pollen grains are stored in the pollen-cells. While doing so, pollen pellets were removed carefully with a fine needle from the pollen-cells of the hive where the pellets remain stacked one above the other. Pellets were preserved individually in small (5 ml) glass vials containing FAA (Formalin-Aceto-Alcohol, 5:5:90) solution.

In productive seasons (late January to early May and mid September to early November), sufficient amounts of honey samples were obtained when pure honey is extracted for marketing from the honey combs using honey extractor. However, in nonproductive seasons, i.e. during mid May to early September and mid November to mid January, pure honey samples of limited amount (4-5 ml) were collected directly from a few honey cells with the help of a clean and sterilized fine-tipped glass pipette aided with rubber teats.



Text-figure 1. Map of West Bengal showing the sampling sites.

Palynological slides from pollen pellets were prepared by acetolysis method (Erdtman 1960). Palynological preparations of honey samples were made by dissolving 2 ml of honey in adequate amount of distilled water followed by centrifugation and acetolysis. The methodology recommended by Maurizio (1951) and International Commission for Bee Botany (Louveaux et al. 1978) was employed for pollen analysis. Pollen grains thus prepared from the samples of pollen pellets as well as honey were examined under a Leica DMLB (Germany) bright field trinocular light microscope with 40x and 100x (oil) apochromatic objectives. Different pollen morphotypes were described using standard terminologies (Erdtman 1952, Kremp 1965, Faegri & Iversen 1989) followed by their identification with the help of reference slides prepared from the local flora as well as published accounts. Photomicrographs of suitable magnifications were made with Leica MPS-60 Photoautomat, using Kodak Gold 100, 35 mm colour films and Kodak colour printing papers.

Majority of the pellets yield pollen grains belonging to a single species. However, some samples were found to be represented by more than one species. Pollen pellets were categorized on the basis of their pollen constituents. Month-wise incidence of different categories of pellets was evaluated. Frequencies of taxa were determined on the basis of at least 100 load samples. For a mixed load, fractional values were considered on the basis of the frequencies of the taxa occurring in the load.

Quantitative analysis, for determining the frequencies of taxa in honey samples collected in a month, was based on the count of at least 100 pollen grains per sample.

OBSERVATION

Monthwise qualitative and quantitative analyses of pollen occurrence in pollen pellets

During January, 120 pellets were collected. All were found to be unifloral. Pollen grains of *Cocos nucifera, Tridax procumbens, Phoenix sylvestris, Luffa acutangula* and *Brassica nigra* were recovered from the pellets. Out of 120 load samples, 51 were comprised of pollen grains belonging to *Cocos nucifera* (42.5%), 27 of *Tridax procumbens* (22.5%), 18 of *Phoenix sylvestris* (15%) and 12 each of *Brassica nigra* (10%) and *Luffa acutangula* (10%) (Text-figure 2A).

Out of 105 load samples collected in the month of February, 96 were unifloral and remaining nine were of mixed type. Among the unifloral pellets, 39 were of *Cocos nucifera*, 21 of *Phoenix sylvestris*, twelve of *Aegle marmelos*, nine each of *Tridax procumbens* and *Solanum melongena* and six of *Litchi chinensis*. Out of the nine mixed pellets, three were of *Phoenix sylvestris* and *Cocos nucifera*, another three were of *Phoenix sylvestris* together with *Litchi chinensis* and the remaining three were of *Phoenix sylvestris* and *Bauhinia malabarica*. Considering the number of unifloral pellets together with the proportionate values in mixed ones, 38% was of *Cocos nucifera*, 25.14% of *Phoenix sylvestris*, 11.43% of *Aegle marmelos*, 8.57% each of *Tridax procumbens* and *Solanum melongena*, 6.86% of *Litchi chinensis* and 1.43% of *Bauhinia malabarica* (Text-figure 2B).

During March, 132 pellets were collected. Out of those, 120 were unifloral and remaining twelve were of mixed type. Among the unifloral pellets, 24 were of *Borassus flabellifer,* 20 were of *Citrus maxima*, twelve each of *Carica papaya, Gmelina arborea, Syzygium cumini*, eight each of *Aegle marmelos*, *Phyllanthus emblica*, *Spondias mangifera* and *Terminalia arjuna* and four each of *Polyalthia longifolia* and *Cocos nucifera*. The mixed pellets were of three types. Five were constituted of *Aegle marmelos* and *Polyalthia longifolia*, four of *Phyllanthus emblica* and *Saraca indica* and the remaining three of *Aegle marmelos* and *Litchi chinensis*. Frequency-wise, *Borassus flabellifer* was represented by 18.18%, *Citrus maxima* by 15.15%, *Aegle marmelos* by 10%, *Carica papaya, Gmelina arborea* and *Syzygium cumini* each by 9.09%, *Phyllanthus emblica* by 7.88%, *Spondias mangifera* and *Terminalia arjuna* each by 6.06%, *Polyalthia longifolia* by 3.94%, *Cocos nucifera* by 3.03% and *Litchi chinensis* and *Saraca indica* each by 1.21% (Text-figure 2C).

During April, 108 pellets were collected. Out of those, 104 were unifloral and remaining four were of mixed type. Among the unifloral pellets, 20 were of *Terminalia arjuna,* 16 each of *Luffa acutangula* and

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Plate 1

1. Part of a hive showing honey cells above and brood chambers below. The queen (marked as Q), drones (marked as D) and the worker bees (marked as W) are visible. 2. Acetolysed preparation of pollen load containing pollen grains of *Xanthium strumarium*, x 470. 3. Acetolysed preparation of pollen load containing pollen grains of *Monochoria hastata* showing monosulcate and rugulo-reticulate exine ornamentation, x 1175. 4. Acetolysed preparation of pollen load containing pollen grains of *Anthocephalus cadamba*, x 470. 5. Acetolysed preparation of pollen load showing 3-4 zonoparasyncolporate pollen grains of *Eucalyptus globulus* and an anasulcate pollen grain of *Cocos nucifera*, x 470. 6. Acetolysed preparation of pollen load containing pollen grains of *Cleome viscosa*, *Anthocephalus cadamba* and *Acacia auriculiformis*, x 470.

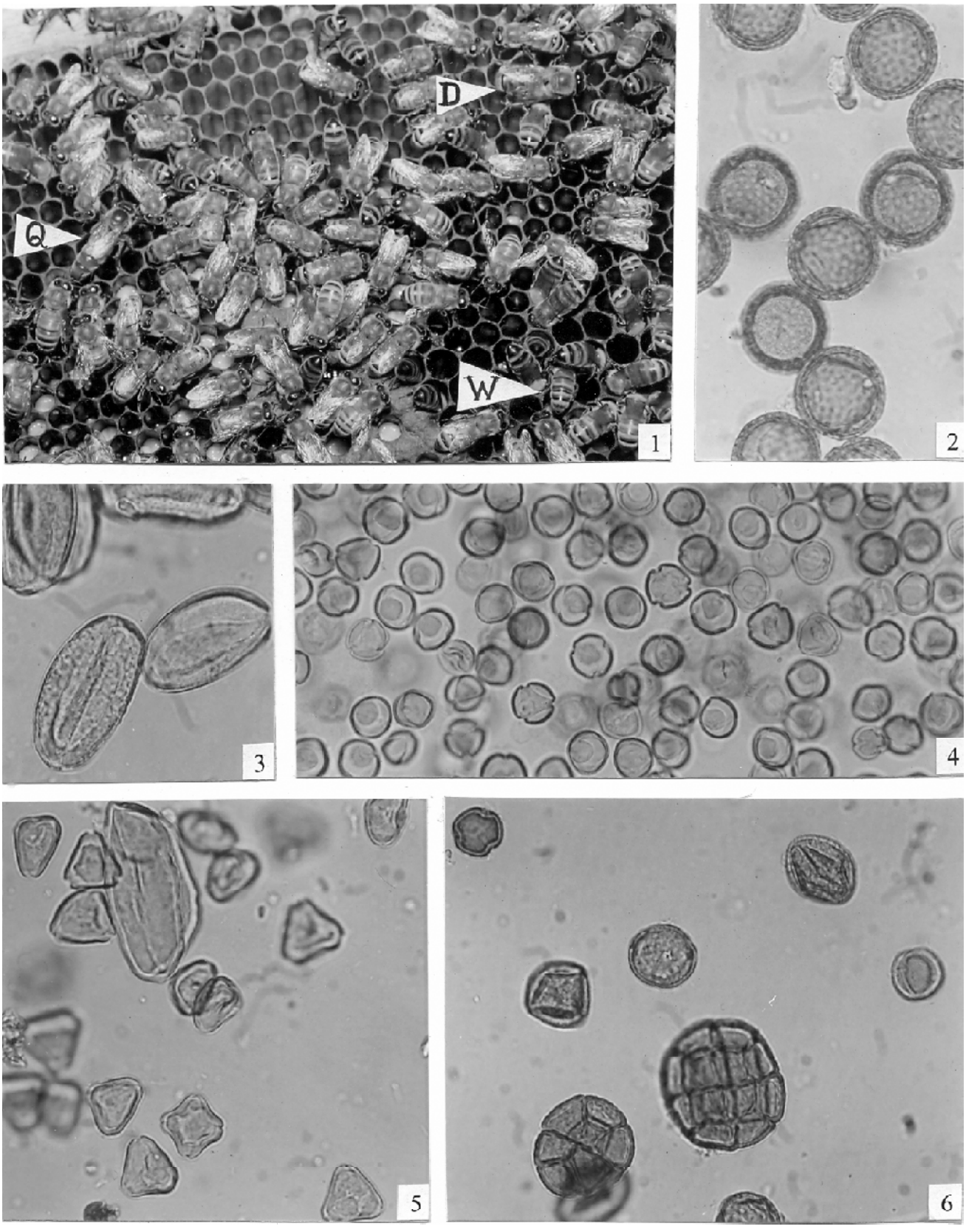

Plate 1

Pongamia pinnata, twelve each of *Borassus flabellifer, Polyalthia longifolia* and *Spondias mangifera* and eight each of *Cocos nucifera* and *Shorea robusta*. The four mixed pellets were comprised of *Croton bonplandianum* and *Jatropha gossypifolia*. Frequency-wise, *Terminalia arjuna* was represented by 18.52%, *Luffa acutangula* and *Pongamia pinnata* each by 14.81%, *Borassus flabellifer, Polyalthia longifolia* and *Spondias mangifera* each by 11.11%, *Cocos nucifera* and *Shorea robusta* each by 7.41%, *Croton bonplandianum* by 2.04% and *Jatropha gossypifolia* by 1.66% (Text-figure 2D).

During May, 114 pellets were collected. Out of those, 96 were unifloral and remaining 18 were of mixed type. Among the unifloral pellets, 31 were of *Borassus flabellifer*, 23 of *Cocos nucifera*, 15 each of *Lagerstroemia speciosa* and *Luffa acutangula* and 12 of *Citrus maxima*. The eighteen mixed pellets were of four types. Six were constituted of *Borassus flabellifer* and *Chrozophora rottleri*, other six of *Borassus flabellifer* and *Cordia sebestina*, three of *Cocos nucifera*, *Chrozophora rottleri, Cordia sebestina, Barringtonia acutangula* and *Syzygium jambos*, while the remaining three pellets were of *Barringtonia acutangula* and *Syzygium jambos*. Frequency-wise, *Borassus flabellifer* was represented by 31.65%, *Cocos nucifera* by 21.24%, *Lagerstroemia speciosa* and *Luffa acutangula* each by 13.16%, *Citrus maxima* by 10.53%, *Chrozophora rottleri* and *Cordia sebestina* each by 3.16%, *Barringtonia acutangula* by 2.37% and *Syzygium jambos* by 1.56% (Text-figure 2E).

During June, 120 pellets were collected. Out of those, 93 were unifloral and remaining 27 were of mixed type. Among the unifloral pellets, 27 were of *Averrhoa carambola*, 21 of *Cocos nucifera*, 15 of *Bauhinia malabarica*, nine each of *Borassus flabellifer* and *Lagerstroemia speciosa* and six each of *Dillenia indica* and *Jatropha gossypifolia*. The mixed pellets, as per their pollen constituents, were of following six types: eight containing pollen grains of *Cocos nucifera*, *Cordia sebestina* and *Syzygium jambos*, six of *Cocos nucifera*, *Chrozophora rottleri* and *Cleome viscosa*, five of *Cocos nucifera* and *Chrozophora rottleri*, four of *Bauhinia malabarica*, *Croton bonplandianum* and *Jatropha gossypifolia*, three of *Bauhinia malabarica* and *Chrozophora rottleri* and one of *Croton bonplandianum* and *Jatropha gossypifolia*. Frequency-wise, *Averrhoa carambola* was represented by 22.50%, *Cocos nucifera* by 21.2%, *Bauhinia malabarica* by 15.25%, *Chrozophora rottleri* by 10.25%, *Borassus flabellifer* and *Lagerstroemia speciosa* each by 7.5%, *Jatropha gossypifolia* by 7%, *Dillenia indica* by 5%, *Croton bonplandianum* by 1.75%, *Cordia sebestina* and *Syzygium cumini* each by 0.75% and *Cleome viscosa* by 0.5% (Text-figure 2F).

During July, 102 pellets were collected. Out of those, 100 were unifloral and remaining two were of mixed type. Among the unifloral pellets, 14 each were of *Anthocephalus cadamba*, *Cleome viscosa* and *Monochoria hastata*, twelve of *Acacia auriculiformis,* eleven of *Cocos nucifera*, ten of *Murraya paniculata*, eight each of *Averrhoa carambola* and *Lagerstroemia speciosa*, four each

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Plate 2

1. Equatorial view of a pollen grain of *Anthocephalus cadamba*, x 1175. 2. Polar view of a pollen grain of *Anthocephalus cadamba*, x 1175. 3. Equatorial view of a pollen grain of *Bauhinia malabarica*, x 1175. 4. Equatorial view of a pollen grain of *Phoenix sylvestris*, x 1175. 5. Equatorial view of a pollen grain of *Cocos nucifera*, x 1175. 6. Equatorial view of a pollen grain of *Limonia acidissima*, x 1175. 7. Polar view of a pollen grain of *Limonia acidissima*, x 1175. 8. Polar view of a pollen grain of *Litchi chinensis*, x 1175. 9. Equatorial view of a pollen grain of *Litchi chinensis*, x 1175. 10. Equatorial view of a pollen grain of *Poa gangetica*, x 1175. 11. Equatorial view of a pollen grain of *Phyllanthus emblica*, x 1175. 12. Polar view of a pollen grain of *Phyllanthus emblica*, x 1175. 13. Equatorial view of a pollen grain of *Polyalthia longifolia*, x 1175. 14. Polar view of a pollen grain of *Polyalthia longifolia*, x 1175. 15. Polar view of a pollen grain of *Averrhoa carambola*, x 1175. 16. Polar view of a pollen grain of *Psidium guajava*, x 1175. 17. Equatorial view of a pollen grain of *Cleome viscosa*, x 1175. 18. Polar view of a pollen grain of *Chrozophora rottleri*, x 1175. 19. Pollen grain of *Sida acuta* in optical section, x 470. 20. Pollen grain of *Sida acuta*, showing surface features, x 470. 21. Pollen grain of *Croton bonplandianum*, x 1175. 22. Polar view of a pollen grain of *Citrus maxima* showing microreticulate sculpturing, x 1175. 23. Polar view of a pollen grain of *Citrus maxima* in optical section, x 1175.

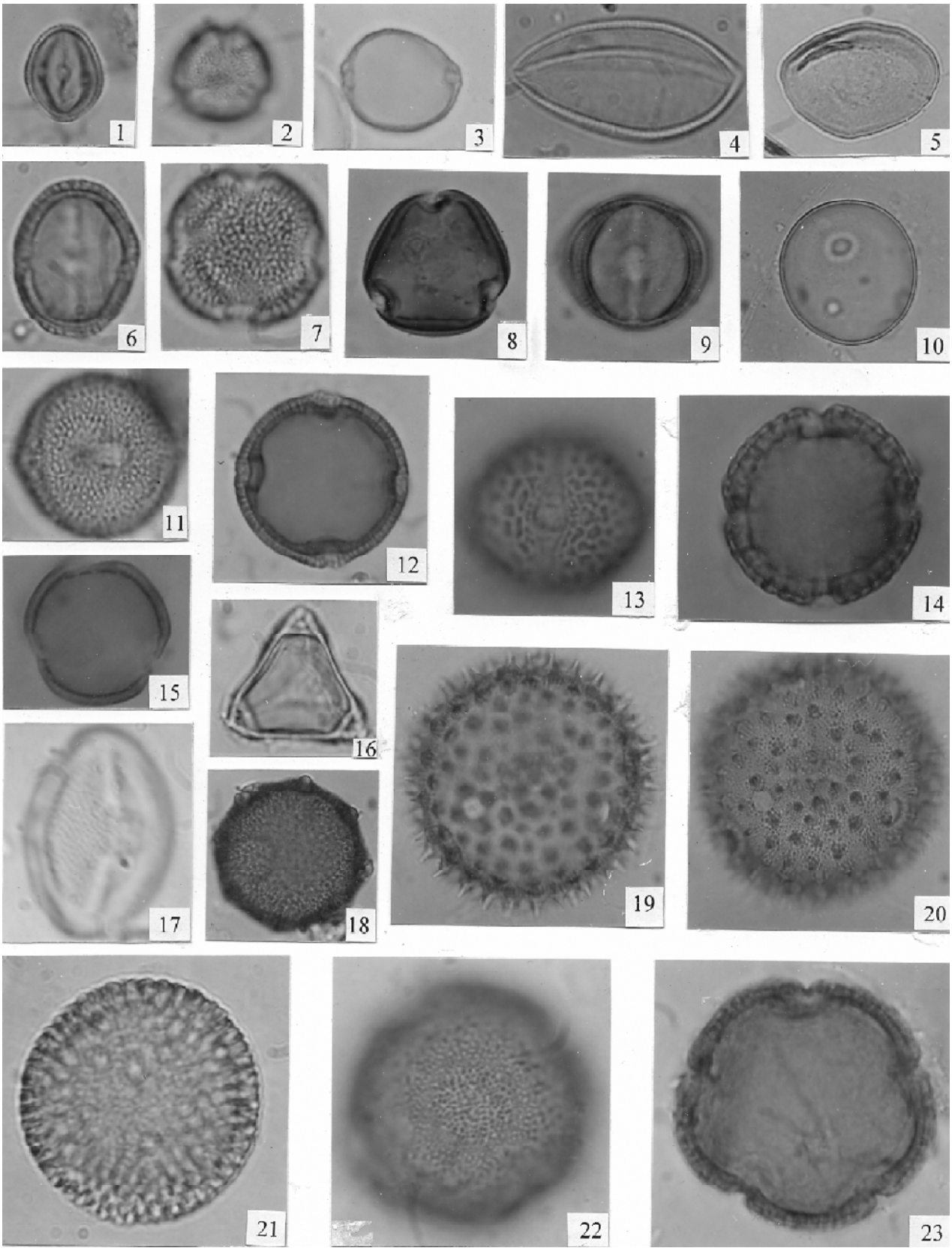
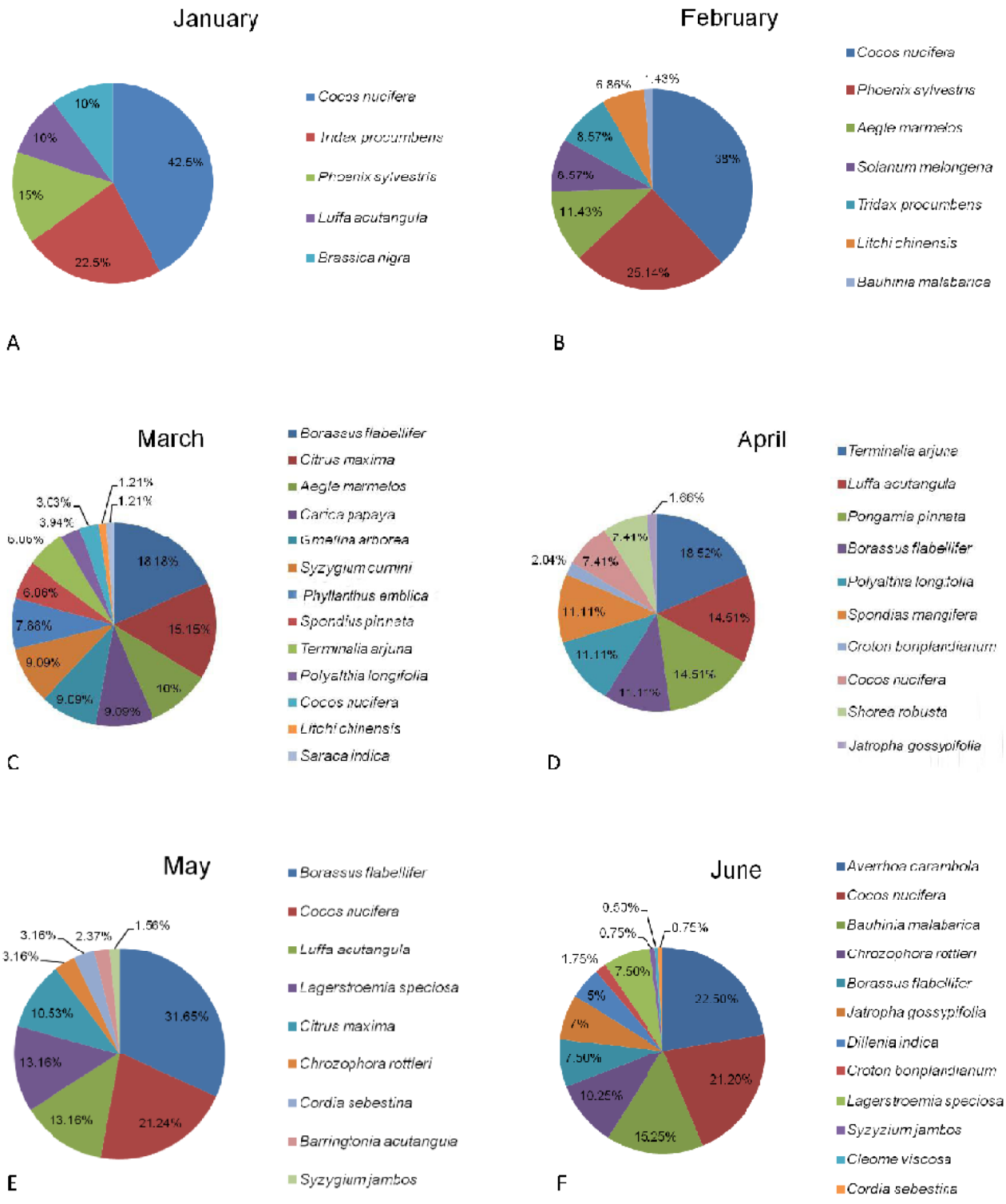


Plate 2



Text figure 2. Pie diagrammes of month-wise pollen forage by *Apis mellifera* in Gangetic West Bengal (January- June).

of *Eucalyptus globulus* and *Syzygium cumini* and one of *Bauhinia malabarica*. The mixed pellets as per their pollen constituents were of one type containing pollen grains of *Cocos nucifera* and *Bauhinia malabarica*. Frequency-wise, *Anthocephalus cadamba*, *Cleome viscosa* and *Monochoria hastata* each were represented by 13.73%, *Cocos nucifera* by 12.55%, *Acacia auriculiformis* by 11.76%, *Murraya paniculata* by 9.80%, *Averrhoa carambola* and *Lagerstroemia speciosa* by 7.84%, *Eucalyptus globulus* and *Syzygium cumini* by 3.92% and *Bauhinia malabarica* by 1.18% (Text-figure 3A).

During August, 136 pellets were collected. Out of those, 132 were unifloral and remaining four were of mixed type. Among the unifloral pellets, 68 were of *Cocos nucifera,* 16 of *Murraya paniculata,* twelve each of *Anthocephalus cadamba* and *Borassus flabellifer,* eight each of *Bauhinia malabarica* and *Cleome viscosa* and four each of *Acacia auriculiformis* and *Monochoria hastata.* The mixed pellets as per their pollen constituents were of one type containing pollen grains of *Acacia auriculiformis, Anthocephalus cadamba* and *Cleome viscosa*. Frequency-wise, *Cocos nucifera* was represented by 50%, *Murraya paniculata* by 11.76%, *Anthocephalus cadamba* by 10%, *Borassus flabellifer* by 8.82%, *Cleome viscosa* by 6.76%, *Bauhinia malabarica* by 5.88%, *Acacia auriculiformis* by 3.82% and *Monochoria hastata* by 2.94% (Text-figure 3B).

During September, 117 pellets were collected. Out of those, 114 were unifloral and remaining three were of mixed type. Among the unifloral pellets, 33 were of *Acacia auriculiformis,* 24 were of *Cocos nucifera*, 15 each of *Eucalyptus globulus* and *Martynia annua*, twelve of *Sida acuta,* six of *Poa gangetica* and three each of *Bauhinia malabarica*, *Monochoria hastata* and *Murraya paniculata*. The mixed pellets as per their pollen constituents were of one type containing pollen grains of *Eucalyptus globulus* and *Cocos nucifera*. Frequency-wise, *Acacia auriculiformis* was represented by 28.21%, *Cocos nucifera* by 22.05%, *Eucalyptus globulus* by 13.85%, *Martynia annua* by 12.82%, *Sida acuta* by 10.26%, *Poa gangetica* by 5.13% and *Bauhinia malabarica*, *Monochoria hastata* and *Murraya paniculata* each by 2.56 % (Text-figure 3C).

During October, 117 pellets were collected. Out of those, 114 were unifloral and remaining three were of mixed type. Among the unifloral pellets, 39 were of *Acacia auriculiformis,* 27 of *Xanthium strumarium*, 12 each of *Cocos nucifera* and *Murraya paniculata*, 9 each of *Monochoria hastata* and *Sida acuta* and six of *Tridax procumbens*. The mixed pellets as per their pollen constituents were of one type containing pollen grains of *Cocos nucifera* and *Monochoria hastata*. Frequency-wise, *Acacia auriculiformis* was represented by 33.33%, *Xanthium strumarium* by 23.08%, *Cocos nucifera* by 11.28%, *Murraya paniculata* by 10.26%, *Monochoria hastata* by 9.23%, *Sida acuta* by 7.69% and *Tridax procumbens* by 5.13% (Text-figure 3D).

During November, 144 pellets were collected. Out of those, 143 were unifloral and one of mixed type. Among the unifloral pellets, 31 were of *Cocos nucifera*, 21 each of *Acacia auriculiformis* and *Tridax procumbens*, 18 of *Brassica nigra*, 16 of *Monochoria hastata*, twelve each of *Luffa acutangula* and *Sida acuta*, nine of *Xanthium strumarium* and three of *Eucalyptus globulus*. The mixed pellet, as per the pollen constituent was of *Cocos nucifera* and *Monochoria hastata*. Frequency-wise, *Cocos nucifera* was represented by 22.08%, *Acacia auriculiformis* and *Tridax procumbens* each by 14.58%, *Brassica nigra* by 12.50%, *Monochoria hastata* by 11.25%, *Luffa acutangula* and *Sida acuta* each by 8.33%, *Xanthium strumarium* by 6.25% and *Eucalyptus globulus* by 2.08% (Text-figure 3E).

During December, 128 pellets were collected. All were found to be unifloral. Pollen grains of *Cocos nucifera*, *Acacia auriculiformis*, *Brassica nigra, Sida acuta, Tridax procumbens* and *Luffa acutangula* were recovered from the pellets. Out of 128 load samples, 32 each were of *Acacia auriculiformis* and *Brassica nigra* (25%), 28 of *Cocos nucifera* (21.88%), 20 of *Sida acuta* (15.63%) and eight each of *Luffa acutangula* and *Tridax procumbens* (6.25%) (Text-figure 3F).

Table 1. Pollen forage calendar of *Apis mellifera* in Gangetic West Bengal.

Incidence Month	Most frequent	Moderately frequent	Less frequent
JAN	*Cocos nucifera, Tridax procumbens*	*Phoenix sylvestris, Luffa acutangula, Brassica nigra*	—
FEB	*Cocos nucifera, Phoenix. sylvestris*	*Aegle marmelos, Tridax procumbens,Solanum melongena, Litchi chinensis*	*Bauhinia malabárica*
MAR	—	*Borassus flabellifer, Citrus maxima, Aegle marmelos, Carica papaya, Gmelina arborea, Syzygium cumini, Phyllanthus emblica, Spondias mangifera, Terminalia arjuna*	*Polyalthia longifolia, Cocos nucifera, Litchi chinensis, Saraca indica*
APR	—	*Terminalia arjuna, Luffa acutangula, Pongamia pinnata, Borassus flabellifer Polyalthia longifolia, Spondias mangifera, Cocos nucifera, Shorea robusta*	*Croton bonplandianum, Jatropha gossypifolia*
MAY	*Borassus flabellifer, Cocos nucifera*	*Lagerstroemia speciosa, Luffa acutangula, Citrus maxima*	*Chrozophora rottleri, Cordia sebestina, Barringtonia acutangula, Syzygium jambos*
JUN	*Averrhoa carambola, Cocos nucifera*	*Bauhinia malabarica, Chrozophora rottleri, Borassus flabellifer, Lagerstroemia speciosa, Jatropha gossypifolia, Dillenia indica*	*Croton bonplandianum, Syzygium cumini, Cordia sebestina, Cleome viscosa*
JUL	—	*Anthocephalus cadamba, Cleome viscosa, Monochoria hastata, Cocos nucifera, Acacia auriculiformis, Murraya paniculata, Averrhoa carambola, Lagerstroemia speciosa*	*Eucalyptus globulus, Syzygium cumini, Bauhinia malabárica*
AUG	*Cocos nucifera*	*Murraya paniculata, Anthocephalus cadamba, Borassus flabellifer, Bauhinia malabarica,Cleome viscosa*	*Acacia auriculiformis, Monochoria hastata*
SEP	*Acacia auriculiformis, Cocos nucifera*	*Eucalyptus globulus, Martynia annua, Sida acuta, Poa gangetica*	*Bauhinia malabarica, Monochoria hastata, Murraya paniculata*
OCT	*Acacia auriculiformis, Xanthium strumarium*	*Cocos nucifera, Murraya paniculata, Monochoria hastata, Sida acuta, Tridax procumbens*	—
NOV	*Cocos nucifera*	*Acacia auriculiformis, Tridax procumbens, Brassica nigra, Monochoria hastata, Luffa acutangula, Sida acuta, Xanthium strumarium*	*Eucalyptus globulus*
DEC	*Acacia auriculiformis, Brassica nigra, Cocos nucifera*	*Sida acuta, Luffa acutangula, Tridax procumbens*	—

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Plate 3

1. Equatorial view of a pollen grain of *Terminalia arjuna*, x 1175. 2. Polar view of a pollen grain of *Pongamia pinnata*, x 1175. 3. Polar view of a pollen grain of *Mangifera indica*, x 1175. 4. Polar view of a pollen grain of *Brassica nigra*, x 1175. 5. Polar view of a pollen grain of *Psidium guajava*, x 1175. 6. Pollen grain of *Spinacea oleracea*, x 1175. 7. Polar view of a pollen grain of *Tamarindus indica*, x 1175. 8. Pollen grain of *Alangium salvifolium*, x 1175. 9. Polar view of a pollen grain of *Dillenia indica*, x 1175. 10. Polar view of a pollen grain of *Coccinia grandis*, x 1175. 11. Polar view of a pollen grain of *Buchanania indica*, x 1175. 12. Polar view of a pollen grain of *Melia azedarach*, x 1175. 13. Polar view of a pollen grain of *Swietenia mahagoni*, x 1175. 14. Equatorial view of a pollen grain of *Mimusops elengi*, x 1175. 15. Polar view of a pollen grain of *Ziziphus mauritiana*, x 1175. 16. Equatorial view of a pollen grain of *Tridax procumbens*, x 1175. 17. Equatorial view of a pollen grain of *Lathyrus sativus*, x 1175. 18. Polar view of a pollen grain of *Moringa oleifera*, x 1175. 19. Polar view of a pollen grain of *Luffa acutangula*, x 1175.

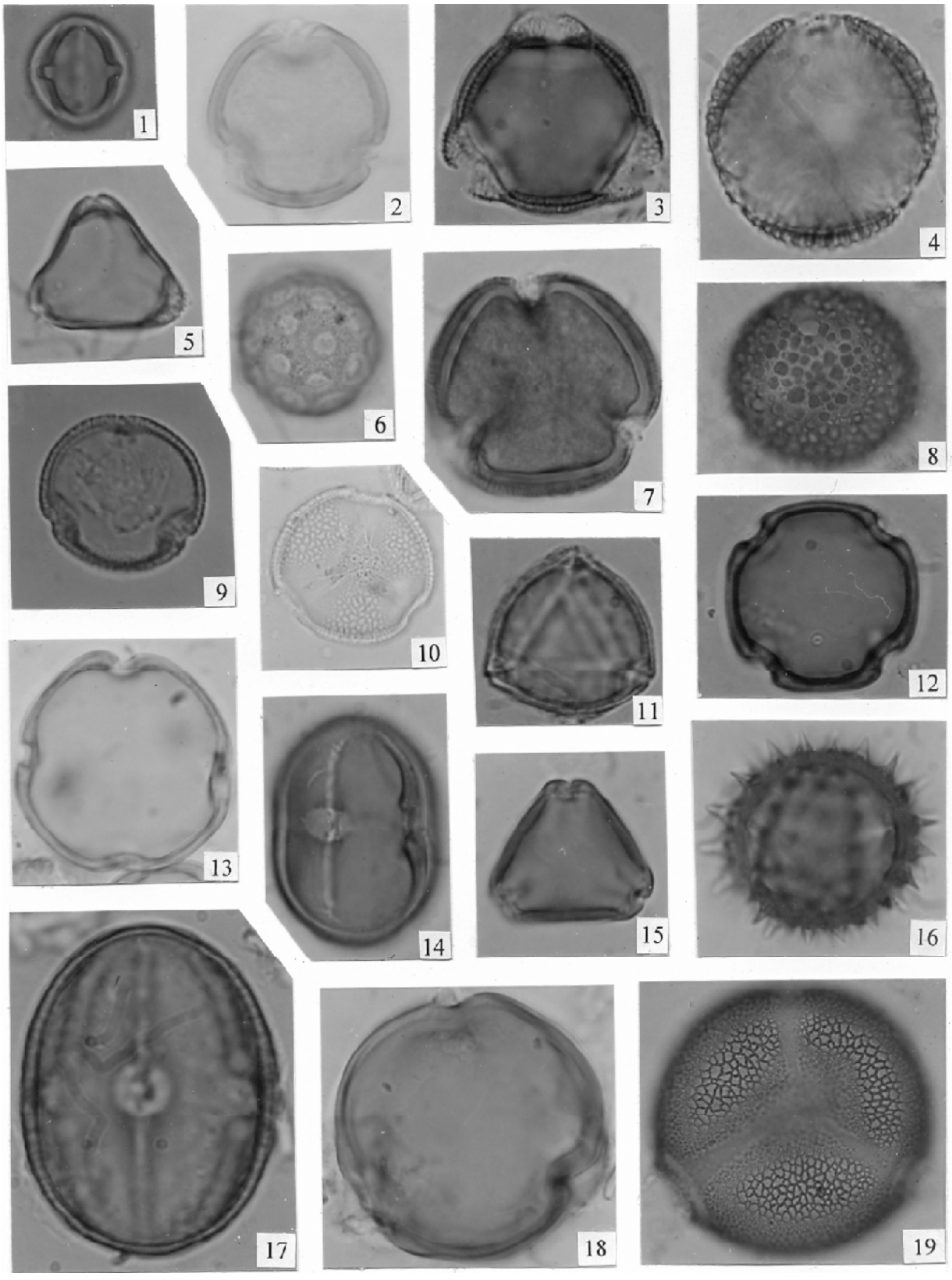
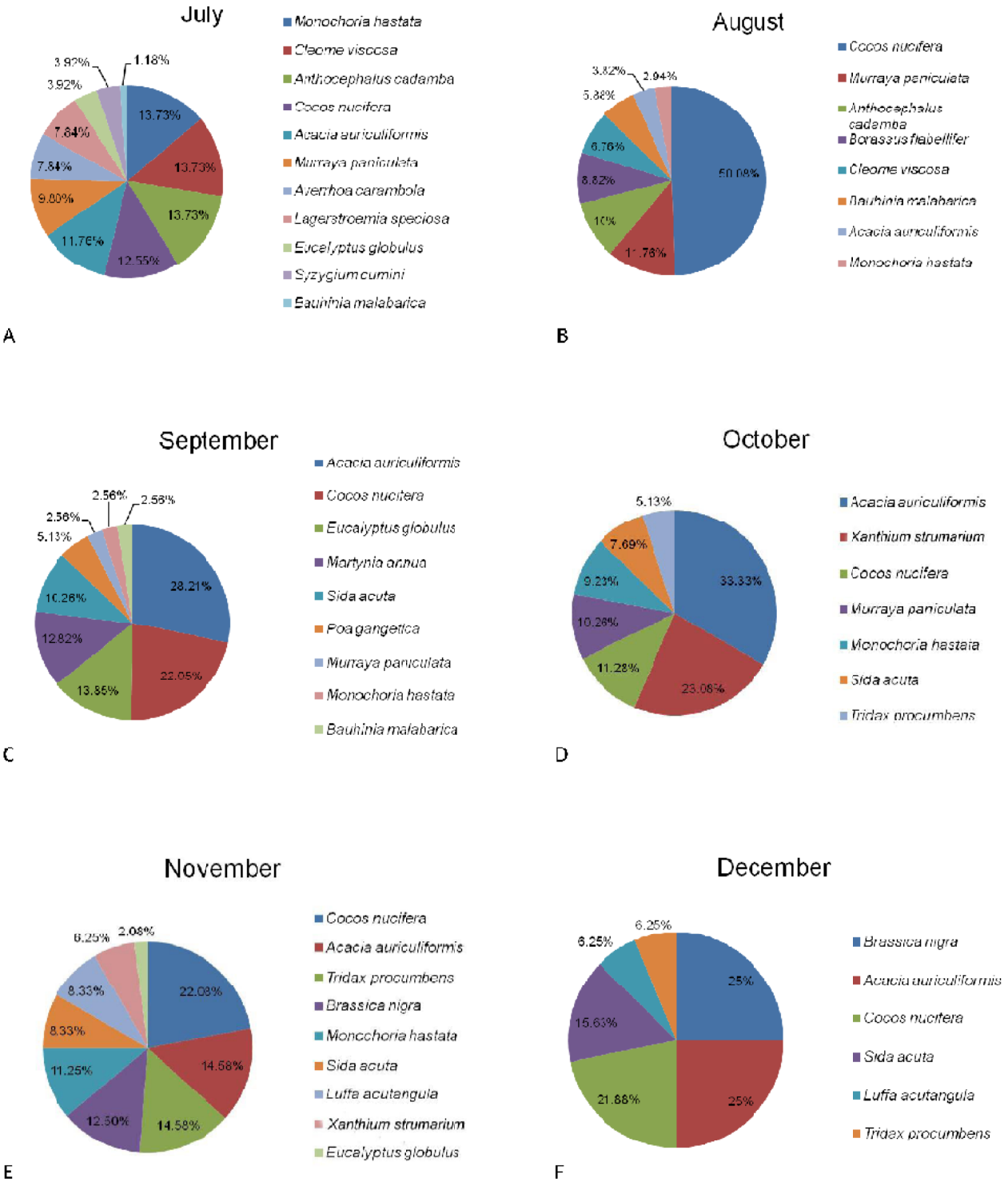


Plate 3



Text figure 3. Pie diagrammes of month-wise pollen forage by *Apis mellifera* in Gangetic West Bengal (July - December).

The month-wise pollen forage calendar of *Apis mellifera* in Gangetic West Bengal is detailed in Table 1.

Monthwise qualitative and quantitative analyses of pollen occurrence in honey samples

Honey samples were collected at regular intervals in different months of the year to understand the nectar forage pattern by the bee species. Altogether, 61 honey samples were collected from the extracted honey in productive seasons and from honey cells of the hives in nonproductive seasons.

Acetolysed preparations of the honey samples were qualitatively analysed. Pollen grains belonging to following species of flowering plants were met with.

During January, five samples of honey were collected from the honey cells. All the samples were multifloral. Quantitative analysis, based on the count of 100 pollen grains from each sample, reveals that pollen grains of *Brassica nigra* (37.5%) were the most frequent, followed by those of *Acacia auriculiformis* (20%), *Cocos nucifera* (16.5%), *Ziziphus mauritiana* (12.5%) and *Tridax procumbens* (10%) which were moderately frequent and pollen grains of *Coccinia grandis* (3.5%) were less frequent (Text-figure 4A).

In February, five samples, three from honey cells of hives and two of extracted honey, were analysed. All samples were multifloral. During this month, most frequently occurring taxa met with in honey samples were *Moringa oleifera* (35%) and *Brassica nigra* (23.5%). Pollen grains of *Cocos nucifera* (19%), *Ziziphus mauritiana* (10%) and *Mangifera indica* (10%) were moderately frequent and those of *Psidium guajava* (2.5%) were less frequent (Text-figure 4B).

During March, seven samples, three from honey cells of hives and four of extracted honey were analysed. All samples were multifloral. Pollen grains of *Borassus flabellifer* (18%), *Syzygium cumini* (14%) and *Moringa oleifera* (12%) were moderately frequent, while *Phyllanthus emblica* (7%), *Terminalia arjuna* and *Raphanus sativus* (5% each), *Aegle marmelos, Azadirachta indica*, *Polyalthia longifolia*, *Pongamia pinnata*, *Psidium guajava* and *Spinacea oleracea* (4% each), *Litchi chinensis*, *Mangifera indica* and *Tamarindus indica* (3% each), *Punica granatum* and *Anisomeles ovata* (2% each), *Hygrophila schulli* (1%) and *Lathyrus sativus* and *Peltophorum pterocarpum* (0.5% each) were less frequent (Text-figure 4C).

In April, six samples, three from honey cells of hives and three of extracted honey were analysed. All samples were multifloral. During this month, most frequently occurring taxa met with in honey samples were *Borassus flabellifer* (32%) and *Syzygium cumini* (21%). Pollen grains of *Melia azedarach* (10%), *Brassica nigra* and *Pongamia pinnata* 8% were moderately frequent and *Shorea robusta* (6%), *Aegle marmelos* (4%), *Hygrophila schulli* and *Peltophorum pterocarpum* (3%) and *Rosa chinensis* (2%) were less frequent (Text-figure 4D).

In May, five samples, three from honey cells of hives and two of extracted honey were analysed. All samples were multifloral. Quantitative analysis of the honey samples reveals that pollen grains of *Sesamum indicum* (27%) were most frequent, followed by those of *Syzygium cumini* (10%) and *Holarrhena pubescens* (9%) which were moderately frequent and *Chrozophora rottleri, Azadirachta indica* (7% each), *Aegle marmelos*, *Pongamia pinnata, Alangium salvifolium* (6% each), *Saraca indica, Dillenia indica* (5% each), *Adhatoda vasica* (4%), *Allamanda cathartica* and *Shorea robusta* (3% each) and *Jasminum auriculatum* (2%) were less frequent (Text-figure 4E).

In June, five samples of honey were collected from the honey cells. All the samples were multifloral. Pollen grains of *Borassus flabellifer* (17%), *Cocos nucifera*, *Datura fastuosa*, *Sesamum indicum* and *Terminalia arjuna* (15% each), *Momordica charantia* (13%) and *Spondias mangifera* (10%) were moderately frequent (Text-figure 4F).

In July, altogether four samples of honey were collected from the honey cells. All the samples were multifloral. During this month, most frequently occurring taxon met with in honey samples was *Anthocephalus cadamba* (32%). Pollen grains of *Terminalia arjuna* (14%) and *Cocos nucifera* (12%) were moderately frequent, whereas less frequent pollen grains were

Holarrhena pubescens, Syzygium cumini (8% each), *Erythrina variegata*, *Vitex negundo, Tectona grandis* (5% each), *Coccinia grandis, Martynia annua* (4% each) and *Allamanda cathartica* (3%) (Text-figure 5A).

In August, five samples of honey were collected from the honey cells. All the samples were multifloral. Quantitative analysis of the honey samples revealed that pollen grains of *Impatiens balsamina* (40%) were most frequent followed by those of *Cocos nucifera* (22%), *Cucurbita maxima* and *Mimusops elengi* (15% each) which were moderately frequent and those of *Adhatoda vasica* (8%) were less frequent (Text-figure 5B).

In September, six samples, three from honey cells of hives and three of extracted honey, were analysed. All the samples were unifloral. The most frequent pollen grains were of *Eucalyptus globulus* (55%), followed by the moderately frequent pollen grains of *Acacia auriculiformis* (30%) and *Nyctanthes arbortristis* (15%) (Text-figure 5C).

In October, four samples of honey were collected from the honey cells. All the samples were multifloral. Quantitative analysis of the honey samples revealed that pollen grains of *Acacia auriculiformis* (42%) were the most frequent followed by those of *Ziziphus mauritiana* (30%) and *Tridax procumbens* (20%) that were moderately frequent and those of *Rosa chinensis* (8%) were less frequent (Text-figure 5D).

In November, altogether five samples of honey were collected from the honey cells. All the samples were multifloral. During this month, most frequently occurring taxon met with in honey samples was *Eucalyptus globulus* (32%). Pollen grains of *Cocos nucifera* (20%), *Tridax procumbens* (18%), *Brassica nigra* and *Ziziphus mauritiana* (15% each) were moderately frequent (Text-figure 5E).

In December, four samples of honey were collected from the honey cells. All the samples were multifloral. Quantitative analysis of the honey samples revealed that pollen grains of *Brassica nigra* (35%) were most frequent, followed by those of *Mikania scandens* (18%), *Datura fastuosa* (11%), *Cocos nucifera* and *Ziziphus mauritiana* (10% each) which were moderately frequent and *Acacia auriculiformis* (7%), *Jasminum auriculatum* (5%), *Sesamum indicum* (3%) and *Zinnia elegans* (1%) were less frequent (Text-figure 5F).

The month-wise nectar forage calendar of *Apis mellifera* in Gangetic West Bengal is detailed in Table 2.

DISCUSSION

Present work reveals that in Gangetic West Bengal, flowers belonging to altogether 73 species of angiosperms are visited by *A. mellifera*. Majority of those have been depicted in Plates 1-4. Among those, 33 species are foraged exclusively for nectar. Those are *Adhatoda vasica*, *Alangium salviifolium*, *Allamanda cathartica*, *Anisomeles ovata*, *Azadirachta indica*, *Coccinia grandis*, *Cucurbita maxima*, *Datura fastuosa*, *Erythrina variegata*, *Holarrhena pubescens*, *Hygrophila schulli*, *Impatiens balsamina*, *Jasminum auriculatum*, *Lathyrus sativus*, *Mangifera indica*, *Melia azedarach*, *Mikania scandens*, *Mimusops elengi*, *Moringa oleifera*, *Momordica charantia*, *Nyctanthes arbor-tristis*, *Peltophorum pterocarpum*, *Psidium guajava*, *Punica granatum*, *Raphanus sativus*, *Rosa chinensis*, *Sesamum indicum*, *Spinacea oleracea*, *Terminalia arjuna,*

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Plate 4

1. Polar view of a pollen grain of *Carica papaya*, x 1175. 2. Equatorial view of a pollen grain of *Carica papaya*, x 1175. 3. Equatorial view of a pollen grain of *Aegle marmelos*, x 1175. 4. Polar view of a pollen grain of *Momordica charantia*, x 1175. 5. Equatorial view of a pollen grain of *Momordica charantia*, x 1175. 6. Preparation of honey sample comprising pollen grains of *Psidium guajava, Syzygium cumini, Azadirachta indica, Aegle marmelos, Moringa oleifera* and *Peltophorum ferrugineum* under low magnification, x110. 7. Polar view of some pollen grains of *Syzygium cumini*, x 470. 8. Equatorial view of a pollen grain of *Barringtonia acutangula*, x 1175. 9. Equatorial view of a pollen grain of *Murraya paniculata*, x 1175. 10. Pollen grains of *Borassus flabellifer*, x 470. 11. Pollen grain of *Martynia annua*, x 1175. 12. Equatorial view of a pollen grain of *Erythrina variegata*, x 1175. 13. Pollen grain of *Jatropha gossypifolia*, x 1175.

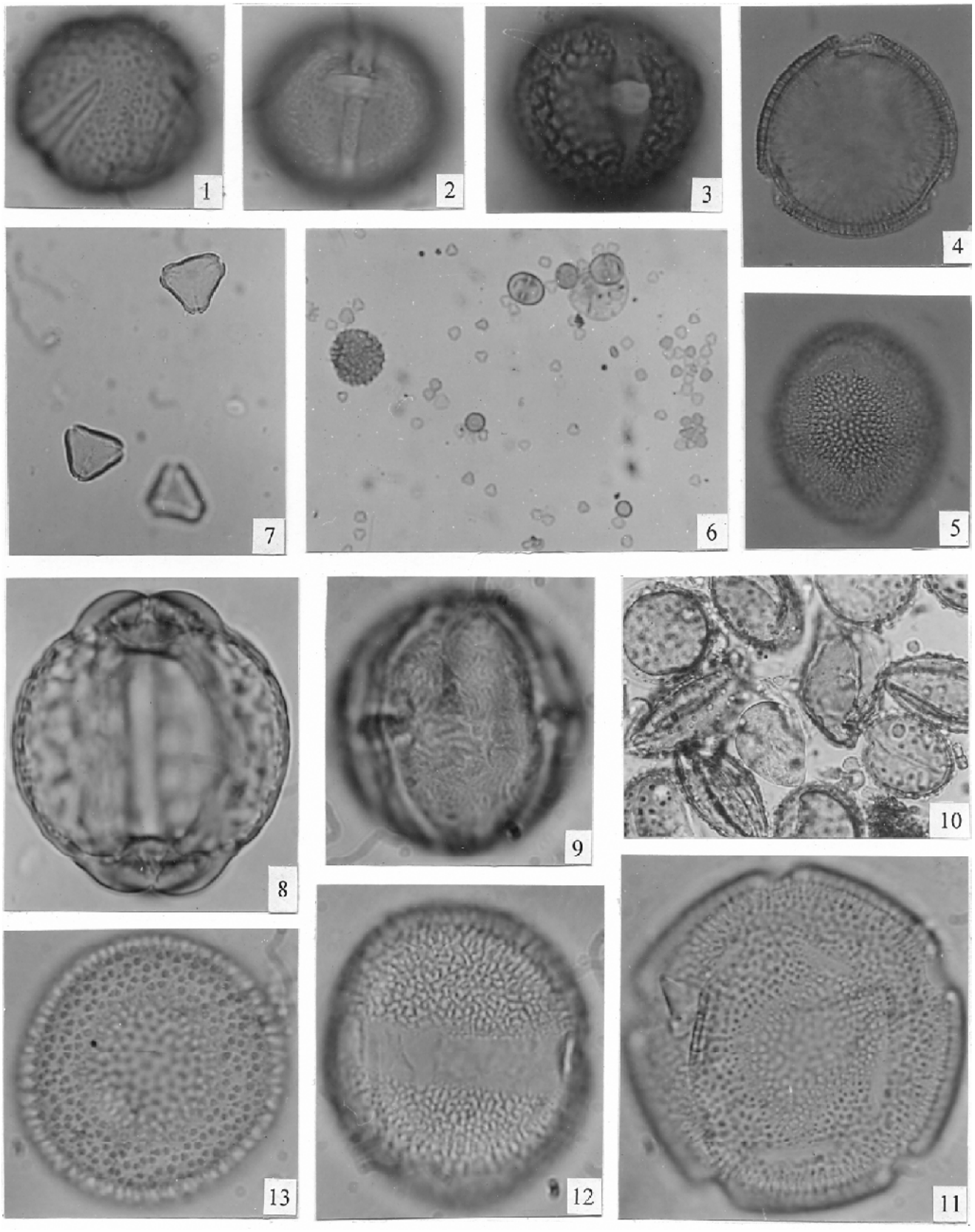
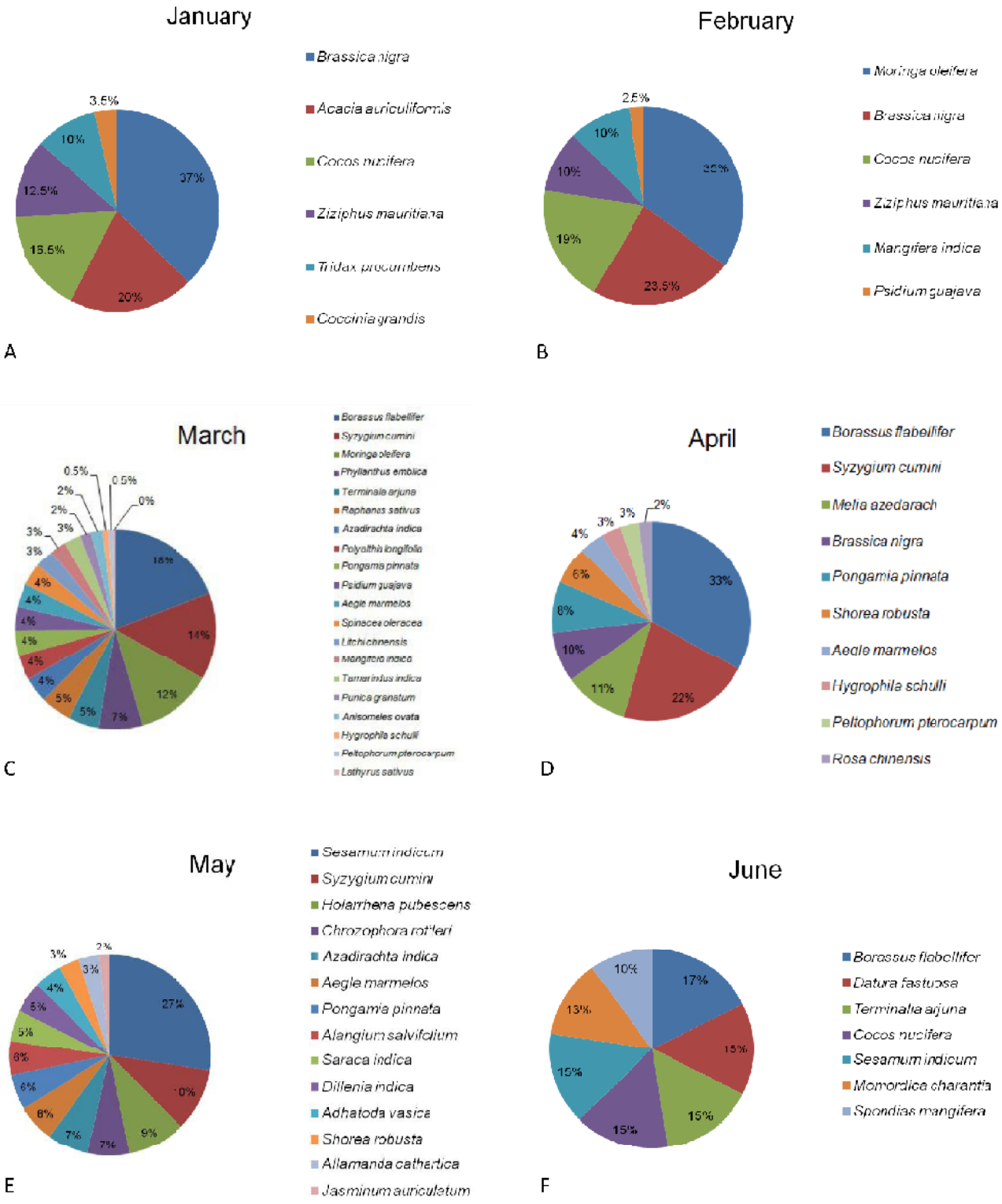
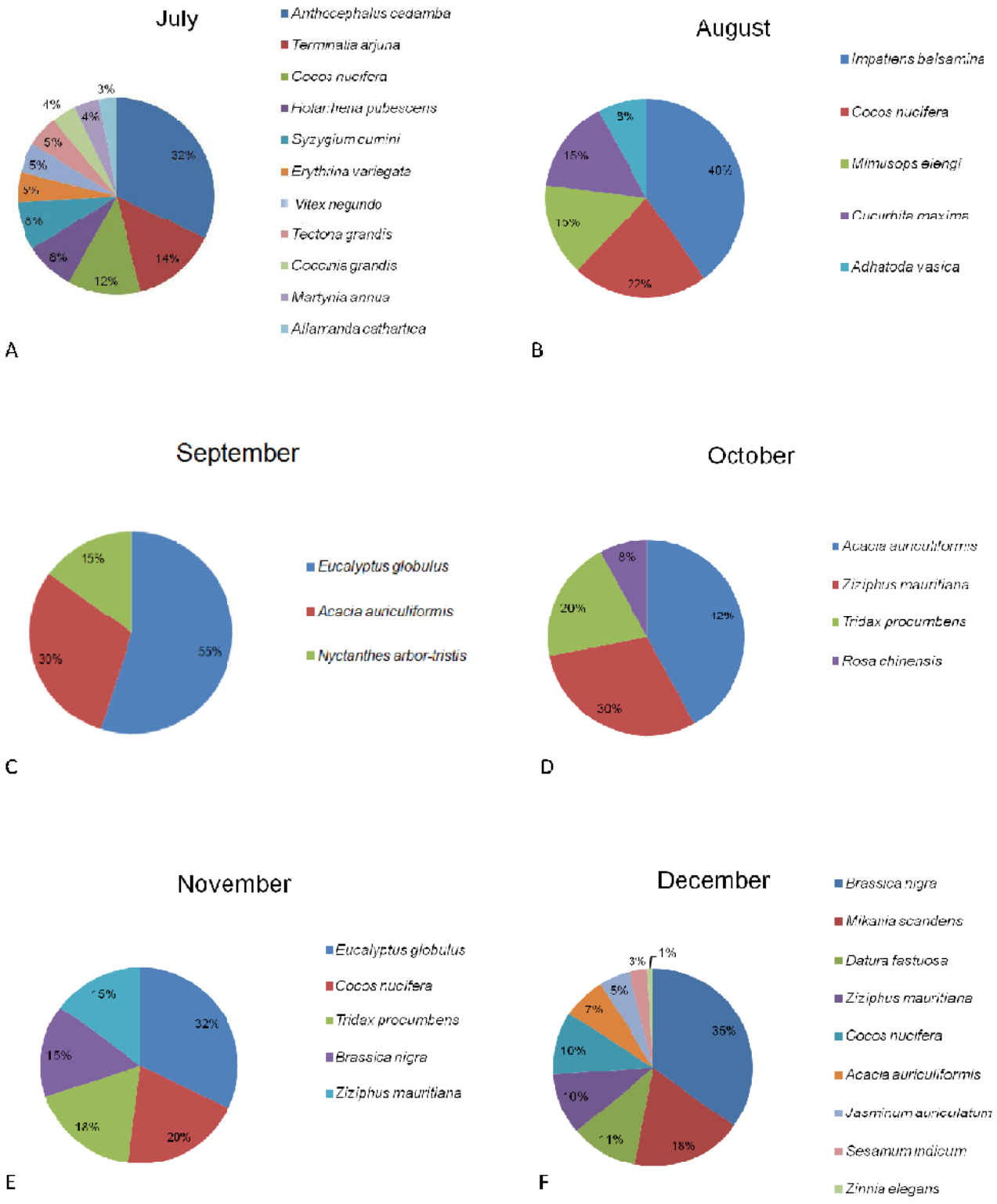


Plate 4



Text figure 4. Pie diagrammes of month-wise nectar forage by *Apis mellifera* in Gangetic West Bengal (January- June).



Text figure 5. Pie diagrammes of month-wise nectar forage by *Apis mellifera* in Gangetic West Bengal (July - December).

Table 2. Nectar forage calendar of *Apis mellifera* in Gangetic West Bengal.

Incidence Month	Most frequent	Moderately frequent	Less frequent
JAN	*Brassica nigra, Acacia auriculiformis*	*Cocos nucifera, Ziziphus mauritiana, Tridax procumbens*	*Coccinia grandis*
FEB	*Moringa oleifera, Brassica nigra*	*Cocos nucifera, Ziziphus mauritiana, Mangifera indica*	*Psidium guajava*
MAR	—	*Borassus flabellifer, Syzygium cumini, Moringa oleifera, Phyllanthus emblica, Terminalia arjuna, Raphanus sativus,*	*Aegle marmelos, Azadirachta indica, Polyalthia longifolia, Pongamia pinnata, Psidium guajava, Spinacea oleracea, Litchi chinensis, Mangifera indica, Tamarindus indica, Punica granatum, Anisomeles ovata, Hygrophylla schulli, Lathyrus sativus, Peltophorum pterocarpum*
APR	*Borassus flabellifer, Syzygium cumini*	*Melia azedarach, Brassica nigra, Pongamia pinnata, Shorea robusta*	*Aegle marmelos, Hygrophylla schulli, Peltophorum pterocarpum, Rosa chinensis*
MAY	*Sesamum indicum*	*Syzygium cumini, Holarrhena pubescens, Chrozophora rottleri, Azadirachta indica, Aegle marmelos, Pongamia pinnata, Alangium salvifolium, Saraca indica, Dillenia indica*	*Adhatoda vasica, Allamanda cathartica,Shorea robusta, Jasminum auriculatum*
JUN	—	*Borassus flabellifer, Cocos nucifera, Datura fastuosa, Sesamum indicum, Terminalia arjuna, Momordica charantia, Spondias mangifera*	—
JUL	*Anthocephalus cadamba*	*Terminalia arjuna, Cocos nucifera, , Holarrhena pubescens, Syzygium cumini, Erythrina variegata,Vitex negundo, Tectona grandis*	*Coccinia grandis, Martynia annua, Allamanda cathartica*
AUG	*Impatiens balsamina, Cocos nucifera*	*Cucurbita maxima, Mimusops elengi, Adhatoda vasica*	—
SEP	*Eucalyptus globulus, Acacia auriculiformis*	*Nyctanthes arbortristis*	—
OCT	*Acacia auriculiformis, Ziziphus mauritiana, Tridax procumbens*	*Rosa chinensis*	—
NOV	*Eucalyptus globulus, Cocos nucifera*	*Tridax procumbens, Brassica nigra, Ziziphus mauritiana*	—
DEC	*Brassica nigra*	*Mikania scandens, Datura fastuosa, Cocos nucifera, Ziziphus mauritiana, Acacia auriculiformis, Jasminum auriculatum*	*Sesamum indicum, Zinnia elegans*

Tamarindus indica, *Tectona grandis*, *Vitex negundo*, *Ziziphus mauritiana* and *Zinnia elegans*.

Out of the 73 species, 20 species serve exclusively as pollen source. Those are *Averrhoa carambola*, *Barringtonia acutangula*, *Bauhinia malabarica*, *Carica papaya*, *Citrus maxima*, *Cleome viscosa*, *Cordia sebestena*, *Croton bonplandianum*, *Gmelina arborea*, *Jatropha gossypifolia*, *Lagerstroemia speciosa*, *Luffa acutangula*, *Monochoria hastata*, *Murraya paniculata*, *Phoenix sylvestris*, *Poa gangetica*, *Sida acuta*, *Solanum melongena*, *Syzygium jambos* and *Xanthium strumarium*.

Remaining 20 species provide both nectar and pollen. Those are *Acacia auriculiformis*, *Aegle marmelos*, *Anthocephalus cadamba*, *Borassus flabellifer*, *Brassica nigra*, *Chrozophora rottleri*, *Cocos nucifera*, *Dillenia indica*, *Eucalyptus globulus*, *Litchi chinensis*, *Martynia annua*, *Phyllanthus emblica*, *Polyalthia longifolia*, *Pongamia pinnata*, *Spondius mangifera*, *Saraca indica*, *Terminalia arjuna*, *Shorea robusta* and *Tridax procumbens*.

The month-wise forage calendar, with respect to both pollen grains and nectar, of *Apis mellifera* in

Table 3. Month wise forage calendar of *Apis mellifera* in Gangetic West Bengal.

Forage Month	POLLEN FORAGE	NECTAR FORAGE
JAN	Most frequent: *Cocos nucifera, Tridax procumbens* Moderately frequent: *Phoenix sylvestris, Luffa acutangula*, *Brassica nigra* Less frequent: -	Most frequent: *Brassica nigra, Acacia auriculiformis* Moderately frequent: *Cocos nucifera, Ziziphus mauritiana, Tridax procumbens* Less frequent: *Coccinia grandis*
FEB	Most frequent: *Cocos nucifera, Phoenix. sylvestris* Moderately frequent: *Aegle marmelos, Tridax procumbens,Solanum melongena, Litchi chinensis* Less frequent: *Bauhinia malabárica*	Most frequent: *Moringa oleifera, Brassica nigra* Moderately frequent: *Cocos nucifera, Ziziphus mauritiana, Mangifera indica* Less frequent: *Psidium guajava*
MAR	Most frequent: - Moderately frequent: *Borassus flabellifer, Citrus maxima, Aegle marmelos, Carica papaya, Gmelina arborea, Syzygium cumini, Phyllanthus emblica, Spondias mangifera, Terminalia arjuna* Less frequent: *Polyalthia longifolia, Cocos nucifera, Litchi chinensis*, *Saraca indica*	Most frequent: - Moderately frequent: *Borassus flabellifer, Syzygium cumini, Moringa oleifera, Phyllanthus emblica, Terminalia arjuna, Raphanus sativus* Less frequent: *Aegle marmelos, Azadirachta indica, Polyalthia longifolia, Pongamia pinnata, Psidium guajava, Spinacea oleracea, Litchi chinensis, Mangifera indica, Tamarindus indica, Punica granatum, Anisomeles ovata, Hygrophylla schulli, Lathyrus stivus, Peltophorum pterocarpum*
APR	Most frequent: - Moderately frequent: *Terminalia arjuna, Luffa acutangula, Pongamia pinnata, Borassus flabellifer Polyalthia longifolia*, *Spondias mangifera, Cocos nucifera, Shorea robusta* Less frequent: *Polyalthia longifolia, Cocos nucifera, Litchi chinensis, Saraca indica*	Most frequent: *Borassus flabellifer, Syzygium cumini* Moderately frequent: *Melia azedarach, Brassica nigra, Pongamia pinnata, Shorea robusta* Less frequent: *Aegle marmelos, Hygrophylla schulli, Peltophorum pterocarpum, Rosa chinensis*
MAY	Most frequent: *Borassus flabellifer, Cocos nucifera* Moderately frequent: *Lagerstroemia speciosa, Luffa acutangula, Citrus máxima* Less frequent: *Chrozophora rottleri, Cordia sebestina,* *Barringtonia acutangula, Syzygium jambos*	Most frequent: *Sesamum indicum* Moderately frequent: *Syzygium cumini, Holarrhena pubescens, Chrozophora rottleri, Azadirachta indica, Aegle marmelos, Pongamia pinnata, Alangium salvifolium, Saraca indica, Dillenia indica* Less frequent: *Adhatoda vasica, Allamanda cathartica,Shorea robusta, Jasminum auriculatum*
JUN	Most frequent: *Averrhoa carambola, Cocos nucifera* Moderately frequent: *Bauhinia malabarica, Chrozophora rottleri, Borassus flabellifer, Lagerstroemia speciosa,* *Jatropha gossypifolia, Dillenia indica* Less frequent: *Croton bonplandianum, Syzygium cumini,* *Cordia sebestina, Cleome viscosa*	Most frequent: - Moderately frequent: *Borassus flabellifer, Cocos nucifera, Datura fastuosa, Sesamum indicum, Terminalia arjuna, Momordica charantia, Spondias mangifera* Less frequent: -
JUL	Most frequent: - Moderately frequent: *Anthocephalus cadamba, Cleome viscosa, Monochoria hastata, Cocos nucifera, Acacia auriculiformis, Murraya paniculata, Averrhoa carambola, Lagerstroemia speciosa* Less frequent: *Eucalyptus globulus, Syzygium cumini, Bauhinia malabárica*	Most frequent: *Anthocephalus cadamba* Moderately frequent: *Terminalia arjuna, Cocos nucifera, , Holarrhena pubescens, Syzygium cumini, Erythrina variegata,Vitex negundo, Tectona grandis* Less frequent: *Coccinia grandis, Martynia annua, Allamanda cathartica*
AUG	Most frequent: *Cocos nucifera* Moderately frequent: *Murraya paniculata, Anthocephalus cadamba, Borassus flabellifer, Bauhinia malabarica,Cleome viscosa* Less frequent: *Acacia auriculiformis, Monochoria hastata*	Most frequent: *Impatiens balsamina, Cocos nucifera* Moderately frequent: *Cucurbita maxima, Mimusops elengi, Adhatoda vasica* Less frequent: -

SEP	Most frequent: *Acacia auriculiformis, Cocos nucifera* Moderately frequent: *Eucalyptus globulus, Martynia annua, Sida acuta, Poa gangetica* Less frequent: *Bauhinia malabarica,* *Monochoria hastata, Murraya paniculata*	Most frequent: *Eucalyptus globulus, Acacia auriculiformis* Moderately frequent: *Nyctanthes arbortristis* Less frequent: -
OCT	Most frequent: *Acacia auriculiformis, Xanthium strumarium* Moderately frequent: *Cocos nucifera*, *Murraya paniculata, Monochoria hastata, Sida acuta, Tridax procumbens* Less frequent: -	Most frequent: *Acacia auriculiformis, Ziziphus mauritiana, Tridax procumbens* Moderately frequent: *Rosa chinensis* Less frequent: -
NOV	Most frequent: *Cocos nucifera* Moderately frequent: *Acacia auriculiformis*, *Tridax procumbens*, *Brassica nigra, Monochoria hastata*, *Luffa acutangula, Sida acuta, Xanthium strumarium* Less frequent: *Eucalyptus globulus*	Most frequent: *Eucalyptus globulus, Cocos nucifera* Moderately frequent: *Tridax procumbens, Brassica nigra, Ziziphus mauritiana* Less frequent: -
DEC	Most frequent: *Acacia auriculiformis*, *Brassica nigra, Cocos nucifera* Moderately frequent: *Sida acuta, Luffa acutangula, Tridax procumbens* Less frequent: -	Most frequent: *Brassica nigra* Moderately frequent: *Mikania scandens, Datura fastuosa, Cocos nucifera, Ziziphus mauritiana, Acacia auriculiformis, Jasminum auriculatum* Less frequent: *Sesamum indicum, Zinnia elegans*

Gangetic West Bengal is detailed in Table 3.

As mentioned earlier, from the production point of view, apiculture is a seasonal practice in Gangetic West Bengal. During the period from the late January to early May and from mid September to early November, *Apis mellifera* accumulates surplus honey enabling commercial extraction. Therefore, late January to early May and mid September to early November, are the productive seasons when honey is extracted by the beekeepers from the hives for commercial purpose. On the other hand, the periods from mid May to early September and mid November to mid January can be regarded as the stress seasons because of the poor foraging by bees due to unfavourable weather condition together with floral dearth. For sustenance of the bee colonies, beekeepers are often compelled to supply very dilute sugar solution in their hives. However, sucrose is not at all an adequate substitute of nectar and pollen for balanced nutrition and maintenance of proper vigour of a bee colony. During those stress seasons, the following plants constitute the bee pasturage: *Acacia auriculiformis*, *Adhatoda vasica*, *Allamanda cathartica, Anthocephalus cadamba*, *Averrhoa carambola, Bauhinia malabarica*, *Borassus flabellifer*, *Cleome viscosa, Coccinia grandis*, *Cocos nucifera*, *Cucurbita maxima*, *Datura fastuosa, Erythrina variegata*, *Eucalyptus globulus*, *Holarrhena pubescens*, *Impatiens balsamina*, *Lagerstroemia speciosa, Martynia annua*, *Mimusops elengi*, *Momordica charantia*, *Monochoria hastata, Murraya paniculata, Nyctanthes arbor-tristis, Sesamum indicum*, *Spondias mangifera, Syzygium cumini*, *Tectona grandis*, *Terminalia arjuna* and *Vitex negundo*. These are of immense importance for sustenance of bee colonies during the stress periods.

The pollen spectra of honey samples reveal that *Apis mellifera* in gangetic West Bengal produce primarily multifloral honeys during the major part of the year. However, in September it produces unifloral honeys of *Eucalyptus globulus* type.

The overall forage calendar of *A. mellifera*, as has presently been worked out, includes the following agricultural or horticultural plants cultivated in the region: *Aegle marmelos*, *Averrhoa carambola*, *Brassica nigra, Carica papaya, Citrus maxima, Coccinia grandis, Cocos nucifera*, *Cucurbita maxima*, *Dillenia indica*, *Litchi chinensis*, *Luffa acutangula, Mangifera indica*, *Momordica charantia, Moringa oleifera*, *Phyllanthus emblica*, *Psidium guajava*, *Punica granatum*, *Sesamum indicum, Solanum melongena, Spondias mangifera*, *Syzygium cumini*, *Syzygium jambos*, *Tamarindus indica* and *Ziziphus mauritiana*. As bees are known to be one of the most

effective groups of pollinators, therefore, while visiting the flowers of above mentioned crops to collect pollen or nectar or both, they may help in their pollination. Therefore, in view of the recent pollination crisis, possibility of use of *A. mellifera* hives can be explored for enhancing the yield of those crops.

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The authors are thankful to the authorities of the University of Burdwan for providing necessary laboratory and library fecilities. Thanks are also due to Mr. Ashok Sashmal of Singur, Mr. Dinanath Kamle of Noapara, Mr. Sabbir Ali of Berhampur and Mr. Pran Kumar Banerjee of Burdwan for their help in collection of samples of pollen pellets and honey from time to time. A Research Fellowship awarded to one of the authors (P. K.) by the Government of West Bengal is also gratefully acknowledged

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Geophytology 42(2): 115-119
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New distributional records of lichen genus *Mycobilimbia* from India

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ABSTRACT

Dubey U., Upreti D. K., Ingle K. K. & Nayaka S. 2013. New distributional records of lichen genus *Mycobilimbia* from India. Geophytology 42(2): 115-119.

New distributional records of three species of *Mycobilimbia* collected during the last two decades from different phytogeographical regions of India are provided. All the species exhibit their wide distribution in tropical to temperate regions of both Eastern and Western Himalayas. No records of the species from Western Ghats and other regions of India are available.

Key-words: Lichen, additional distribution, *Mycobilimbia*, India.

INTRODUCTION

The lichen genus *Mycobilimbia* is represented by 44 species in the world, of which 3 species are known from India. The close morphological and anatomical similarities between lichen genera *Biatora* Fr. and *Mycobilimbia* Rehm. resulted into systematic and nomenclatural confusion between the two taxa. Some authors accept the genus *Mycobilimbia* (Vitikainen et al. 1997, Diederich & Serusiaux 2000, Hafellner & Türk 2001, Llimona & Hladun 2010) while other includes it in *Biatora* (Purvis et al. 1992). *Mycobilimbia* was originally circumscribed by Hafellner (1984) as heterogeneous. Awasthi and Mathur (1987) described three species of this genus from India, based on the limited number of species either collected from Darjeeling district of West Bengal in Eastern Himalayas or few localities of Uttarakhand in the Western Himalayas. Räsänan (1950) described *Mycobilimbia calcuttensis* Räsänan, a new species from India (Holotype at Helsinki Herbarium and Isotype at LWG), which is a nonlichenized fungus according to Singh and Sinha (2010).

During the last 2 decades, a large number of field explorations for collection of lichens from various regions of India were conducted and additional distributional records of the species of *Mycobilimbia* are added to the present distribution. The species of *Mycobilimbia* mostly prefer to grow on rock, mosses or on soil over rock mostly in tropical to temperate Himalayan regions between 300m and 2200m both in Eastern and Western Himalayas.

MATERIAL AND METHOD

The study is based on the lichen samples lodged in the Herbarium of National Botanical Research Institute, Lucknow (LWG). Morphological characters were examined on dry material under a stereozoom microscope and anatomical details were examined with a compound microscope. The hand cut sections of apothecia were mounted in water, 10% KOH (K), Paraphenylenediamine (Pd), Lugol's solution (I) and cotton blue. Secondary metabolites of the apothecia were identified by Thin Layer Chromatography (Orange et al. 2001).

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TAXONOMIC TREATMENT

Mycobilimbia hunana (Zahlbr.) D. D. Awasthi in D. D. Awasthi & R. Mathur

Proc. Indian Acad. Sci., Pl. Sci. 97(6): 501. 1987.
Bacidia hunana Zahlbr. In Hand. Mazz. Symb. Sin 3: 113. 1930.

Plate 1, figure 1

Description: Thallus terricolous sometimes saxicolous, cracked; surface grey, granulose; apothecia single or in groups, 0.2-0.8 mm in diameter, plane to convex; disc dark brown to black, epruinose; margin entire, pale yellow; exciple red-brown, 54-77 µm thick at margin, K+ violet-brown, fading below; epithecium red-brown, 12-14 µm thick, K-; hymenium hyaline, 76-92 µm thick, K-, I+ deep blue; hypothecium pale red-brown, 38-50 µm thick, K-; asci cylindrico-clavate, 8-spored; ascospores colourless, oblong-ellipsoid to rarely fusiform, both the ends rounded, sometimes one end slightly tapering than the other, transversely 3-septate, 21-28 x 6-9 µm; paraphyses colourless, simple.

Chemistry: Thallus K-, C-, KC-, P-.

Remarks: The species is characterized by K+ violet brown exciple, 3-septate, 20-28 × 6-9 µm sized ascospore. *M. philippina* is close to the species in morphology but differs in having K- exciple and slightly less wide 5-6 µm ascospores. Earlier, *Mycobilimbia hunana* was reported to occur in Nagaland and West Bengal hills only (Singh & Sinha 2010). Now, the species exhibits its wide extended distribution in Cachar district of Assam, Upper and West Siang districts of Arunachal Pradesh, Gangtok area of Sikkim, Champawat and Chamoli district of Uttarakhand and Kalimpong division of Darjeeling district.

Specimens examined: Assam: Cachar district, Ching Coorie area, on rocks, 17 May 2007, U. Dubey and B. Singha 07-016299 (LWG); Arunachal Pradesh: West Siang district, Kamba, alt. 370 m, on rocks, 26 Jan 2007, U. Dubey 07-009065 (LWG); Upper Siang district, Jengging, near circuit house, alt. 945 m, on rock, 18 Nov 2008, D. K. Upreti, U. Dubey, R. Khare and G. K. Mishra 08-009310/A (LWG); Sikkim: Gangtok, near Burtuk Basti, alt. 1700 m, on rocks, 5 March 1994, G.P. Sinha (BSHC); Uttarakhand: Chamoli district, Gupta Kashi, 2 km from Temple in forest, alt. 1300-1400, on rocks, 23 Sept 1976, Dange 76518, 76519 (LWG-LWU); Champawat district, Dunaghat, alt. 1750 m, on rocks, 28 Nov 2010, G. K. Mishra 10-015249; Gurauli, alt. 1400 m, on rocks, 28 Nov. 2010, G. K. Mishra, 10-015375, 10-015376 (LWG); Uttarkashi district, Silkyara, 1620 m, 15 Sept 1977, A. Singh 95331 (LWG); West Bengal: Darjeeling district, Tiger hill, alt. 2250 m, on ground, 1954, Awasthi 3140 (LWG-AWAS); Darjeeling Pashok road at about 7 miles from Darjeeling, alt. ca. 1900 m, on soil by road side, 6 march 1967, Awasthi & Agarwal 67-175 (LWG-LWU); Kalimpong division way to Musong from Kalimpong alt. ca. 1500 m, on hard soil by road side, 16 May 1967, Awasthi & Agarwal 67-326/B (LWG-LWU); Kalimpong division way to Musong from Kalimpong alt. ca. 1500 m, on hard soil by road side, 16 May 1967, Awasthi & Agarwal 67-326/B (LWG-LWU).

Mycobilimbia philippina (Vain.) D. D. Awasthi in D. D. Awasthi & R. Mathur

Proc. Indian Acad. Sci., Pl. Sci. 97(6): 501. 1987.
Bilimbia philippina Vain., Ann. Acad. Sci. Fenn., Sér A, 159(6): 76. 1920.

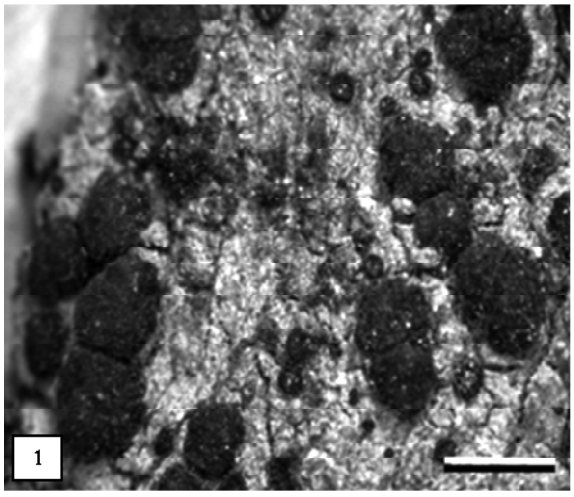
Plate 1, figure 2

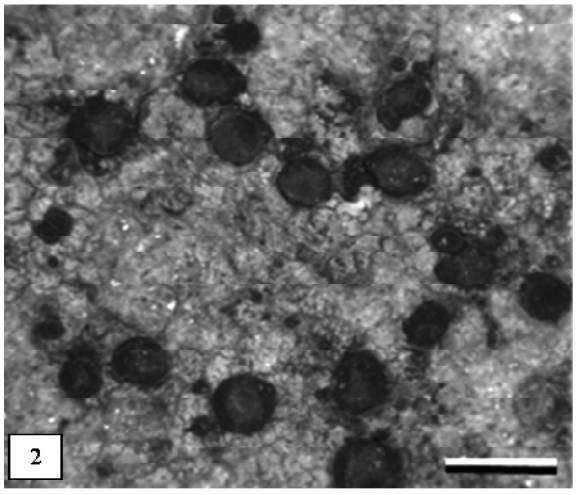
Description: Thallus terricolous sometimes saxicolous, cracked; surface grey, furfuraceous; apothecia single or in groups, 0.5-1 mm in diameter, plane to convex; disc black, epruinose; margin entire, brown; exciple red-brown, 70-80 µm thick at margin, K-, fading below; epithecium red-brown, 10-15 µm thick, K-; hymenium hyaline, 70-80 µm thick, K-, I+

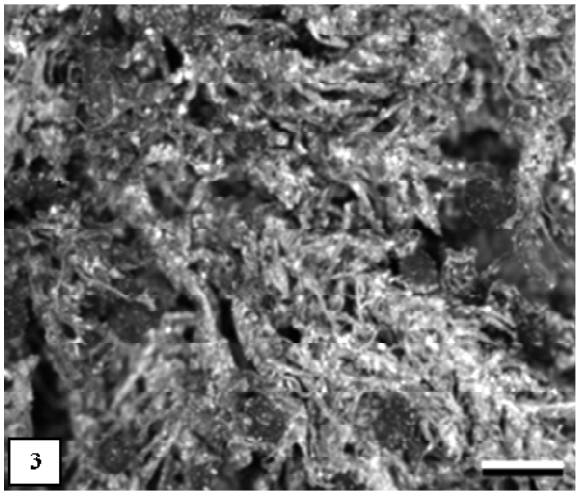
→

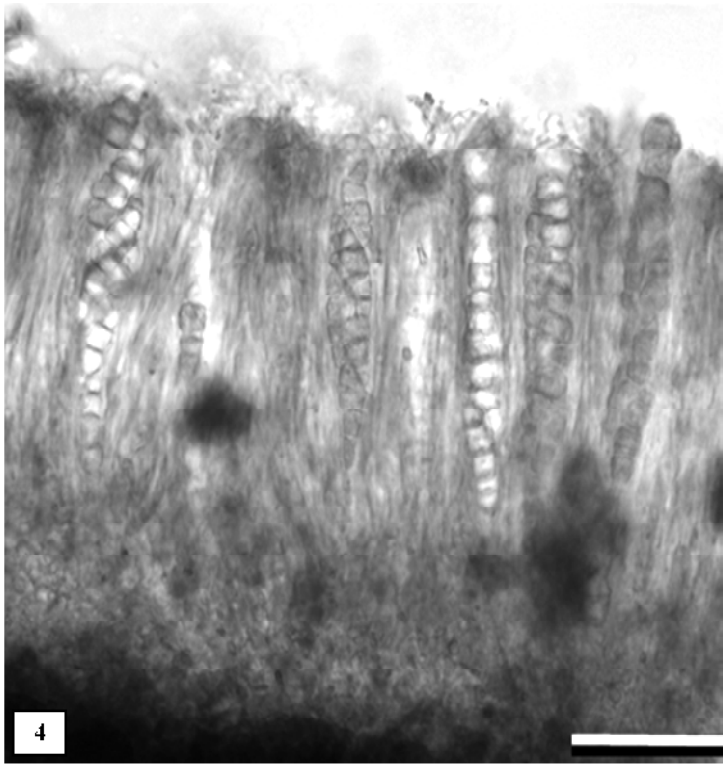
Plate 1

1. *Mycobilimbia hunana*, habitus. 2. *Mycobilimbia philippina*, habitus. 3. *Mycobilimbia sphaeroides*, habitus. 4. Ascus. 5. Ascospores. Scales: A & B = 2 mm; C = 1 mm; D & E = 50 µm.









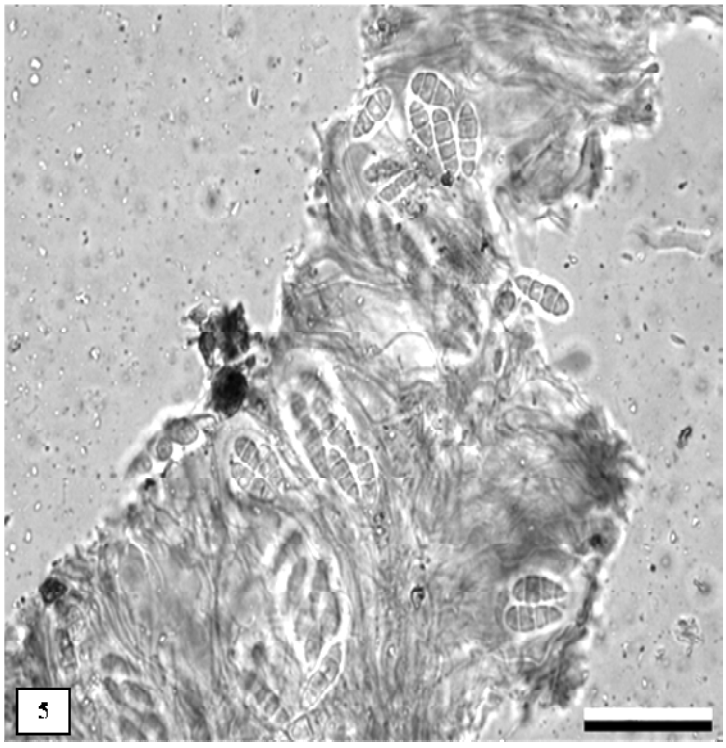


Plate 1

deep blue; hypothecium pale yellow, 40-45 µm thick, K-; asci cylindrico-clavate, 8-spored; ascospores colourless, oblong-ellipsoid to rarely fusiform, both the ends rounded, transversely 3-septate, 20-30 x 4-6 µm; paraphyses colourless, simple to branched.

Chemistry: Thallus K-, C-, KC-, P-.

Remarks: The species is characterized by K- exciple, 20-30 × 4-6 µm sized ascospores. It is close to *M. hunana* but differs in having less wide ascospores and K- exciple**.** Singh & Sinha (2010) reported the occurrence of this species in Arunachal Pradesh, Manipur, Nagaland, Uttarakhand and West Bengal Hills. The present study further extends the distribution of the species in Cachar district of Assam, Upper Siang district of Arunachal Pradesh, Upper Shillong region in Meghalaya, Chakrata hills, Champawat and Munsiyari and Milam region of Uttarakhand and Kalimpong and Kurseong areas of Darjeeling hills in West Bengal.

Specimens examined: Assam: Cachar district, Ching Coorie area, on rocks, 17 May 2007, U. Dubey & B. Singha 07-016297, 07-016298 (LWG). Arunachal Pradesh: Upper Siang district, Jengging, towards forest road, on vertical rocks, 30 Oct. 2007, U. Dubey 07-012360 (LWG); Dibang Valley district, Roing, Salley lake area, 300 m, on soil, 31 Aug. 1986, D. K. Upreti & M. Ranjan 201565 (LWG); Meghalaya: Upper Shillong peak, by road side, 1950 m, on soil, 6 Oct. 1964, D. D. Awasthi 6479, 6458 (LWG-AWAS); Uttarakhand: Dehradun district, Chakrata hills, on way to Deoban, alt. 1700 m, or rocks, 28 Nov. 2010, G. K. Mishra 10-015029 (LWG); Sukhidak, Shyamla Tal, 1200 m, on rocks, 24 June 1993, D. K. Upreti, 212821 (LWG); Pauri district, Nagdeo, 1950 m, on soil, 15 Oct. 1969, A. Singh 86944 (LWG); Pithoragarh district, Lake Ghati area before Munsiyari, 1200 m, on rocks, D. K. Upreti, 09-012635 (LWG); Lilam to Bogudiyar enroute to Milam Glacier alt. 1800-2450 m, on soil, 17.10.2007, S. Joshi 07-010552 (LWG); West Bengal: Darjeeling district, Kalimpong division, on way to Munsong from Kalimpong, alt. 1500 m, on hard soil by road side, March 10, 1967, D. D. Awasthi & M. R. Agarwal 67-326/A (LWG-LWU); Kurseong, Dow Hill, on soil, 1950 m, 23 Feb. 1966, D. D. Awasthi & M. R. Agarwal 66-2783 (LWG-LWU); Darjeeling, Pashok road, alt. 6-7 miles from Darjeeling, alt. 1950 m, on soil by road side, 6 March 1967, D. D. Awasthi & M. R. Agarwal 67-174 (LWG-LWU); Kurseong, near St. Mary College, 1650-1800 m, 22 Feb. 1966, D. D. Awasthi & M. R. Agarwal 66-178 (LWG-LWU).

Mycobilimbia sphaeroides D. D. Awasthi in D. D. Awasthi & R. Mathur

Proc. Indian Acad. Sci., Pl. Sci. 97 (6): 502. 1987.
Bacidia sphaeroides Vain., Acta Soc. Fauna Fl.Fenn.53(1): 234. 1922.

Plate 1, figure 3

Description: Thallus muscicolous, effuse; surface ash grey, slightly granulose; apothecia few, aggregated in groups, constricted at base, 0.2-0.5 in diameter, plane to convex; disc pale red-brown, epruinose; margin entire, concolorous to disc and later excluded; exciple colourless, 70-80 µm thick at margin, K-; epithecium colourless, K-; hymenium 80-105 µm thick, I+ deep blue then vinose red; hypothecium colourless, 60-70 µm thick, K-; ascospores elongate ellipsoid, transversely 3-4 septate, 20-30 x 4-5 µm; paraphyses simple to branched.

Remarks: The species is characterized by its muscicolous habitat, colourless hypothecium and K- exciple. The species is endemic to India and known from a single locality in temperate region of the Western Himalayas. *M. berengeriana* (A. Massal.) Hafellner & V. Wirth is similar to the species in muscicolous habitat and granular condition of thallus, however it differs in having dark brown hypothecium and simple ascospores.

Specimen examined: Uttarakhand: Dehradun district, Mussoorie, Chakrata hills, on way to Deoban, alt. ca. 8500 ft., on rocks among decaying mosses, 22.06.1976, D. D. Awasthi & M. Joshi 76.71 (LWG-LWU).

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Anatomical variations in Indian Mesozoic pentoxylean stems

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ABSTRACT

Sharma B. D., Bohra D. R., Suthar O. P. & Harsh R. 2013. Anatomical variations in Indian Mesozoic pentoxylean stems. Geophytology 42(2): 121-126.

Anatomical variations are described in the pentoxylean stems collected from the Rajmahal Hills, Jharkhand. The fossil stem taxa considered here are *Pentoxylon, Nipanioxylon, Guptioxylon* and *Purioxylon*. In all these, stem surface is more or less smooth except for the dwarf shoots of *Pentoxylon* which have elliptical leaf bases in close spirals. The vasculature is polystelic and the secondary wood is pycnoxylic. Patches of sclerotic cells are seen in the ground tissue. In *Pentoxylon,* there are 5-7 endocentric steles surrounding a pentagonal pith. *Nipanioxylon* has 8 concentric or exocentric steles in a ring outside the pith periderm. *Guptioxylon* has 4-6 main concentric steles, endocentric or little irregular in shape; cortical and pith bundles are of various shapes and sizes. In *Purioxylon*, the pith periderm is surrounded by a ring of manoxylic bundles which are collateral, conjoint and endarch. Cortical bundles are of various sizes and have pycnoxylic wood. Phylogenetic importance of this study is also discussed.

Key-words: Anatomy, pentoxylean stems, Mesozoic, Rajmahal Hills, Jharkhand, India.

INTRODUCTION

Srivastava (1944, 1945) instituted two new pentoxylean stems taxa, i.e. *Pentoxylon sahnii* and *Nipanioxylon guptae,* from the petrified cherts from Nipania, Rajmahal Hills, Jharkhand. Sahni (1948) accepted the establishment of *P. sahnii* but was little hesitant for *N. guptae*. Vishnu-Mittre (1957) believed *N. guptae* a distinct taxon but the material he studied was probably a conifer (Bose et al. 1985). Sharma et al. (2010), on the basis of study of better preserved material and slides, described *N. guptae* as a distinct pentoxylean stem different from *Pentoxylon*. Sharma (1969a) published a paper on *P. sahnii* and suggested the manner of origin of the cortical bundles. Sharma (1969b) instituted *Guptioxylon amarjolense*, a new pentoxylean stem. It has, in addition to the four main steles, medullary and cortical steles (bundles) of various shapes and sizes. Sharma (1972a) described another species of *Guptioxylon*, *G. endocentrica*, from Amarjola which has six endocentric main steles resembling that of *P. sahnii* but it has a number of pith bundles in addition to the cortical ones. Sharma (1972b) described one more pentoxylean stem *Purioxylon jurassica* from Amarjola, Rajmahal Hills. It has a pith periderm, manoxylic collateral, conjoint and endarch bundles while the cortical bundles have pycnoxylic woods. Sharma (1973a) showed 6-7 steles in a thin shoot of *Pentoxylon sahnii*. Sharma (1973b) described the anatomy of two kinds of short shoots collected from Amarjola. Sharma (1974a) published a paper on *Pentoxylon* and reported the presence of a distinct periderm layer surrounding the five steles in *P. sahnii*.

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This is not a common feature of *P. sahnii*. Sharma (1974b) described the branching pattern of *P. sahnii*. More than two types of branching pattern were suggested. Sharma (1979) published further observations on the anatomy of short shoots of *P. sahnii* and suggested that the traces to leaves and a branch originate in an identical manner and favoured the polystelic vasculature in *P. sahnii*. Sharma (1980) described that in *P. sahnii* vascular supply to a branch originates from 2-3 steles of the stem and a branch base receives a number of bundles similar to that of a leaf base.

Bose et al. (1985) published a review paper on *Pentoxylon* plant and discussed the anatomy of four types of shoots but without proper diagrams. This happened because neither they collected enough material themselves nor prepared slides and the description was based on old slides present at the Birbal Sahni Institute of Palaeobotany, Lucknow. They also treated *Guptioxylon amarjolense* and *G. endocentrica* as synonym of *P. sahnii* without giving proper justification. Bose et al. (1985) did not make any comment on *Purioxylon jurassica* Sharma 1972b. On the other hand, Sharma and associates collected hundreds of specimens and prepared a large number of slides for the publication purpose. Sharma and Bohra (1980) and Sharma et al. (1987) discussed the phylogeny of the Pentoxyleae and derived the pentoxylean anatomy from medullosan pteridosperms through *Guptioxylon* like an intermediate taxon. Suthar et al. (1988) described the anatomy of a new type of branch system identical to that of the peduncle of *Carnoconites compactus* Srivastava (Sahni 1948, figure 35). Srivastava and Banerji (2000) also published a review paper on *Pentoxylon* plant but they did not discuss much on its vasculature. Sharma (1996, 2001) and Sharma et al. (2010) discussed the vasculature of pentoxylean stems on the basis of study of better preserved specimens and good slides prepared from them.

In the present paper, anatomical variations in the pentoxylean stems, collected from Amarjola, Sonajori and Nipania localities, are described. Phylogenetic interpretations are also given.

MATERIAL AND METHOD

Hard and silicified fossiliferous cherts were collected from Nipania and Sonajori localities. Sections of these cherts were cut with a diamond edge wheel. In the Amarjola locality, fossils are found embedded in ferruginous sandy rock and are fragilc. These were cooked in canada-balsam prior to their sectioning with a wire bandsaw. Slides were prepared by the usual techniques of grinding and polishing methods and mounted in dilute canada balsam.

DESCRIPTION

Pentoxylon sahnii Srivastava 1945

More than one hundred petrified specimens of this taxon were collected by the authors from Amarjola. These range in size from 7 to 50 mm in diameter and 15 to 100 mm in length. Stem surface is smooth to transversely wrinkled. Similarly, a number of short shoots with elliptical leaf bases in close spirals could also be collected from Amarjola (Sharma et al. 2001). These range in size from 6-20 mm in diameter and 25 to 30 mm in length (Text-figure 6). At Nipania and Sonajori, the stems and short shoots are found embedded in silicified cherts and are visible only in thin sections. However, casts of the short shoots are visible in some of the cherts collected from Nipania.

Cross section through a thick shoot shows a typical periderm layer in the outer portion of cortex. Cortex has patches of sclerotic cells. Normally, 5 endocentric steles are present surrounding a pentagonal pith (Text-figures 2, 5). Patches of sclerotic cells are also present in pith. Mucilage canals are absent in the ground tissue. Each stele has a crushed primary xylem and well developed centripetal secondary xylem (Text-figure 1). Secondary xylem of the centrifuged side is either absent or comparatively poorly developed (Text-figures 1, 4-5). Growth rings are present in the secondary xylem. Secondary phloem is nicely preserved in many sections (Text-figure 14) and consists of tangentially arranged sieve cells and the fibers (Sharma & Bohra 1977). A tangential longisection shows 1-8 cells high uniseriate wood rays (Sharma 1969a). Radial longisection shows presence of uniseriate contiguous bordered pits on radial walls of tracheids (Sharma 1969a). Biseriate pits

are rare (Srivastava 1945, pl. 5, figure 42). Pits in cross field 1 or 2, large, circular with a narrow border.

Sharma (1973a, 1974a, b, 1980) observed many variations in the stelar system of the stem of *P. sahnii*. There is no relation between thickness of stem and number of main steles. A thin shoot may have 6-7 steles (Text-figure 3). In some of the sections through the stem an internal periderm (Sharma 1974a, b) surrounding the steles is present (Text-figure 5). The cortical bundles originate as a result of fission of the centrifugal secondary xylem of steles (Text-figure 1). These detached portions either act as leaf traces or traces to a branch. Sometimes, a portion of the centripetal secondary xylem also passes to the base of the branch (Sharma 1974b).

In short shoots, collected from Amarjola (Sharma et al. 2001), 5 or 6, circular steles are present surrounding the pentagonal pith. Centripetal and centrifugal xylems are more or less equally developed. Primary xylem is also preserved but protoxylem position remained unclear, i.e. not mesarch (Text-figures 7-9). Leaf traces, originate from either side of the primary xylem plate (Text-figure 7). The ground tissue has patches of sclerotic cells (Text-figure 8). The second type of short shoots (thin shoots) have distantly placed leaf bases (Text-figure 10) (Sharma 1973b). Centrifugal xylem is poorly developed while ceritripetal one has comparatively much developed xylem with growth rings. Leaf traces originate from centrifugal xylem (Text-figure 11). Srivastava (1945), Sahni (1948) and Vishnu-Mittre (1957) figured cross sections of short shoots from Nipania bearing 5 plates of xylem surrounding a wide pith. We also have similar slides (Text-figure 12).

Bose et al. (1985) described breaking down of the five steles into a number of vascular pieces in the terminal portion of the shoot (Bose et al. 1985, figure 3C). Such a condition has not been observed in any specimen by us. Suthar et al. (1988) described a new type of shoot system (Text-figure 13) in *P. sahnii* which resembles the peduncle of *Carnoconites compactus* (Sahni 1948, figures 42-43). The vascular system has 5-7, narrow curved vascular arms (Text-figure 13) made up of 2-5 cells thick xylem. Endarch leaf (bract) traces originate frequently and in the leaf (bract) base the bundles become diploxylic and are arranged in an arc or row.

Nipanioxylon guptae Srivastava 1945

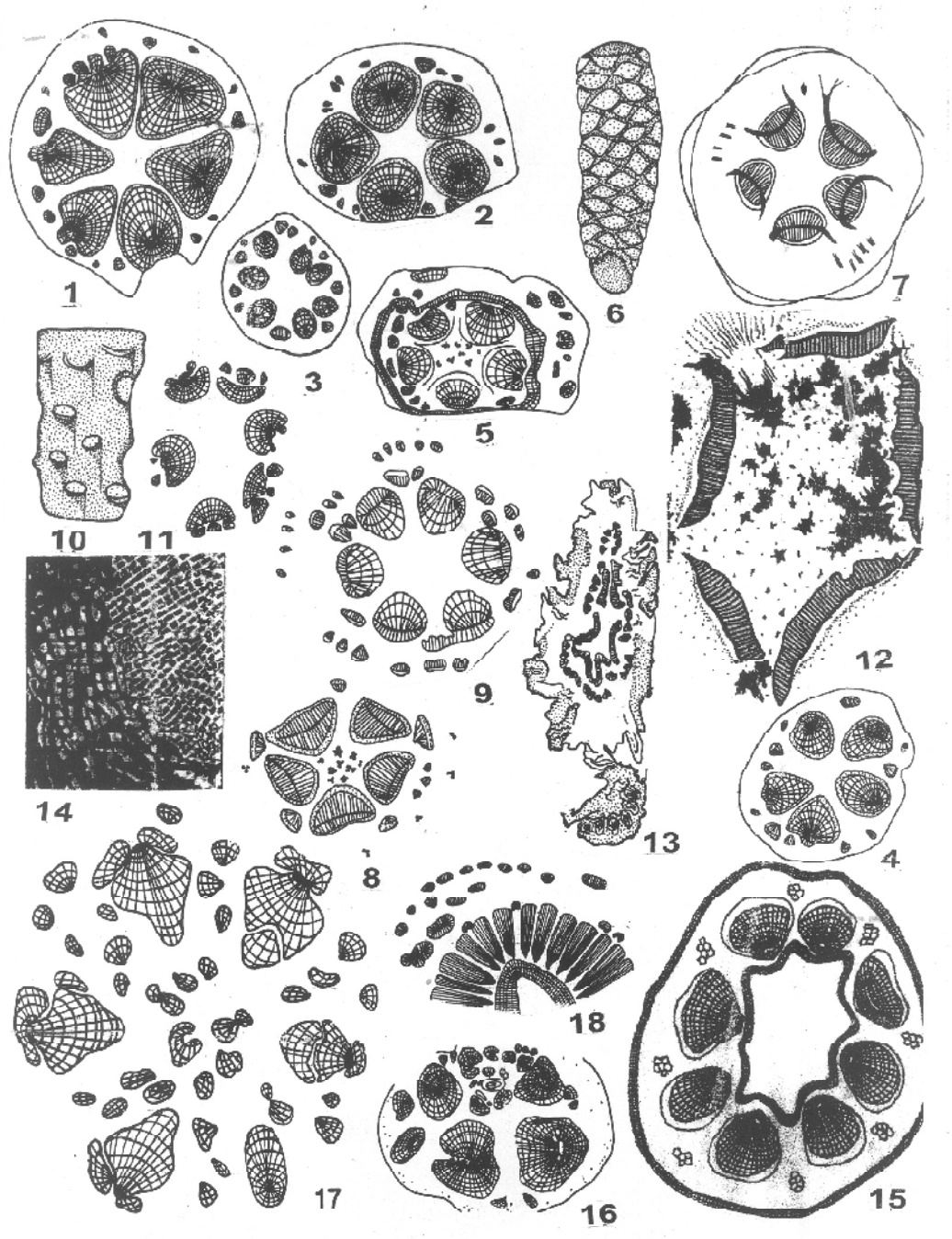
While preparing thin sections through the Nipania cherts, we observed four cross sections through the stem of *N. guptae*. The periphery is bound by a periderm layer. Cortex has patches of sclerotic cells. There are 8 exocentric steles outside the pith periderm (Text-figure 15). Wood is compact with growth rings. Primary xylem is poorly preserved. Centripetal xylem is much less in amount than that of the centrifugal side. In an oblique section, uniseriate contiguous bordered pits could be seen on radial walls of the tracheids. Anatomy suggests distinction of *N. guptae* from *Pentoxylon sahnii*. More investigations are needed on this controversial taxon.

Guptioxylon amarjolense Sharma 1969b

Two petrified specimens were collected from Amarjola and from the type specimen No. BIG/Raj. A. five serial sections were prepared. Stem surface is smooth, 8-19 mm in diameter and approximately 80 mm in length. There are 4 large concentric or little endocentric steles of unequal sizes. Primary xylem is crushed, secondary xylem is compact and differentiated into growth rings. Pith has smaller sized steles (bundles) of various shapes and sizes. Cortex also has many steles of various sizes and shapes and are exarch, mesarch and endarch (Text-figure 16). Sharma (1974a) identified two more variations, i.e. *Guptioxylon* A and *Guptioxylon* B. Further investigations are needed on this taxon.

Guptioxylon endocentrica Sharma 1972a

Stem thick, 50 mm in diameter with six endocentric steles of variable sizes which are arranged in a ring surrounding a large pith (Text-figure 17). Primary xylem is crushed; secondary xylem compact and differentiated into growth rings. Centrifugal xylem is much reduced. Medullary bundles many exarch, endarch or mesarch. Cortical bundles endarch and originate from the centrifugal xylem of the main steles (Text-figure 17). It resembles *P. sahnii* but differs in the presence of medullary bundles. Sclerotic nests are present in the ground tissue.



Text-figures 1-18. 1. *Pentoxylon sahnii* C.S. stem–six endocentric steles, cortical bundles originate from centrifugal xylem x6. 2. Same. More or less concentric steles x6. 3. Same. A thin shoot with 7 endocentric steles x6. 4. Same shoot with 5 steles x 6. 5. Same. An internal periderm surrounds the 5 steles x6. 6. Same. A short shoot with elliptical leaf bases in close spirals x3. 7. Same. C.S. short-shoot with 5 steles each having centripetal and centrifugal secondary xylems, primary xylem gives rise leaf traces from either ends x12. 8. Same. C.S. 5 steles without growth rings. Sclerotic cells present in the ground tissue x12. 9. Same. Short shoot C.S. 5 steles with growth rings and leaf traces x12. 10. Same. Thin shoot with distantly placed leaf bases x3. 11. Same. C.S. thin shoot, 6 steles with poorly developed centrifugal xylem. Centripetal xylem has growth rings x6. 12. Same C.S. short shoot from Nipania. 5 arc shaped stele having only centripetal xylem Patches of sclerotic cells common x24. 13. Same. Short shoot resembling in anatomy to the peduncle of *Carnoconites compactus* x8. 14. Thick stem C.S. with well developed secondary phloem outside secondary xylem of stele x72. 15. *Nipanioxylon guptae*. C.S. stem with two periderm and 8 exocentric steles. Secondary xylem compact with growth rings x12. 16. *Guptioxylon amarjolense* C.S. stem with 4 unequal steles, medullary and cortical bundles many x6. 17. *G. endocentrica* C.S. stem with 6 endocentric steles and many medullary and cortical bundles present x8. 18. *Purioxylon jurassica* C.S. stem with pith periderm, manoxylic vascular ring and cortical bundles of various sizes x8.

***Purioxylon jurassica* Sharma 1972b**

The type specimen No. B VI/Raj A has longitudinal wrinkles and an axillary bud. Four serial sections were prepared through the type specimen. Pith fistular and parenchymatous with a periderm layer. Outside it are present loosely arranged collateral, conjoint and endarch bundles (Text-figure 18). Cortex has many steles (bundles) of various sizes and shapes and all have compact secondary xylem with exarch, mesarch and endarch protoxylem resembling those of *Guptioxylon*. Outer portion of cortex has mucilage canals, a character different from other pentoxylean stems. Sharma (1972b, 1974a) considered the anatomy of *Purioxylon* an intermediate type between *Pentoxylon* and the cycads.

DISCUSSION

A new group 'the Pentoxyleae' of Jurassic gymnosperms was established on the basis of study of petrified plants which showed peculiarities in anatomical characters (Sahni 1948). For example, in *Pentoxylon* five endocentric steles made the vascular system. Wood was compact and differentiated into growth rings, wood rays were small and uniseriate, tracheids had uniseriate contiguous bordered pits on radial walls (Srivastava 1945). Leaf midrib had a row or an arc of 5-8 diploxylic bundles. In a seed cone, ovules were orthotropus and attached directly to the cone axis. Microsporophylls radial with balloon shaped microsporangia (Vishnu-Mittre 1953). Anatomical variations are noticed in pentoxylean stems collected from Amarjola, Nipania and Sonajori localities of the Rajmahal Hills. Sharma et al. (2010) have included four stem genera, i.e. *Pentoxylon*, *Nipanioxylon*, *Guptioxylon* and *Purioxylon* in the Pentoxyleae. Anatomical variations are also noticed in the vegetative and fertile short shoots. The former produce leaves (*Nipaniophyllum*) whereas the latter give rise origin separately to seed bearing cones and the microsporophylls. Bose et al. (1985) though divided the stem and its branches into four types yet the description remained unclear for want of proper diagrams. On the other hand, Sharma (1973a, b, 1974a, b, 1979, 1980, 1996, 2001), Sharma et al. (2010) and Suthar et al. (1988) explained the anatomical variations and their phylogenetic importance with the help of suitable photographs and drawings. Vascular supply to leaf and a branch originate in an identical manner and as such this has been related to those of *Cycadeoidea* (Delevoryas 1968) and *Gnetum* (Maheshwari & Vasil 1961). Srivastava (1945) considered *Nipanioxylon guptae* a distinct taxon different from *Pentoxylon* in number and orientation (exocentric, opposite to endocentric of *Pentoxylon*) of steles and presence of pith periderm. However, the wood is identical in being compact and presence of growth rings. Ground tissue has patches of sclerotic cells. Sahni (1948) though considered the investigation incomplete yet he assigned the material to the Pentoxyleae. Bose et al. (1985) studied some of the old slides of Srivastava present at the Birbal Sahni Institute of Palaeobotany, Lucknow and, on the basis of photographs published in Srivastava (1945), considered *Nipanioxylon* related to conifers. Bose et al. (1985) did not make any mention of Plate 9, figure 91 and its enlargement (Plate 10, figure 95) of Srivastava (1945). These are not collateral bundles of a conifer stem. No conifer stem has pith periderm, exocentric steles and patches of sclerotic cells in the ground tissue. Sharma et al. (2010) described *N. guptae*, a distinct pentoxylean stem and different from *Pentoxylon*. Their observations are based on 4 slides prepared through Nipania cherts. However, further investigations are required on this taxon and related organs.

Guptioxylon endocentrica Sharma (1972a) has stelar system more or less identical to that of *Pentoxylon sahnii*. But the presence of medullary bundles separate it from *P. sahnii*. *G. amarjolense* is quite distinct from *P. sahnii* in the number and morphology of steles. Medullary and cortical bundles are many and of various shapes and sizes. Sharma (1973a, 1974a) derived the vasculature of *G. amarjolense* from a medullosan stem and traced the evolution of *Pentoxylon sahnii* through *G. endocentrica* by disappearance of medullary bundles.

Purioxylon jurassica Sharma (1972b) is peculiar in having characters of cycads and pentoxylean stems. Presence of manoxylic vascular ring and mucilage canals in outer portion of cortex relate *Purioxylon* with cycads

while the compact wood of cortical bundles associates it with the pentoxylean taxa. Further investigations are needed on this taxon.

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An ebenaceous fossil wood from the Neyveli lignite, South Arcot District, Tamil Nadu, India

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ABSTRACT

Mukherjee D. & Prasad M. 2013. An ebenaceous fossil wood from the Neyveli lignite, South Arcot District, Tamil Nadu, India. Geophytology 42(2): 127-133.

A fossil wood, referable to the family Ebenaceae, has been recovered from the Neyveli lignite (Miocene) of South India. The fossil wood is characterized by apotracheal parenchyma occurring in 1-2 seriate, close, concentric tangential lines at regular intervals and 1-2 seriate heterogeneous xylem rays and shows affinity with the extant taxon *Diospyros malabarica* (Desr.) Kostel., presently occurring in Indo-Malayan region. The present finding indicates existence of tropical evergreen vegetation under humid climatic condition which was responsible for the formation of lignite in the Neyveli area.

Key-words: Carbonized wood, *Diospyros malabarica* (Desr.) Kostel., Ebenaceae, anatomy, climate, Neyveli lignite, South India

INTRODUCTION

The palaeobotanical study on Neyveli lignite revealed occurrence of both mega- and microfossils. A number of angiosperm fossil woods, belonging to several families, have so far been reported from these lignites (Awasthi 1984, Agarwal 1989, 1991, 1998). Recently, more than 50 wood specimens, collected from the Neyveli Lignite Mine-I, were studied. Most of them represent families Dipterocarpaceae, Anacardiaceae, Rhizophoraceae, Ebenaceae, Combretaceae and Lecythidaceae. Of these, one new fossil wood species, showing close affinity with the genus *Diospyros* Linn. (family Ebenaceae), has been described and discussed in the present paper. Palynofloras obtained from these lignite deposits are rich in algal and fungal remains, pteridophytic spores and angiosperm pollen (Navale 1962, Thiergart & Frantz 1963, Ramanujam 1963, 1966a, b, 1967, 1982, Ramanujam & Ramachar 1963, 1980, Deb 1972, Deb et al. 1973, Venkatachala 1973, Navale & Misra 1979, Ambwani et al. 1981, Bande & Ambwani 1982, 1983, Reddy et al. 1982, 1984, Thanikaimoni et al. 1984, Ramanujam & Reddy 1984, Sarma et al. 1984, Saxena 1984, Ramanujam et al. 1984, 1985, 1988, Siddhanta 1986, Sarma & Ramanujam 1988, Sarma & Reddy 1988, Singh & Misra 1991a, b, c, Singh et al. 1992, Misra et al. 1996).

GEOLOGY OF THE AREA

The Neyveli lignite deposits are developed in the northeastern part of South Arcot basin (Ariyalur-Pondicherry sub-basin) aligned in a NE-SW direction (Lat. 11°15'-11°40'N: Long. 79°25'-79°40'E) in Tamil Nadu state (Text-figure 1, Table 1). Available records suggest Eocene to Mio-Pliocene age for these deposits. The Precambrian basement (schists and gneisses) is succeeded by fossiliferous limestone, calcareous sandstone and marlstone (Late Cretaceous) whereas the Cuddalore Formation (Miocene-Pliocene) tops the sequence.

The subsurface lignite, in the upper part of Cuddalore Formation, lies as a major seam (less than 6 to 27 m in thickness) in Neyveli field at depths varying

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between 45 and 150 m below ground level. There is no major depositional disturbance. The lignite seam is uniform and non-banded in nature (Balasunder 1968, Subramanian 1969, Gowrisankaran et al. 1987, Banerji 1988, Singh et al. 1992). It is massive and compact when fresh, with dark brown to black colour and granular to fibrous texture (Text-figure 1B).

MATERIAL AND METHOD

The material for the present study comprised of carbonized woods collected from the Neyveli Lignite Mine-I, Tamil Nadu, South India. For anatomical study, the microtome sections (transverse, tangential and radial longitudinal) of the wood were cut using standard techniques. Suitable thin sections were studied under high power microscope. The photographs were prepared with the help of a digital camera (DS-20) attached to the microscope. Anatomical description of the wood is according to the recommendations of IAWA Committee (1989).

SYSTEMATIC DESCRIPTION

Order: Ericales

Family: Ebenaceae

Genus: *Diospyros* Linn.

***Diospyros neyveliensis* D. Mukherjee & M. Prasad, sp. nov.**

Plate 1, figures 1, 3-5, 7-9

Material: 3 pieces of carbonized woods, measuring 4-6 cm in length and 3-5 cm in width.

Description: Wood diffuse porous. Growth rings indistinct. Vessels small to medium sized, tangential diameter 64-120 μm; radial diameter 68-208 μm; solitary as well as multiples of 2-4 (rarely 6), 5-6 vessels per mm^2. The vessels are filled with dark contents (probably resin), circular to oval when solitary while those in radial multiples are generally flattened at the points of contact (Plate 1, figures 1, 3-4); vessel members 160-400 μm in length with usually truncate to tailed end, perforations simple; intervessel pits small to medium (4-6 μm) in diameter, alternate, orbicular to oval in shape; bordered, pits alternate with linear to lenticular apertures (Plate 1, figure 9). Parenchyma apotracheal and paratracheal; paratracheal parenchyma scanty associated with the vessels; apotracheal parenchyma 1-2 seriate, regular concentric slightly wavy lines, about 15-20 lines/mm (Plate 1, figures 1, 3); parenchyma cells thin walled, 12-16 μm in diameter and 55-180 μm in length. Xylem rays fine, 1-2 seriate, mostly uniseriate, 14-30 μm in width and 3-8 cells and 120-750 μm in length (Plate 1, figures 5-7); ray tissues heterogeneous with rays composed of both upright and procumbent cells; ray cells thin walled; tangential height of procumbent cells 16-26 μm in diameter and 16-68 μm in radial length; tangential height of upright cells 40-60 μm and 16-35 μm in radial length. Ray cells profusely crystalliferous in nature (Plate 1, figure 8). Fibres aligned in radial rows, polygonal, semi-libriform, moderately thick walled, non-septate; 12-16 μm in diameter; 150-330 μm in length.

Holotype: LU.NL-01, Department of Geology, Lucknow University, Lucknow.

Locality: Neyveli Lignite Mine-I, Tamil Nadu, South India.

Horizon and Age: Neyveli Formation, Miocene.

Modern affinities: The diagnostic features of the fossil wood, such as 1-2 seriate, close, concentric,

→

Plate 1

1, 3-5, 7-9. *Diospyros neyveliensis* sp. nov. 1. Cross section of the wood in low power, showing shape, size and distribution of vessels and parenchyma, Slide no. LU.NL-01. 3. Cross section, magnified to show the distribution of vessels and wavy pattern of parenchyma lines, Slide no. LU.NL-01. 4. A part of cross section, highly magnified to show the scanty parenchyma and vessels filled with dark resinous matter, Slide no. LU.NL-01. 5. Tangential longitudinal section, showing mostly uniseriate xylem rays and the nature of fibres and parenchyma strands, Slide no. LU.NL-02. 7. A part of tangential longitudinal section, magnified to show the details of xylem ray cells (upright and procumbent cells as seen in living wood of *D. malabarica*), Slide no. LU.NL-02. 8. Radial longitudinal section showing heterocellular xylem rays, Slide no. LU.NL-02. 9. Magnified intervessel pit pairs, Slide no. LU.NL-03.

2, 6. *Diospyros malabarica* (Desr.) Kostel. 2. Cross section, showing similar shape, size and distribution of vessels and parenchyma. 6. Tangential longitudinal section, showing similar structure of xylem rays and nature of fibres and parenchyma strands.

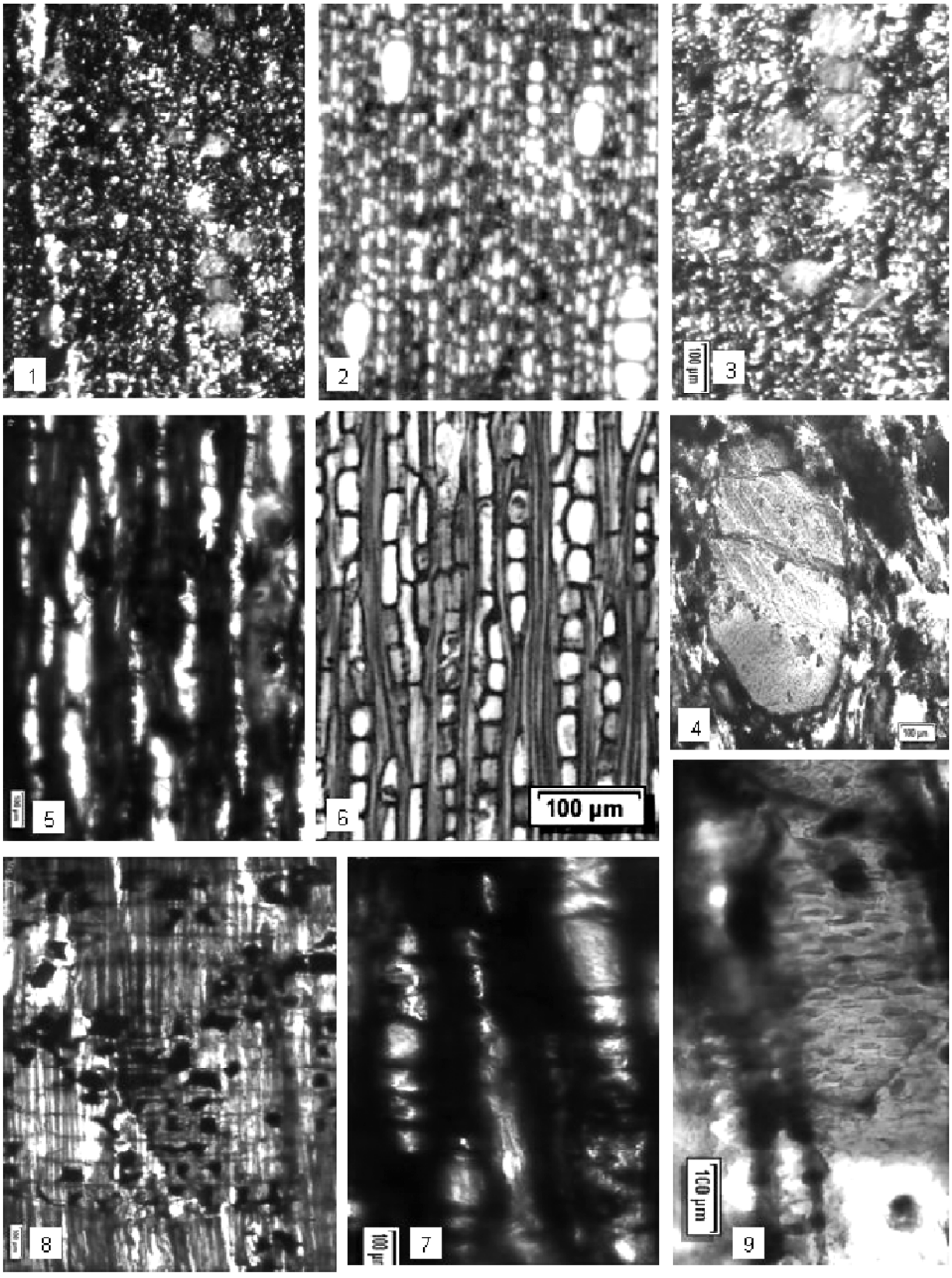
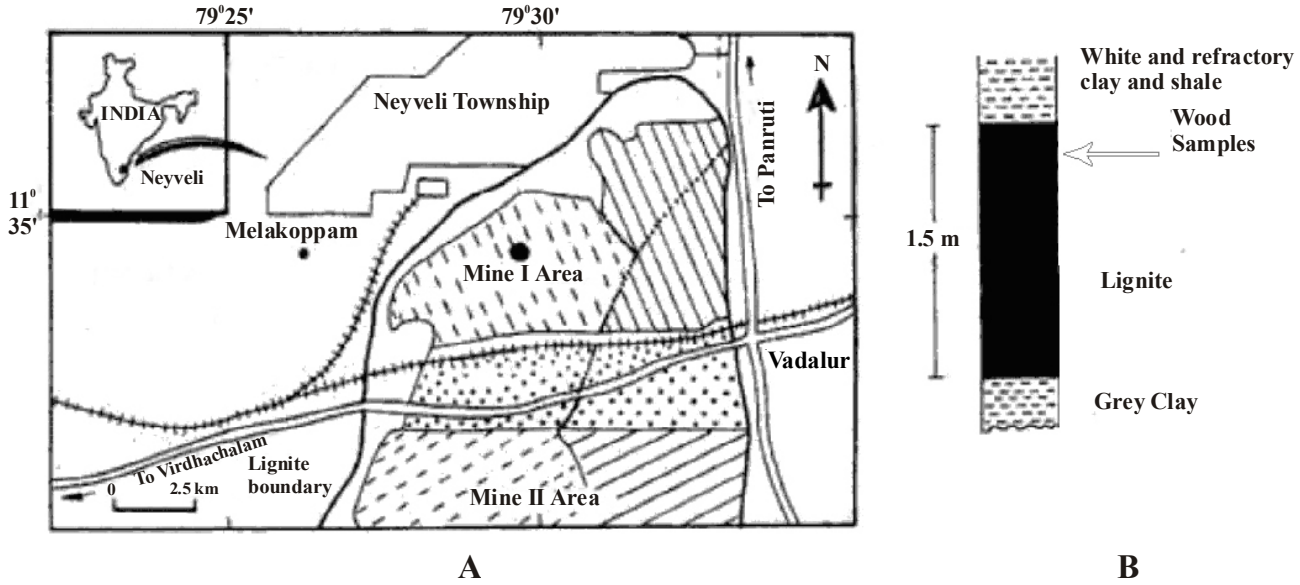


Plate 1



Text-figure 1. A. Showing location of Neyveli Lignite Mine 1, South Arcot District, Tamil Nadu; B. Stratigraphic section showing sample position.

tangential lines at regular interval and 1-2 seriate heterogeneous xylem rays, are seen in the extant woods of the families Apocyanaceae, Ebenaceae, Rubiaceae and Sapotaceae (Pearson & Brown 1932, Metcalfe & Chalk1950). Presence of small to medium sized vessels with small pits, frequent upright cells and non-septate fibres collectively suggest its affinity with the genus *Diospyros* Linn (Maba Forst.) of the family Ebenaceae. The members of other families differ from the present fossil either in vessel size or in the distribution of parenchyma. However, on critical examination of thin sections of about 40 species of the genus *Diospyros* Linn. and other published anatomical details (Kanehira 1924, Desch 1959, Kribs 1951, Normand 1960, Miles 1972, Ilic 1991), it was found that the fossil wood is closer to *D. malabarica* (Desr.) Kostel. (BSIP wood slide no. 2307, Plate 1, figures 3, 6).

Fossil records and comparison: Fossil woods resembling the genus *Diospyros* Linn. are described under the form genus *Ebenoxylon* Felix 1882. So far, 26 species of this genus have been recorded from the Tertiary sediments of India and abroad. Of which, 12 species are known from the Indian subcontinent (Table 2). The present fossil wood has been compared with all the known Indian species as well as available species of other continents. It was found that the present fossil

Table 1. Geological succession around Neyveli Lignite field, South India (after Subramanian 1969).

Age	Formation and Lithology
Recent	Soil, alluvium, laterite and kankar
Late Miocene	Cuddalore Formation: Argillaceous sandstone, lignite bearing sandstone, grits, sands, clays and pebbles
----------Probable unconformity----------	
Eocene	Black clay, shale, grey limestone with fossils
----------Unconformity----------	
Mesozoic (Cretaceous)	Ariyalur Formation: Shale, limestones, siliceous limestones, marls, etc.
----------Unconformity----------	
Precambrian (Archaean)	Intrusive dolerites, quartz veins, granitoids, gneisses

wood is entirely different from them in one or other characters; however, it shows some similarity with the fossil wood, *Ebenoxylon kalagarhensis* Prasad 1989, described from the Middle Miocene sediments of Kalagarh area, Uttarakhand. Both the fossil woods, from Neyveli and Kalagarh, possess 1-2 seriate, regular concentric lines of apotracheal parenchyma, 1-2 seriate (mostly uniseriate), heterogeneous xylem rays and small to medium bordered pits. However, the present species differs from *E. kalagarhensis* in the size of vessels. The fossil wood *Ebenoxylon arcotense* (Awasthi) Awasthi 1984, described from the same locality, is also different from the present fossil wood as it bears vessels

Table 2. Fossil woods referred to the family Ebenaceae

Fossil Taxa	Locality	Horizon/Age
Ebenoxylon ebenoides Schenk 1883, Kaiser 1890	Libyan desert near Regenfeld	Late Cretaceous
Ebenoxylon diosyroides Eilix 1882, 1883, Kaiser 1890	Antigua	Tertiary
Ebenoxylon speciosum Platen 1908	California	Tertiary
Ebenoxylon tenax Beck 1886, Kaiser 1890, Schonfeld 1947	Saxony	Oligocene
Ebenoxylon tunetanum Fliche 1898, Edwards 1931	Tunisia (Ain Cherichera)	Pliocene
Ebenoxylon sp. Fliche 1898	Myteline (Orthymnos)	Tertiary
Ebenoxylon boreale Platon1908	Alaska	Tertiary
Ebenoxylon aegypticum Krausel 1939	Egypt	Tertiary (Oligocene)
Ebenoxylon knollii Hofmann 1944, Greguss 1956	Prambachtrichen, Darno Berges (Kom Heves), Hungary	Oligocene
Ebenoxylon hofmannae Greguss 1956	Darno Berges , Hungary	Oligocene
Diospyros sp. cf. *D. ebenaster* Greguss 1967	Hungary	Miocene
Ebenoxylon miocenecum Prakash 1978, Antal et al. 1996	Kalagarh (Uttarakhand), W. Bengal, India	Late Miocene
Ebenoxylon siwalicus Prakash 1981	Kalagarh (Uttarakhand), India	Late Miocene
Ebenoxylon obliquiporosum Awasthi & Ahuja 1982	Varkala Beds, Kerala, South India	Mio-Pliocene
Ebenoxylon deccanense Trivedi & Srivastava 1982	Deccan Intertrappean, Madhya Pradesh, India	Early Tertiary
Ebenoxylon kalagarhensis Prasad 1989	Kalagarh (Uttarakhand), India	Middle Miocene
Ebenoxylon candoleana Prasad 1993	Kalagarh (Uttarakhand), India	Middle Miocene

of comparatively larger size (140-250 μm) and the xylem rays are composed of oval to circular cells (procumbent cells) as compared to mainly upright cells (elongated cells). The other species can be differentiated in having different size and frequency of the vessels and nature of parenchyma band. The rays in these species are either homogeneous or have only few upright cells. In view of the noted differences, the present fossil wood is attributed to a new species as *Diospyros neyveliensis*.

DISCUSSION AND CONCLUSION

The present investigation on the carbonized woods, collected from the Miocene sediments of Neyveli Lignite deposits, South India, revealed occurrence of a new taxon, *Diospyros malabarica* **(**Desr**.)** Kostel. of the family Ebenaceae. Although a number of taxa are known from this fossil site but none of them are referable to this species. The genus *Diospyros* Linn. comprises about 500 species referable to trees and shrubs. It is widely distributed throughout the tropical and subtropical regions of the world (Willis 1973). About 40 species have been found to occur in the Indian region that mostly grow in South India, Sri Lanka, Myanmar, Bangladesh and the northern parts of India (Gamble 1972, Purkayastha 1982). The comparable species *Diospyros malabarica* (Desr.) Kostel. presently grows in the Indo-Malayan region (Desch 1957). Thus the occurrence of this Malayan representative in Neyveli area (India) suggests that some of the flora of south-east region must have been migrated to Neyveli before being fossilized during the Miocene time. The genus *Diospyros malabarica* (Desr.) Kostel. of evergreen forests of Malayan region indicates prevalence of warm and humid climate in the Neyveli area during the Miocene period.

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Liochlaena subulata (A. Evans) Schljakov (Jungermanniaceae, Marchantiophyta): an addition to the hepatic flora of eastern Himalaya

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ABSTRACT

Sahu V. & Asthana A. K. 2013. *Liochlaena subulata* (A. Evans) Schljakov (Jungermanniaceae, Marchantiophyta): an addition to the hepatic flora of eastern Himalaya. Geophytology 42(2): 135-138.

Liochlaena subulata (A. Evans) Schljakov, a species with fertile plants, is reported from Singalila National Park (Darjeeling) which is new to eastern Himalaya. Earlier, it was known from western Himalaya and South India. It belongs to family Jungermanniaceae and characteristically possesses flagelliform and gemmiparous shoots developing near stem apex, bearing apical cluster of 1 celled gemmae.

Key-words: *Liochlaena subulata*, Jungermanniaceae, gemmiparous shoot, gemmae, Eastern Himalaya.

INTRODUCTION

Amakawa (1960) proposed 4 subgenera, *Plectocolea*, *Solenostoma*, *Luridae* and *Jungermannia*, under genus *Jungermannia*, which are closely related and sometimes difficult to differentiate without female inflorescence. As far as the study on Indian *Jungermannia* is concerned, only few workers (Kashyap 1932, Hattori 1966, Udar & Kumar 1981, 1983, Srivastava & Singh 1986a, b, 1988, 1995, Srivastava & Amakawa 1991, Srivastava et al. 2003, Singh & Nath 2007, Singh & Singh 2007, 2009, Srivastava 2008) have paid attention to this genus.

In a recent contribution, Singh and Singh (2007) listed 41 Indian species under four subgenera, viz. *Jungermannia* L. and *Liochlaena* Nees (with single species each), *Plectocolea* (Mitt.) Amak. (with 11 species) and *Solenostoma* (Mitt.) Amak. (with 28 taxa).

During the present investigation, plants corresponding to *Jungermannia subulata* A. Evans have been identified from Sirikhola (Darjeeling, W. Bengal), part of Singalila National Park (S.N.P.). This species was earlier reported from western Himalaya and South India by Tewari and Pant (1994), Bapna and Kachroo (2004) and Srivastava (2008). Váňa and Long (2009), in a comprehensive treatment to the Jungermanniaceae of Sino-Himalayan region, assigned three genera *Jungermannia* L. s.str., *Liochlaena* Nees and *Solenostoma* Mitt. (including *Plectocolea*) to the species of *Jungermannia* L. described earlier. According to their treatment *J. subulata* has been synonymised under *Liochlaena subulata* (A. Evans) Schljakov. Hence current status of *Jungermannia subulata* is *Liochlaena subulata* which is reported here from S.N.P. for the first time and is a new addition to east Himalayan bryoflora.

TAXONOMIC DESCRIPTION

Liochlaena subulata (A. Evans) Schljakov in J. Váňa & D.G. Long, Nova Hedwigia 89(3-4): 485-517. 2009.

Text-figures 1A-M

Synonyms: *Jungermannia subulata* A. Evans; *Jungermannia breviperiantha* C. Gao et X. L. Bai., syn. nov.

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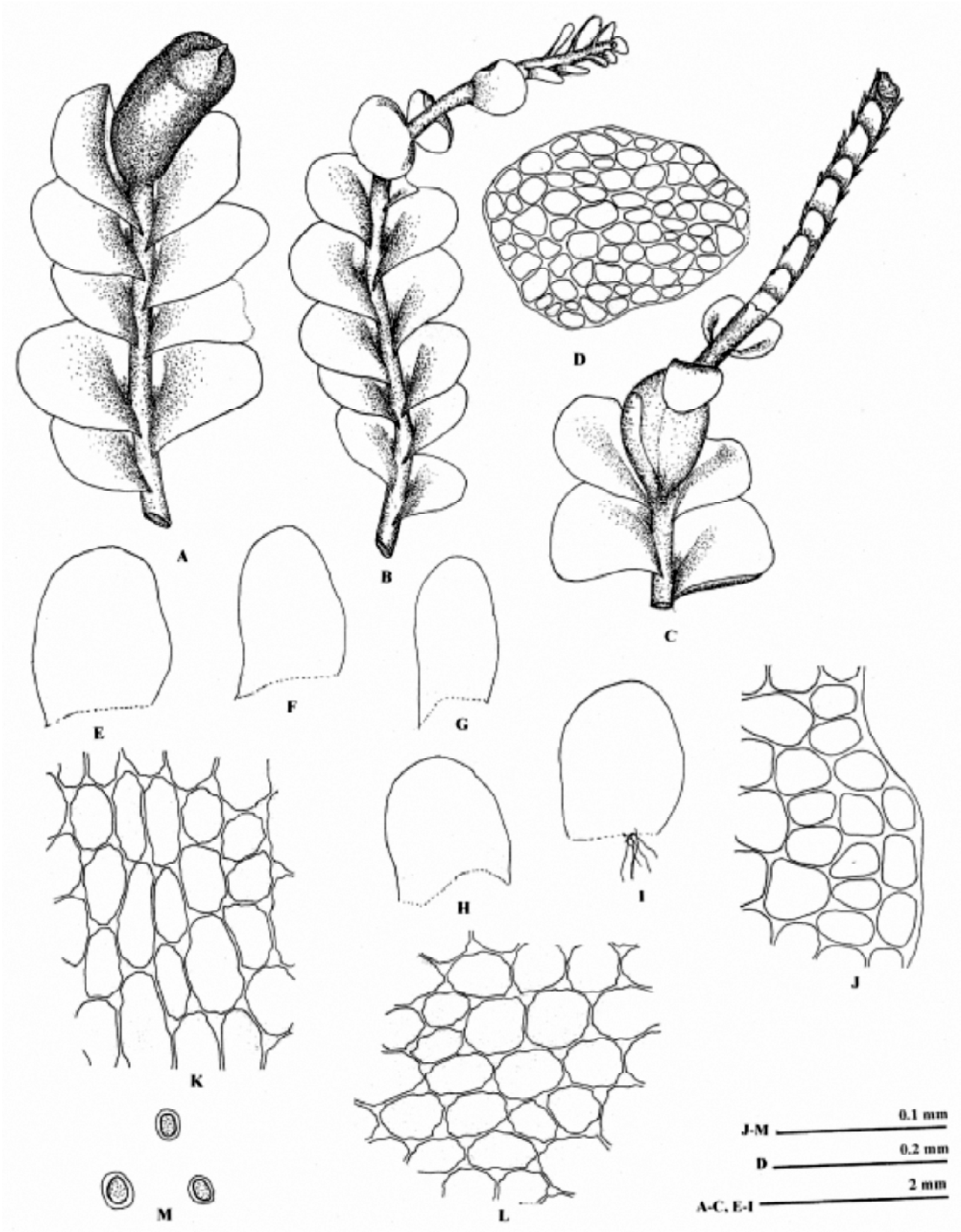

Text-figure 1. A-M. *Liochlaena subulata* (A. Evans) Schljakov. A. Female plant with perianth. B, C. Plants with flagelliform and gemmiparous apex, respectively. D. Cross section of stem. E-I. Leaf lobes. J. Marginal cells of leaf. K. Basal cells of leaf. L. Median cells of leaf. M. Gemmae.

Table 1. Showing comparative and distinguishing features of *Liochlaena lanceolata* Nees and *Liochlaena subulata* (A. Evans) Schljakov

***Liochlaena lanceolata* Nees**	***Liochlaena subulata* (A. Evans) Schljakov**
Dioecious	Dioecious
Brownish green	Olive Green
Plants 16-27 mm long and 1.39 -2.06 mm wide	Plants 8-22 mm long and 2-3 mm wide
Stem 9-11 celled across	Stem 9-10 celled across
Leaves loosely- closely imbricate, oblong rectangulate to ovate-oblong, 0.9-1.2 mm long and 0.9-1.2 mm wide	Leaves closely imbricate, ovate to oblong rectangulate, 1.5-2 mm long and 1.12-1.5 wide
Leaf marginal cells 16.6-23.3 x 16.6-26.6 µm; median cells 16.6-29.9 x 13.3-23.3 µm; basal cells 23.3-36.6 x 16.6-23.3 µm, trigones tri-radiate to sub-nodulose	Leaf marginal cells 20-32 x 16-24 µm; median cells 28-48 x 16-28 µm; basal cells 48-64 x 20-32 µm, trigones somewhat bulging
Gemmae 2 celled, ovoid elliptical	Gemmae 1 celled oval, 12-16 µm wide
Perianth cylindrical-clavate, 0.7-1.6 x 0.4-0.8 mm	Perianth cylindrical, 2.5 x 0.8 mm

Description: Plants in dense mats, olive green or yellowish green, 8-22 mm long and 2-3 mm wide. Plants irregularly branched, creeping with erect, flagelliform and gemmiparous shoots. Stem in cross section 260 µm wide, cortical and medullary cells undifferentiated; 10 cells across the diameter, cortical cells 28-40 µm long and 20-32 µm wide, medullary cells 28-44 µm long and 20-36 µm wide, polygonal. Numerous colourless rhizoids present on the ventral surface of the stem. Leaves imbricate, widely spreading, ovate to oblong-rectangular, 1.5-2 mm long and 1.12-1.5 mm wide. Leaf marginal cells quadrate to rectangular 20-32 µm long and 16-24 µm wide, median cells 28-48 µm long and 16-28 µm wide, basal cells 48-64 µm long and 20-32 µm wide, thin walled, trigonous, trigones somewhat bulging. Gemmae, 12-16 µm wide, green, oval or rounded in shape. Dioecious, male inflorescence not seen, female inflorescence terminal, Perianth erect, cylindrical in shape, exserted, non-plicate, 2.5 mm long and 0.8 mm wide, abruptly ends into a small beak.

Specimens examined: India, eastern Himalaya, Darjeeling - along upper Sirikhola stream, 8.11.2003, (alt. ca. 7800 ft) leg. A. K. Asthana and V. Sahu, 225464A (LWG); western Himalaya, Mukteshwar (5 km from Ramgarh), 04.11.2008, leg. A. K. Asthana & V. Sahu, 248980C (LWG).

Habitat: On soil, in association with *Isopterygium* sp., *Fissidens taxifoilius* Hedw. and *Orontobryum darjeelingensis* Nath et al.

Range of distribution: India - Himachal Pradesh, Uttarakhand, South India; Nepal, Bhutan and China.

DISCUSSION

Liochlaena subulata (A. Evans) Schljkov is closely related to *Liochlaena lanceolata* Nees, however, the latter can be clearly distinguished by narrower plants (1.39-2.0 mm wide), smaller leaf cells, subnodulose trigones, 2 celled gemmae and cylindrical-clavate perianth. A comparative account of the distinguishing features of *Liochlaena subulata* and *Liochlaena lanceolata* is given in Table 1. *Solenostoma rubripunctatum* (S. Hatt.) R. M. Schust. differs from *Liochlaena subulata* in having stem 5-7 cells across, purple to colourless rhizoids, distant to contiguous leaves, slightly thick walled leaf cells and feebly developed or no trigones.

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High frequency plant production via shoot organogenesis in *Leucosceptrum canum* Smith (Lamiaceae)

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ABSTRACT

Maity S. K. & Kundu A. K. 2013. High frequency plant production via shoot organogenesis in *Leucosceptrum canum* Smith (Lamiaceae). Geophytology 42(2): 139-145.

Leucosceptrum canum Smith, the only short tree species of Lamiaceae, does not produce viable seeds and is mainly propagated vegetatively. A rapid in-vitro propagation of whole plant was achieved from axillary shoot culture in Murashige and Skoog Medium (MS) supplemented with 6-benzylaminopurine (BAP, 2 mg/l), Adenine sulphate (AdS, 40 mg/l) and thiamin HCl (4 mg/l). The multiplication rate of the explant was 90% and each explant developed 10.53± 0.5 shoots averaging 4.82± 0.3 cm length within 40 days of culture. The regenerated shoots were rooted on MS medium containing indolebutyric acid (IBA, 1 mg/l) and the explants producing 12.53± 0.3 roots per shoot within a period of 30 days. It is direct and more efficient method for ensuring trueness to type than any other in-vitro procedure. The explants were acclimatized by transferring them to earthen pots containing a mixture of autoclaved soil:sand:compost (1:1:1) and they were immediately covered with transparent polybag. This system provides high fidelity micropropagation system for efficient and rapid production of this important plant.

Key-words: *Leucosceptrum canum*, Lamiaceae, high frequency plant production, shoot organogenesis.

INTRODUCTION

Leucosceptrum canum Smith (Lamiaceae) is a tomentose or villous shrub or small tree. It is mainly distributed in temperate Himalaya from Kumaon to Bhutan at 610 to 2440 m and Khasia mountains at 1220 to 1525 m above sea level (Flora of British India 1885).

Propagation of *Leucosceptrum canum* from seed offers one possibility for large scale cultivation of the plant. But one of the constraints in this method of propagation is the very short span of seed viability. The vegetative growth of this plant is periodic. Hence, it is felt that there is a great need of large scale propagation of this plant. In-vitro techniques therefore could be of advantage. Micropropagation of *Leucosceptrum canum* would provide large amount of highly uniform plantlets suitable for further propagation in the field. Micropropagation by shoot bud proliferation has proved to be the most reliable method for large scale production of many medicinal plants. So in this paper, we describe in-vitro propagation of *Leucosceptrum canum*.

Commercial exploitation and elimination of natural habits, consequent to urbanization, have led to gradual extinction of several plants. In recent years, there has been an increased interest in in-vitro culture techniques which offer a viable tool for mass multiplication and germplasm conservation of rare, endangered and threatened plants (Ajithkumar & Seeni 1998, Prakash et al. 1999, Aastha et al. 2010). Micropropagation is an effective approach to conserve such germplasm. In-vitro propagation has proven as a potential technology for mass scale production of plant species

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(Wawrosch et al. 2001, Martin 2003, Azad et al. 2005, Hassan & Roy 2005, Hassan et al. 2009). Therefore, it is important to develop an efficient micropropagation technique for *Leucosceptrum canum* to rapidly disseminate superior clones once they are identified.

MATERIAL AND METHOD

Plant material and explant preparation: The young shoot buds (both terminal and axillary) were used as explant. Shoot cuttings with the youngest two to five leaves were collected from plants grown in the experimental garden of the institute. Material is collected fresh in the morning hours while the plants are still turgid, and not during mid day when they tend to be flaccid. Material collected from the garden is invariably heavily contaminated with dust and microorganisms. After excision, the shoot tips (about 1-3 cm in length) were subjected to preliminary washing under running tap water for 10 minutes to 30 minutes which reduces the microflora to a substantial extent. Healthy and uniform explants were agitated thoroughly in 5% savlon solution for 8-10 minutes. Explants were then rinsed under running tap water. Then they were surface sterilized with 0.1% (w/v) aqueous mercuric chloride solution for 8 minutes, followed by 4-5 rinses of 3 minutes duration in sterile distilled water.

Media preparation: The shoot bud explants were transferred to 20 ml Murashige and Skoog (1962) medium (MS) containing 3% sucrose supplemented with various concentrations of 6-benzylaminopurine (BAP), Adenine sulphate (AdS), indoleacetic acid (IAA), indolebutyric acid (IBA), a-naphthaleneacetic acid (NAA) and thiamin HCl either individually or in combination. The medium pH was adjusted to 5.8 prior to adding 0.7% agar (w/v, Qualigens) and was autoclaved at 121°C for 15 minutes. The cultures were incubated at 24±1°C under 16 hours daily illumination with fluorescent light (12000 lux). The medium was dispensed into 25x150 mm culture tubes containing 20 ml medium or 100 ml wide mouth conical flasks containing 50 ml medium each and cotton plugs were used to close the culture tubes.

Explants were cultured on MS medium supplemented with various concentrations and combinations of plant growth regulators for shoot bud differentiation in different experiments. The surface sterilized shoot buds were subsequently dried in a petridish containing sterile filter paper and placed on the culture medium (one shoot per culture tube). Each treatment was replicated three times, using a total of six replicates for each treatment. The cultures were maintained at culture room conditions and subcultured onto the fresh media every ten days intervals. The tissue culture raised microshoots longer than 3-4 cm were counted and harvested after 40 days and cultured on fresh medium for rooting.

Rooting of microshoots: For induction of roots, the microshoots having the length above 4 cm, regenerated from multiple shoot clusters, were cultured on hormone free MS medium as well as MS medium supplemented with different concentrations of IBA (0.5-3 mg/l). The cultures were incubated at 24±1°C under 16 hours daily illumination with fluorescent light.

Acclimatization: Rooted plants were taken from the rooting medium and washed several times with sterile distilled water. Plantlets were potted in sterile sand:loam:peat in a ratio of 1:1:1 mixture, covered with a polythene bag to maintain high humidity and were kept under controlled temperature at 22-26°C and light (12000 lux) conditions in the culture room. The bag was removed periodically for gradual hardening. After 2-3 weeks, when new leaves emerged from such plantlets, they were taken outside the culture room and kept in a shady place under normal temperature and

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Plate 1

1-6. In-vitro regeneration through multiple shoot multiplication of *Leucosceptrum canum*. 1. Shoot bud explant of *Leucosceptrum canum* cultured on MS + BAP (2.0 mg/l) + AdS (40 mg/l) + thiamin HCl (4.0 mg/l). 2. Formation of multiplied shoots on MS + BAP (2.0 mg/l) + AdS (40 mg/l) + thiamin HCl (4.0 mg/l) after two weeks of culture. 3-4. Rooting of in-vitro raised shoots on MS + IBA (1.0 mg/l). 5. Potted in-vitro raised plantlets. 6. Peroxidase isozyme pattern.

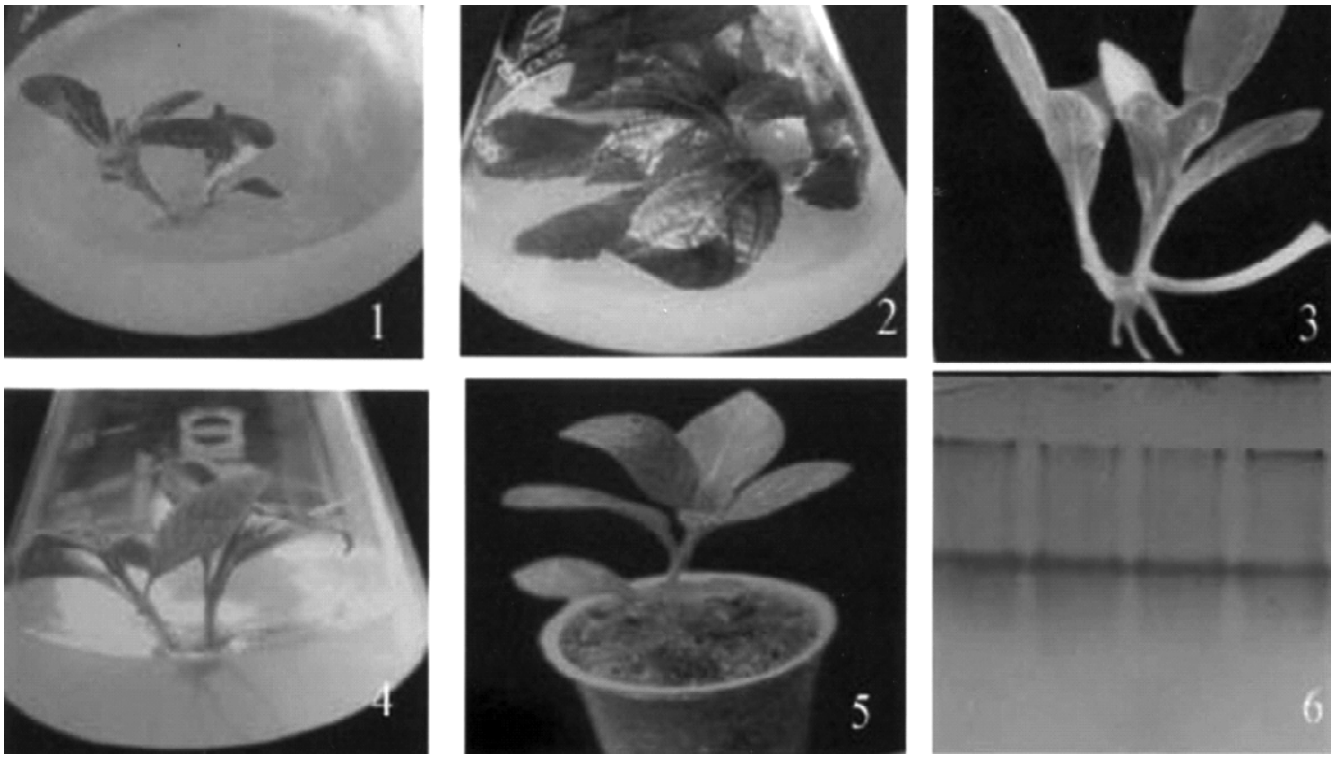

Plate 1

light. They were watered every two days for 15 days.

Isozyme analysis: Isozyme (peroxidase) analysis was performed by macerating 1 gm leaf material collected from mature plants and two months old tissue culture raised plants growing in the same environment. The leaves were excised and kept in -70°C for some days to avoid chlorophyll interference. The materials were crushed in an ice-cold mortar pastle with ice-cold PEB buffer (the composition of PEB buffer were 0.1 M Tris-HCl, 0.25 M Sucrose, 1% Polyvinylpyreledon (PVP), 1% Ascorbic acid, 0.1% Cystein HCl, 1 mM EDTA, 0.4 mM $MgCl_2$, 0.4 mM DTT, 1% β-marcaptoethanol. All the chemicals were dissolved in double distilled water and the pH was adjusted to 6.8).

The homogenate was collected and centrifuged in a RC 5B Sorval Refrigerated centrifuge for 45 minutes at 12000 rpm. The clear supernatant was collected and again centrifuged in a Beckman L7-55 Ultracentrifuge at 40000 rpm for 2 hours. After centrifugation, the pellet was discarded and the supernatant was lyophilized for 10-12 hours as required. SDS-PAGE was performed using 12% polyacrylamide gels. After polymerization, 150 mg of protein samples were loaded to each well with the help of a micropipette fitted with multiflex tips (MULTI, USA).

After the loading, the apparatus was attached to an electric power supply. The gel was run at constant current of 60-80 voltage. The entire operation was performed in an air-conditioned room. Ice bags and cubes were placed all around the apparatus to maintain low temperature.

When the run was completed, i.e. as the tracking dye reached the anodic end, the power supply was switched off and the glass plates having the gels were removed from the apparatus. The stacking gel part was cut off and the rest was incubated in buffer and substrate solution of Isozyme. The gel was incubated in the staining solution containing 20 ml of 0.15 (M) acetate buffer and then were added 50 ml of Guaicol and 50 ml of H_2O_2 for 5-10 minutes at 4°C. When the blue coloured bands appeared, the reaction was arrested by immersing the gel in distilled water and finally the gel was stored in 1% acetic acid.

RESULTS

The surface sterilization procedure followed in the present study yielded 90% of the plant (Plate 1, figure 1) free of microbial contamination. Multiple shoot development could not be induced from the axillary bud of *Leucosceptrum canum* on a growth regulator free MS medium (M 1). The present experiment revealed that addition of cytokinin to the medium was essential to induce multiple shoot formation in the explant. In a series of media (M2-M15) supplemented with BAP, AdS, IAA and vitamin thiamin HCl were tested to induce multiple shoot formation (Table 1). MS medium containing only BAP as a cytokinin at a concentration of 1.0 mg/l (M2) induced shoot multiplication within 10-15 days. Initially, 1-2 shoot buds were developed. After that, number of shoot bud development was increased gradually when the cultures were maintained in the same medium up to 2-3 passages (10 days duration of each passage). In presence of only BAP, 5.23±0.3 shoots were formed per explant at the end of 4th passage. Number of shoot buds production did not increase even after increasing the concentration of only BAP up to 2 mg/l. Addition of AdS and thiamin HCl along with BAP improved the rate of multiplication. The best multiplication rate (M8) was achieved (Plate 1, figure 2) in MS medium containing BAP (2 mg/l), AdS (40 mg/l) and excess thiamin HCl (4 mg/l) (actual concentration in medium 4.1 mg/l because the MS medium contains 0.1 mg/l of thiamin HCl). The multiplication rate of the explant was 90% and each explant developed 10.53±0.5 shoots averaging 4.82±0.3 cm length within 40 days of culture (Table 1). The other media (M3, M4, M6 and M7) containing lower concentration of AdS (20 mg/l) showed lower multiplication rate. The use of higher concentration of BAP (3-4 mg/l) along with AdS and thiamin HCl resulted in poor multiplication rate (M 9 and M10). Low multiplication rate was also found in absence of thiamin HCl (M6). Addition of IAA (0.5 mg/l) in combination with BAP, AdS and thiamin HCl containing medium (M11 and M12) also exhibited comparatively lower multiplication. The use of IAA (1mg/l) with only BAP (1 mg/l) did not show any advantage rather the multiplication rate became lowest. In order to increase the rate of shoot multiplication, all cultures in M8 medium were maintained up to 4th passage. After 5th passage, all cultures gradually developed into dense cluster of shoots but the growth of individual shoot became stunted. The number of shoots was so high that it was very difficult to count and to separate individual shoot from the cluster. In such cases, the microshoots were separated individually and subcultured on M4 medium.

Table 1. Nutrient media used for micropropagation of axillary shoot bud of *Leucosceptrum canum* (MS basal medium with 3% sucrose, 0.7% agar and pH=5.8). Results are the mean of 6 replicates ± SE (after 40 days of culture).

Medium	Growth regulators (mg/l)			Vitamin	Mean number of shoots	Mean length of shoot (cm)
	BAP	AdS	IAA	Thiamin		
M1	0.0	0.0	0.0	0.0	00	00
M2	1.0	0.0	0.0	0.0	5.23 ± 0.3	1.42 ± 0.3
M3	1.0	20	0.0	0.0	6.33 ± 0.4	1.52 ± 0.5
M4	1.0	20	0.0	4.0	6.42 ± 0.5	2.66 ± 0.3
M5	1.0	40	0.0	4.0	6.33 ± 0.5	2.36 ± 0.6
M6	2.0	20	0.0	0.0	2.85 ± 0.1	2.84 ± 0.4
M7	2.0	20	0.0	4.0	7.15 ± 0.3	3.55 ± 0.5
M8	2.0	40	0.0	4.0	10.53 ± 0.5	4.82 ± 0.3
M9	3.0	40	0.0	4.0	6.52 ± 0.6	2.33 ± 0.4
M10	4.0	40	0.0	4.0	6.42 ± 0.6	2.34 ± 0.8
M11	1.0	40	0.5	4.0	3.31 ± 0.8	2.45 ± 0.5
M12	1.0	40	1.0	4.0	3.81 ± 0.3	2.85 ± 0.4
M13	1.0	40	1.0	0.0	4.65 ± 0.5	2.55 ± 0.6
M14	1.0	0.0	1.0	0.0	2.65 ± 0.5	2.43 ± 0.5
M15	2.0	4.0	2.0	4.0	2.42 ± 0.5	2.44 ± 0.5

After 20 days of subculture, the stunted microshoots were grown normally. Among them, shoots longer than 4 cm were harvested and remaining microshoots were transferred to the fresh multiplication medium (M4) and this process was repeated in every subculture.

Multiple shoot proliferation and elongation: The shoot length increased in response to increasing BAP concentration, reaching the highest growth with 2.0 mg/l depending on AdS (40 mg/l) and thiamin HCl (4 mg/l) treatments and declining when BAP concentration reached 3 mg/l. The best combination for *Leucosceptrum canum* shoot elongation consisted of BAP (2 mg/l), AdS (40 mg/l) and thiamin HCl (4 mg/l) (Table 1). The medium supported effective enhancement in shoot length and recorded a maximum length of 10.53±0.5 cm within 40 days.

Rooting of microshoots: Microshoots recovered from axillary bud explant cultures had no roots. Rooting could not be induced in the excised shoots in an auxin free MS medium even after 30 days. For rooting 3-4 cm long shoots were separated as minicutting, cultured on MS medium supplemented with IBA (0.5-3 mg/l) and no cytokinin for the development of a proper root system (Plate 1, figures 3, 4). Roots were produced within 3 weeks of culture. Of all the concentrations tried for rooting on in-vitro raised shoots, the best results were obtained in IBA at 1.0 mg/l (12.53±0.3 roots per explant) (Table 2).

Table 2. Effect of IBA on root regeneration of *Leucosceptrum canum* after 30 days incubation. Results are the mean of 6 replicates±SE.

IBA (mg/l)	No. of roots	Root length (cm)
0.0	00	00
0.5	10.23 ± 0.2	4.76 ± 0.6
1.0	12.53 ± 0.3	7.46 ± 0.4
1.5	10.33 ± 0.4	6.66 ± 0.7
2.0	8.50 ± 0.2	3.50 ± 0.7
2.5	3.73 ± 0.2	2.55 ± 0.5
3.0	2.23 ± 0.4	2.11 ± 0.6

The explants showing root initiation after 8-10 days of starting the culture were transferred to medium of the same composition to promote further proliferation (with the increase of number of root laterals, length of roots, etc.) with the lapse of 25 days. The results indicate that IBA concentrations supplied to MS medium significantly influenced root proliferation and shoot growth. The best rooting treatment were 1 mg/l, since it gave the highest percentage of root induction. Higher levels of IBA reduced root number. When other auxins like IAA and NAA were added to the medium, callus was formed from the shoot base, which did not favour root formation.

Establishment of plants in soil: After rooting, the plants were transferred to vermicompost (Plate 1, figure 5) and acclimatized to green house condition. Regenerated plants were very sensitive to changes in the physical environment. They were grown in very high humidity and respond to decreased relative humidity too slowly to prevent desiccation of the rooted plants. Regenerated plants must be acclimatised to increased light intensity in much the same manner as acclimatisation to decreased relative humidity.

For detection of peroxidase, the Guaicol -H_2O_2 method has been used as the staining substrate. Both, the mother plant as well as regenerated plants, show bands in the upper (+ve) region of the gel. There was no difference in intensity of bands between the mother plants as well as regenerated plants (Plate 1, figure 6) of *Leucosceptrum canum*.

DISCUSSION

This paper provides protocols for rapid rooted shoot production in *Leucosceptrum canum* using axillary shoot bud explants. Axillary shoot buds have the potential for unlimited shoot proliferation because of the presence of apical meristem constantly undergoing cell division and cell differentiation. This potentiality was not expressed when the excised explants were grown in culture medium containing no growth regulators. The presence of cytokinin in the medium is obligatory for shoot proliferation. In *Leucosceptrum canum*, higher number of shoots per explant was recorded on a medium containing BAP, AdS and excess amount of vitamin like thiamin HCl. Therefore, BAP was the most effective cytokinin in shoot proliferation in the explant, but the rate of multiplication was augmented in presence of AdS and thiamin HCl. So, BAP alone is not adequate for the production of an acceptable rate of proliferation. Similar results were reported by Kaur et al. (1998),

Eeswara et al. (1998) and Maity et al. (2001). AdS and thiamin HCl along with BAP were also found necessary for higher rate of proliferation. The presence of adenine in the medium is reported to promote axillary bud differentiation in many cases (Sivakumar & Krishnamurthy 2000, Chetia & Handique 2000, Maity et al. 2001). Furthermore, increase in BAP concentration (3-4 mg/l) and keeping the same concentration of AdS and thiamin HCl, caused decrease in shoot bud proliferation. So, higher concentration of BAP is not effective for increasing shoot bud proliferation in case of *Leucosceptrum canum*. This is in agreement with the observation of banana-Lal Kela by Ganapathi et al. (1998). It has been observed that the shoot bud proliferation was reduced in absence of thiamin HCl in the medium. There are several reports which suggest that thiamin is known to stimulate cell division and the completion of differentiation occurred only in a culture medium and thiamin HCl was considered to be a growth factor (Cramer & Bridgen 1997, Maity et al. 2001). Auxin (IAA) in low concentration in the medium along with BAP, AdS and thiamin HCl stimulated the shoot proliferation but at higher level caused a suppression of shoot proliferation. Highest number of shoots per explant was noted in M8 medium in absence of IAA. So, IAA was not necessary for shoot proliferation. Similar results were reported by Marwani and Sarosa (2003) in *Papuacalia versteegii* and Anita and Pullaiah (1999) in *Sterculia* species.

IBA (1 mg/l) was found to be the ideal concentration for root initiation, root length and number of root laterals. IBA is an effective auxin in root induction in a wide range of plants from herbs to tree (Jasrai et al. 1999). IBA was reported to have favoured root initiation in several plant species in culture (Maity et al. 2001, Nandwani & Myazoe 2002). The efficiency of auxins alone for root induction on microshoots in the present system is similar to the report on *Artocarpus altilis* (Nandwani & Myazoe 2002), *Scutellaria integrifolia* (Joshee & Yadav 2002), *Solanum trilobatum* (Alagumanian et al. 2004), etc.

When other auxins like IAA and NAA were added to the medium, callus was formed from the shoot base, which did not favour root formation. Root developments were inhibited by BAP, in the presence of either IBA or NAA. This observation was at per with those of Furmanowa and Olszowska (1992) and Saez et al. (1994).

Isozyme profile (peroxidase) showed no variation between donor and in-vitro raised plants through multiple shoot formation. Although, isozymes have been used extensively for genomic modification and for identification of varieties and cultivars (Livneh & Vardi 1998).

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February 2013

Aerobryopsis wallichii (Bryophyta), a new record for India

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ABSTRACT

Prajitha B., Manju C. N. & Prakashkumar R. 2013. *Aerobryopsis wallichii* (Bryophyta), a new record for India. Geophytology 42(2): 147-149.

Aerobryopsis wallichii, a rare moss, is reported from the Silent Valley National Park in the Western Ghats as a new record for India.

Key-words: *Aerobryopsis wallichii*, Meteoriaceae, new record, Silent Valley National Park, India

INTRODUCTION

Aerobryopsis Fleisch. (Meteoriaceae) comprises nine validly published species (Crosby et al. 1999) and has a wide distribution in the tropical regions of the world, especially in the southern and eastern Asia. The genus is characterized by hanging branches, complanate foliation, papillose cells and a U-shaped leaf insertion (Buck 1994). The leaves are somewhat clasping, unicostate, with leaf cells linear, very thick-walled, porose and unipapillose on both surfaces. The axillary hairs are composed of 4 short and hyaline cells. The setae are very long and roughened. The capsules have an annulus of small, quadrate cells and striate exostome teeth. The three species of *Aerobryopsis* distributed in India, viz. *A. membranacea* (Mitt.) Broth., *A. longissima* (Dozy & Molk.) M. Fleisch. and *A. eravikulamensis* Manju & Rajesh, are also reported earlier from the Western Ghats. *Aerobryopsis eravikulamensis* Manju & Rajesh is a recent endemic find from the Western Ghats (Manju et al. 2012). During our recent survey in the Silent Valley National Park of Kerala State, we could collect another species of *Aerobryopsis,* viz. *A. wallichii* (Brid.) Fleisch., which was not recorded earlier from India. This species is described here with photomicrographs. Gangulee (1976), in his studies on the mosses of eastern India and adjacent regions, reported this species from East Nepal and Sri Lanka.

TAXONOMIC DESCRIPTION

Aerobryopsis wallichii (Brid.) A. Fleisch., Musci Fl. Buitenz. 3: 789. 1908

Plate 1, figures A-H

Synonyms: *Hypnum wallichii* Brid., Bryol. Univ. 2: 416. 1827; *Neckera wallichii* (Brid.) Card. ex C. Mueller in Syn. 2: 141. 1850; *Aerobryum wallichii* (Brid.) C. Mueller, Linnaea 40: 262. 1876; *Papillaria wallichii* (Brid.) Ren. & Card., Rev. Bryol. 23: 102. 1896.

Description: Plants yellowish green, dark brown at maturity, slender, hanging from the branches, about 10 cm long, pinnately branched; Stem 60 µm wide, T.S. of stem shows 3-5 layers of small (3-5 µm wide), thick walled outer cortical cells and 3-4 layers of large (5-8 µm wide), thin walled central cortical cells; leaves complanate, lanceolate, 2-2.5 mm long, 0.4 mm broad, broader at base, base flat, apex gradually narrowed into a long acuminate point, acumen 0.4-0.5 mm long,

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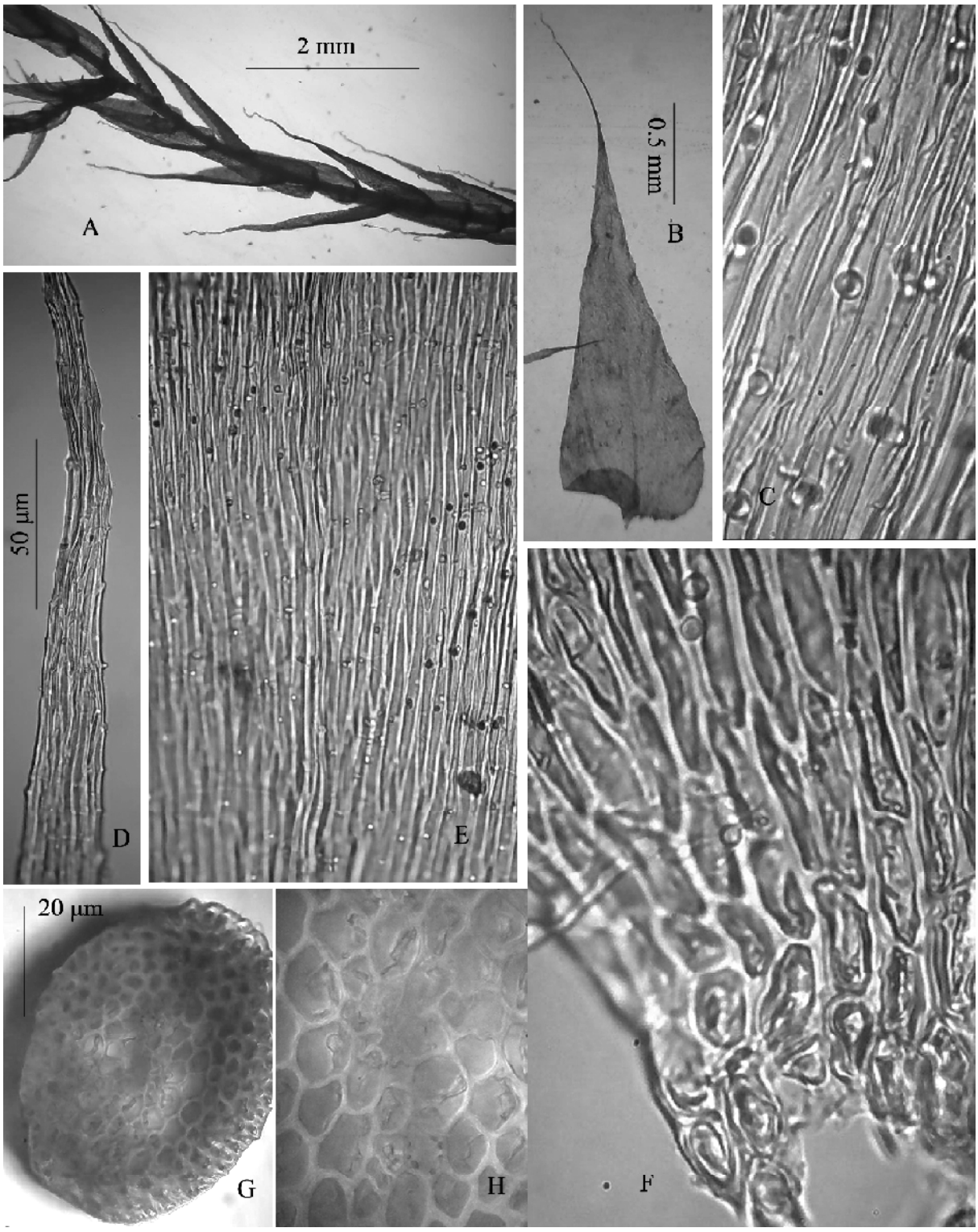

Plate 1

A-H. *Aerobryopsis wallichii*. A. Branch. B. Leaf. C. Leaf papilla of leaf centre. D. Leaf tip cells. E. Leaf middle cells. F. Leaf basal cells. G. Stem C.S. H. Middle cortical cells at stem.

margin denticulate throughout, sharp at tip; costa single vanishing half the leaf, clear at the basal part, becomes faint at tip; leaf cells narrow, elongate with a single central papilla except at apex and basal cells; 40-52 x 6-8 µm at tip, 55-60 x 5 µm below; alar cells little prominent with smooth wide cells, 15-19 x 13-15 µm.

Specimen examined: India, Kerala, Palakkad district, Silent Valley National Park (1200 m), Rejilesh, Anoop & Hareesh 5337 (MBG), 18.03.2011.

Distribution: India (Kerala), Eastern Nepal, Sri Lanka.

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Geophytology 42(2): 151-157
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The lichen genus *Phlyctis* (Phlyctidaceae) in India

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ABSTRACT

Joshi S. & Upreti D. K. 2013. The lichen genus *Phlyctis* (Phlyctidaceae) in India. Geophytology 42(2): 151-157.

The paper provides an account of the status of lichen genus *Phlyctis* in India. Six species are known from India. A key for all the six species is also provided. Almost all the species exhibit their distribution in tropical rain forests of eastern Himalayas and Western Ghats. The genus needs thorough investigation to resolve taxonomic complexities and exhaustive collection to determine the exact status within India.

Key-words: *Phlyctis*, *Phlyctella*, depsidones, Western Ghats, eastern Himalayas, India.

INTRODUCTION

The genus *Phlyctis* comprises ca. 20 species world-wide (known from temperate to tropical forests of America, Africa, China, India and New Zealand). It was delimited from the closely related *Phlyctella* Kremp., on the basis of multicelled-muriform vs. transversely septate ascospores, which was considered to be of less taxonomic significance (Galloway 1988, 2007). In India, the genus is currently represented by six species. In addition to *P. himalayensis* and *P. polyphora*, the genus is supplemented by four recently described species: *Phlyctis karnatakana*, *P. subagelaea*, *P. monosperma* and *P. subhimalayensis* (Joshi et al. 2010, 2012). Until recently, the situation within India was rather poor as only two species (*P. himalayensis* and *P. polyphora*) were reported by Awasthi (1991, 2000) from eastern Himalayan region of India. The previously known *Phlyctella indica* D. D. Awasthi, *Phlyctis arachnoides* Kremp. and *Phlyctis effusa* Müll. Arg. have already been synonymized to *Graphidastra byssiseda* (Müll. Arg.) G. Thor, *Lasioloma arachnoideum* (Kremp.) R. Sant. and *Cryptothecia effusa* (Müll. Arg.) R. Sant., respectively. The diversity of *Phlyctis* is poorly studied in the country, even if it is expected to be spread in tropical to temperate evergreen forests of Himalayas and Western Ghats. The scattered and poor collection, together with insufficient characterization of the genus, may be solely responsible for wide ignorance of the genus in India for the last one decade. Nevertheless, recent studies suggest high diversity of the genus in considerably wide, dense and humid forests of the country.

According to recent taxonomic developments and changes, the genus *Phlyctis* is currently known to represent vast variable characteristics perhaps due to transfer of *Phlyctomia*, *Phlyctella* and *Phlyctidea* to *Phlyctis*. The important morpho-anatomical and chemically distinguishing features such as thallus type, colour, ascospores size, configuration and number, and secondary metabolites explain no well defined criteria to discriminate species within *Phlyctis*. The genus represents crustose to sub-leprose thalli, 1- to 8-spored asci, transversely to muriform ascospores of inconsistent dimensions and a wide variety of secondary metabolities (depsidones) or lacking compounds. Such large diagnostic variations are usually unacceptable to delimit a genus, which further includes majority of taxa having either no well defined character to be considered as separate species or with dubious identities (Joshi et al. 2012).

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The so far neglected genus *Phlyctis* in India is in much need of thorough taxonomic investigation due to hardly distinguishable, poor in taxonomically important characters. The present study is put forth in order to resolve our understanding of some poorly known groups in Indian lichen flora and thereby improving our knowledge of delimitation complexities among closely related genera within the family Phlyctidaceae.

MATERIAL AND METHOD

During the course of investigation on lichen genus *Phlyctis* from India, the specimens preserved in the herbarium of National Botanical Research Institute, Lucknow (LWG), and recent collections (by DKU) were segregated. The morphological and anatomical characters were studied under dissecting and compound microscopes respectively. The chemistry was performed by following the methods given by Orange et al. (2001). Lugol's solution was used to check the amyloidity of apothecial anatomy.

TAXONOMIC DISCRIPTION

Phlyctis (Wallr.) Flot. nom. cons.

(Phlyctidaceae, Ostropales)

Phlyctis is generally characterized by crustose, corticolous, ±cracked-areolate or powdery, granular, arachnoid to byssoid, immersed or superficial thallus, in different shades of grey and white. Photobiont chlorococcoid. Prothallus often present, pale to whitish or blackish. Ascomata apothecia, small, often clustered or aggregated in groups to scattered, immersed, scarcely emergent to chroodiscoid, rounded to irregular in shape. Disc reddish brown, brown to black, mostly densely pruinose, concave or flat. Margins irregularly crenate to rounded or indistinct. Proper exciple poorly developed. Epihymenium granular, opaque to brownish, up to 90 µm high. Hymenium, hyaline, clear, up to 310 µm high. Hypothecium hyaline to pale-brownish, up to 110 µm high. Paraphyses unbranched slender to branched, anastomosing, free to conglutinated in apices. Ascus clavate, 1–8-spored, I+ blue. Ascospores colourless, or smoky grey or pale yellow when old, with or without apiculae, fusiform, oblong to ellipsoid, transversely septate to densely muriform, I+ wine red to purplish blue or I–. Chemically, the genus, produces a wide range of secondary metabolites (atranorin, norstictic, connorstictic, stictic, constictic, hypostictic, protocetraric, fumarprotocetraric, salazinic and psoromic acids) or lacking compounds.

Key to *Phlyctis* species from India

1. Thallus lacking lichen substances……..…. ..... ***P. subhimalayensis***

1a. Thallus containing lichen substances……..2

2. Ascospores transversely septate……..…..3

2a. Ascospores muriform.....5

3. Ascospores 130–180 × 30–40 µm…….. .....***P. monosperma***

3a. Ascospore 20–75× 5–8 µm……4

4. Ascospores 20–30 × 5–7 mm... ***P. karnatakana***

4a. Ascospores 60–75 × 6–8 µm.....***P. himalayensis***

5. Asci 1-spored, ascospores 60–130 × 12–30 mm.....***P. subagelaea***

5a. Asci 3–8- spored, 60–110 × 7.5–9.5 µm ....***P. polyphora***

***Phlyctis himalayensis* (Nyl.) D. D. Awasthi**

Lichenol. Indian Subcontinent: 15. 2000=

Phlyctella himalayensis Nyl., Lich. Nova Zealand 73. 1888.

Description: Thallus, corticolous, crustose, ash-grey with yellowish ting, subleprose. Apothecia minute to small up to 0.4 mm diam., adnate. Disc black-brown,

→

Plate 1

1-4. Recently described species of *Phlyctis* from India. 1. *P. karnatakana*. 2. *P. monosperma* (note the apothecia). 3. *P. subagelaea*. 4. *P. subhimalayensis*.

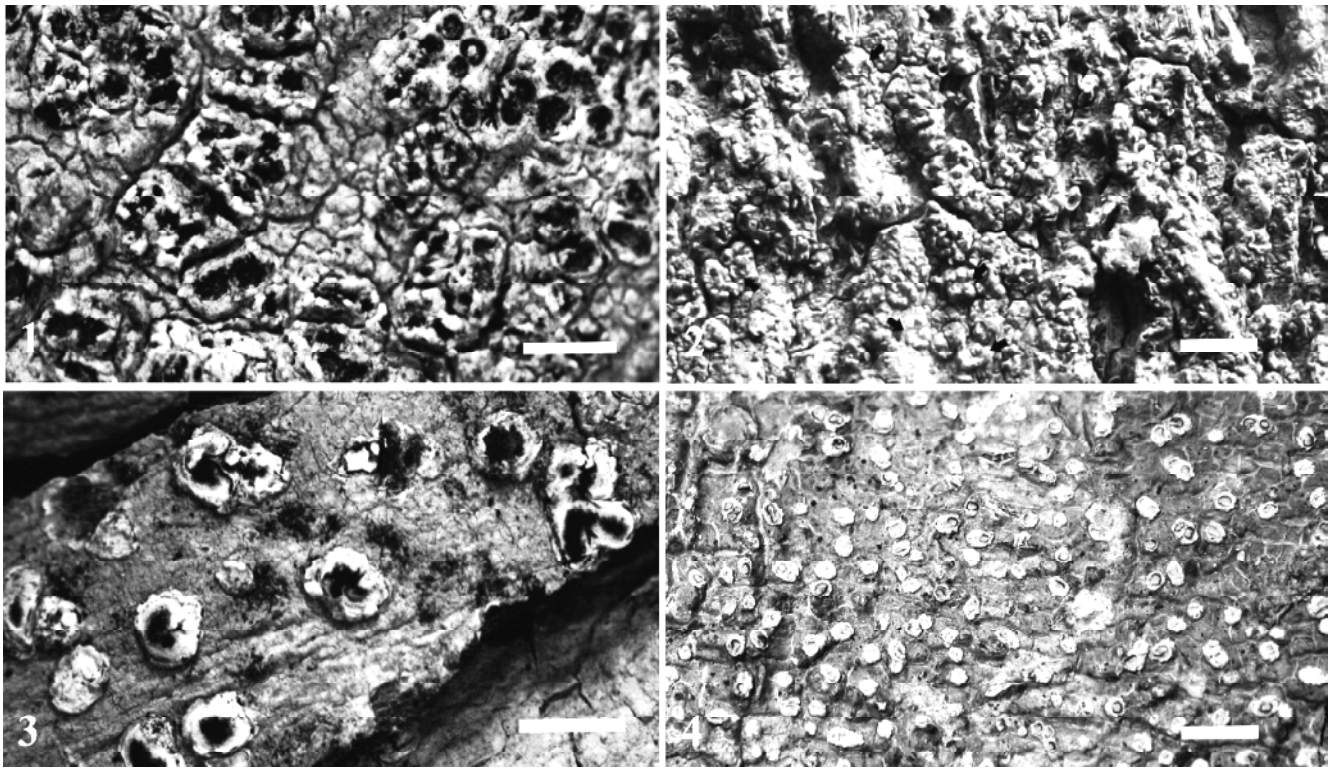

Plate 1

concave to flat. Exciple concolorous to thallus. Hymenium hyaline but brownish above. Hypothecium brownish. Paraphyses unbranched and free. Asci 8-spored. Ascospores hyaline, transversely 7-septate, fusiform, 60-75 × 6-8 µm.

Chemistry: K+ red (?). Norsticitc acid.

Ecology and distribution: The species has been reported from tropical moist and humid rain forests of eastern Himalayan region of India (Meghalaya) and from Thailand.

Remarks: *P. himalayensis* exhibits similarity to P. *karnatakana* S. Joshi & Upreti in having 7-septate ascospores but is separated on the basis of ascospores size. The latter species has ascospores of 20–30 × 5–7 µm, which are comparatively smaller than 60–75 µm ascospores of *P. himalayensis*. The other 7-septate, *P. oleosa* has smooth, corticated thallus while *P. subuncinata* contain stictic acid in medulla. *P. longifera* differs from *P. himalayensis* in having somewhat larger ascospores of 55–86 × 5–7 µm and containing stictic acid as major thallus compound. Due to unavailability of holotype (deposited in BM) the exact current status of the taxa is still uncertain. The characters are based on the description provided by Awasthi (1991). The species has not been collected since 1967. The material (acc. no. 1258) collected from eastern Himalayan region in the state of Assam, Shillong district, Mawphlong, on bark by Dharne and Roychowdhury, at an altitude of 1500 m in 1967, shows subsimilarity to *P. himalayensis*.

***Phlyctis karnatakana* S. Joshi & Upreti**

The Bryologist 113 (4): 726. 2010.

Plate 1, figure 1

Description: Thallus corticolous, crustose, whitish-grey, subleprose, ecorticated, in irregular patches, cracked. Photobiont chlorococcoid. Prothallus indistinct. Apothecia numerous, mostly aggregated, round to irregular in margins, granular, semi-immersed, uneven, 0.3–0.4 mm in diam. Disc black, plane, slightly pruinose, 0.06–0.2 mm diam. Margin concolorous to thallus, straight to incurve, entire to eroded in older apothecia. Exciple indistinct to absent. Epihymenium minutely granular, brown-opaque, up to 25 µm thick, K–, I–. Hymenium hyaline, clear, 100–130 mm high.

K–, I– Hypothecium pale-yellow to pale-brown, 15–20 mm thick, K–, I–. Paraphyses, slender, simple, conglutinate, apices anastomosing, 1–1.5 mm diam. Asci 8– spored, clavate, thin walled, 75–80 × 15–25 mm, K–, I+ red. Ascospores hyaline, fusiform, crescent shaped, transversely 7-septate, I–, 20–30 × 5–7 mm.

Chemistry: Thallus K+ red, PD+ yellow-orange, C–. Norstictic acid detected in TLC.

Ecology and distribution: *Phlyctis karnatakana* grows on tree trunks in the evergreen forest. It is well distributed in tropical to temperate areas of Western Ghats in southern India at an altitude ranging between 644 and 2550 m. The species is described from Karnataka and Maharashtra.

Remarks: *Phlyctis karnatakana* is recognized by the whitish-grey, decorticate thallus and curved fusiform, transversely 7-septate ascospores, 20–30 × 5–7 µm in size. Other transversely 7-septate taxa are *P. himalayensis* Nyl., *P. oleosa* Stirt. and *P. subuncinata* Stirt. But all three species have larger ascospores of 60–75 µm, 45–85 µm, 40–72 µm, respectively. Further, *P. uncinata* produces stictic acid as thallus compound. *P. karnatakana* can be comparable with *P. longifera* (Nyl.) D. J. Galloway & D. Guzmán, in ascospores septation, those in latter ranges 7 to 11-septate per ascospore but the latter species too has larger ascospores (55–86 µm) and contains stictic acid in medulla.

Specimen examined: Karnataka, Shimoga district, near Jog Falls, Kargal, alt. 644 m, on bark in evergreen forest, Lumbsch, Upreti, Divakar & Tandon 19743/L (LWG); Goa, Goa proper near Panjim, on bark, May 2009, Jayesh Rawal 09–011804 (LWG); Chikmagalure district, Chikmangalure, way to Kummangundi, alt. ca. 1100 m, on bark of tree, 02.05.1979. Awasthi, Upreti & Misra 79–403, 79–458 (LWG-LWU); alt. 1300 m, on bark of tree twig, 02.05.1979, Awasthi, Upreti & Misra 79–443 (LWG-LWU); Mangalore district, Seklashpur, way to Mangalore, Shiradi Ghat, alt. 770 m, on bark, 03.05.1979, Awasthi, Upreti & Mishra 79–560, 79–591, 79–647, 79–656 (LWG); Maharashtra, Satara district, Devi Path, alt. 1394 m, on bark, 27.03.2010, R. Bajpai 10–013316 (LWG); Panchgani near Koteshwar temple, on *W. fruticosa*, 27.03. 2011, R. Bajpai 11–015075 (LWG); near Forest Research Centre, Gureghar, alt. 1193m, on *W. fruticosa*, 27.03.2011, R. Bajpai 11–015532 (LWG); Koyana valley, Ghatmatha village, alt. 695m, on *Morus alba*, 23.03.2010, R. Bajpai 11–013857/B (LWG); alt. 631m, on *Erythrina* twigs, 24.03.2010, R. Bajpai 10–013323 (LWG); on *W. fruticosa*, 23.03. 2010, R. Bajpai 10–013988 (LWG); Mahabaleshwar, Lingmala fall near temple, on bark of *M. edule*, 26.03.2011, R. Bajpai 11–015068 (LWG); behind Pratapgarh fort, on twigs of *W. fruticosa*, 28.03.2011, R. Bajpai 11–015057 (LWG); Medha road near graveyard, on bark of *Memecylone umballatum*, 26.03.2011, R. Bajpai 11–015034 (LWG); Khandala, alt. 1200 m, on bark, 02.12.1962, P. Chandra, s.n. (LWG); Tamil Nadu, Nilgiri Hills, Upper Bhavani Road from Avalanche, Kolaripetta top, alt. 2550m, on *Rhododendron* tree twigs, 24.06.1971, K. P. Singh 71.713 (LWG-LWU); on way to Doddabetta, alt. ca. 1800 m, on bark of tree, 30.11.1973, K. P. Singh 73.416 (LWG-LWU).

***Phlyctis monosperma* S. Joshi & Upreti**

The Lichenologist, 44(3): 363. 2012.

Plate 1, figure 2

Description: Thallus corticolous, crustose, growing in association with epiphytic bryophytes, uneven, whitish to whitish-grey, coarsely to finely granular, loose, continuous, ±cracked due to bark texture. Photobiont chlorococcoid. Prothallus white to indistinct. Apothecia numerous, scattered, sometimes aggregated in groups of 2–3, mostly irregular, rarely roundish, uneven, 0.5 to 1.5 mm in diam., immersed to level with thallus. Disc concave to ±plane, greyish to brownish, covered heavily with white ± granular pruina, irregular, loose. Margins concolorous to thallus, up to 0.3 mm thick, raised, straight to slightly incurved, entire, eroded in older apothecia, ± granular. Proper exciple indistinct to poorly developed. Epihymenium brownish, granular, opaque, 25–35 µm high, K–, I+ reddish. Hymenium hyaline, clear, 170–190 µm high, K–, I–. Hypothecium pale to hyaline, 35–40 µm high, K–, I–. Paraphyses densely anastmosing, branched, conglutinate, coherent, 2.0 to 2.5(–3) µm thick. Asci 1-spored, broadly clavate, 135–170(–197) × 35–45

µm, K–, I+ pale yellow turning reddish. Ascospores hyaline, oblong-ellipsoid with round apices, thin walled, transversely consistently 15-septate, appear multicelled muriform in older stage due to disintegration of transverse septa, (130–)140–150(–180) × 30–40µm, cells 9–13(–15) µm high, lenticular, I+ wine red.

Chemistry: K–, C–, KC–, P+ yellow. Psoromic acid chemosyndrome detected in TLC.

Ecology and distribution: The species occurs in subtropical evergreen forests of eastern Himalayas and Western Ghats of India. It inhabits the rough tree bark among epiphytic bryophytes at an altitude of above 2000 m.

Remarks: *Phlyctis monosperma* is characterized by whitish-grey, loose, ± granular thallus, 1-spored asci, transversely 15-spetate ascospores and the psoromic acid chemosyndrome. It shows close resemblance to *Phlyctis megalospora* (P. James) D. Galloway & G. Guzmán in its 1-spored asci, oblong-ellipsoid, transversely septate ascospores, presence of psoromic acid and its association with mosses. However, *Phlyctis megalospora* differs in containing atranorin, norstictic and protocetraric acids as an additional thallus compounds and larger, 285–390 × 79–95 µm, 17–23-septate ascospores. Another psoromic acid containing *Phlyctis psoromica* Elix & Kantvilas, with transversely septate ascospores differs in having 4–8-spored asci and smaller, 3–7-septate ascospores of 30–52 × 4–6 µm. A relatively rare and localized *Phlyctis chilensis* D. Galloway & G. Guzmán, from cool temperate region of south America, exhibits similarity with the new taxon in having 1-spored asci but differs in containing norstictic and connorstictic acids as thallus compounds and has larger, muriform ascospores (190–285 × 55–70 µm). A muriform Indian species *Phlyctis subagelaea* S. Joshi & Upreti, also has 1-spored asci with ecorticated, whitish-grey thallus but differs from the new species in containing fumarprotocetraric acid as secondary compound (erroneously mentioned as containing norstictic acid in holotype discussion in Joshi et al. (2010).

Specimens examined: India, West Bengal, Darjeeling district, Sukhia forest, on bark among moss, 1976, S. Chandra & M. Ranjan, 26815 (LWG). Tamil Nadu, Kodaikanal, Silver cascade, on bark, 1979, S. Chandra & M. Ranjan, 26816 (LWG).

***Phlyctis polyphora* Stirt.**

Proc. Roy. Soc. Glasgow 13: 184. 1881.

Description: Thallus corticolous, crustose, whitish to pale or pale red, thin. Apothecia 0.4–1.2 mm diam., pruinose. Hypothecium hyaline to yellowish. Asci 3–8-spored. Ascospores muriform, hyaline, oblong-fusiform 16–32 transverse and 1–2 vertical septate, 60–110 × 7.5–9.5µm.

Chemistry: K–, C–.

Ecology and distribution: Corticolous species reported over the bark of trees growing in evergreen forests in eastern region of India. It is endemic to India (Singh & Sinha 2010).

Distribution– India (Assam).

Remarks: *Phlyctis agelaea* (Ach.) Flotow closely resembles *P. polyphora* in having muriform ascospores but has K+ yellow-red thallus (norstictic acid) and somewhat smaller ascospores of 35–91× 11–35 µm. *P. nepalensis* Räs. also has muriform ascospores and K– thallus but differs in having 1- or rarely 2-spored asci, smaller ascospores of 45–53 × 12–16 µm and thallus containing unknown lichen substance, producing grey spot at Rf class 5. The scanty diagnostic characters of *P. polyphora* are based on description provided by Awasthi (1991), due to unavailability of holotype (deposited in BM and GLAM) collected by A. Watt. The species has not been collected since 1881, thus exhaustive sampling is prerequisite to certify its occurrence and exact taxonomic placement based on recent systematic classification of the genus.

***Phlyctis subagelaea* S. Joshi & Upreti**

The Bryologist 113 (4): 725–726. 2010.

Plate 1, figure 3

Description: Thallus corticolous, crustose, ecorticated, whitish-grey, ± roughened, uneven, cracked, usually thin, determinate, forming small patches. Photobiont a green protococcoid alga. Prothallus indistinct to ± a blackish layer. Apothecia numerous, scattered, irregular to ± rounded, emergent, 1–2 mm in diam. Disc brown to blackish, concave,

heavily pruinose. Epithecium granular, brownish, 10–15 mm thick, K–, I–. Hymenium hyaline, clear, 60–100 mm high, K–, I–. Hypothecium hyaline, 25–30 mm thick, K–, I–. Paraphyses branched, anastomosing, 1.5–2 mm thick. Asci 1-spored, broadly clavate, thin walled, 120–150 × 20–40 mm, K–, I+ reddish. Ascospores hyaline, oblong-ellipsoid, apices rounded, muriform, 60–130 × 12–30 mm, I+ purplish-blue.

Chemistry: Thallus K+ yellow, PD+ orange, C–, KC+ red. Fumarprotocetraric acid detected in TLC.

Ecology and distribution: *Phlyctis subagelaea* grows on bark of tropical rain forests trees of southern India. Presently, the species is described only from the type locality in India (Kerala).

Remarks: *Phlyctis agelaea* (Ach.) Flotow, is close to *P. subagelaea* in having ascospores size ranges (35–) 45–80(–91) × 11–32(–35) mm but differs in the thallus containing norstictic acid, smaller apothecia of 0.2–0.5(–1) mm in diam., and 2(–4) –spored asci. The native species *P. polyphora* Stirt., differs from the new taxon in having a K– thallus and 3– 8-spored asci as mentioned by Awasthi (1991). *Phlyctis subagelaea* is similar to *P. nepalensis* Räs., *P. argena* (Sprengel) Flotow and *P. chilensis* D. Galloway & G. Guzmán in having 1-spored asci. But, *P. nepalensis* has K– thallus (unknown grey spot at Rf- class 5), smaller apothecia of 0.1–0.3 mm diam. and epruinose disc. *Phlyctis chilensis* differs in having larger ascospores of (190–)230–270(–285) × 55-70 µm in size, whereas, *P. argena*, a sorediate species has smaller apothecia of 0.2–0.4 mm in diam., and ascospores of (75–)100–150(–205) × 25–50(–53) µm. Moreover, both the latter species produce norstictic and connorstictic acids (Galloway & Guzmán 1988; Tønsberg 2004).

Specimen examined: Kerela, Idukki district, Periyar Tiger Reserve, Thekkady, on bark, 23.03.2006, Biju Haridas 06–009837 (LWG).

***Phlyctis subhimalayensis* S. Joshi & Upreti**

The Lichenologist 44(3): 365. 2012.

Plate 1, figure 4

Description: Thallus corticolous, crustose, thin, smooth, greenish-grey to whitish-grey, continuous, cracked, photobiont chlorococcoid. Prothallus indistinctly white to absent. Apothecia numerous, scattered, sometimes 2–3 confluent, roundish, elongate to angular, uneven, 0.5 to 1.0 mm diam., immersed, semi-immersed to chroodiscoid. Disc plane to concave, black, pruinose, rounded when completely exposed or sometimes slit-like when covered by margins, rarely irregular. Margins whitish, indistinctly 2–5 lobate, up to 0.3 mm thick, exfoliating in older apothecia, radially fissured and divided into 2–3 lamellae. Proper exciple undeveloped to poorly developed. Epihymenium brownish, minutely granular, opaque, 10–25 µm thick, K–, I+ blue, turning wine-red. Hymenium hyaline, clear, 60–90 µm high, K–, I–. Hypothecium slightly brownish to pale-yellow, 15–30 µm, K–, I–. Paraphyses simple, straight, slender, unbranched, coherent, up to 1.0 µm thick. Asci 8-spored, clavate, cylindrical, (45–) 60–90 × 6–10 µm, K–, I+ blue, contents turning yellow-orange. Ascospores hyaline, transversely 5–7-septate, cells 2–6 µm high, acicular to fusiform, mostly curved, 20–35(–40) × 2–4 µm, I– , content turning yellow.

Chemistry: Thallus K–, C–, KC–, P–. No lichen substance detected in TLC.

Ecology and distribution: The species is described from cool temperate forests of Uttarakhand in northern Himalayas and Arunachal Pradesh in eastern Himalayas of India. It grows luxuriantly on *Quercus semecarpifolia* and *Acer nepalensis* trees at an altitude of 2500 m and higher.

Remarks: *Phlyctis subhimalayensis* is characterized by thallus lacking lichen substances, chroodiscoid apothecia with pruinose black apothecial discs, white exfoliating margins and transversely 5–7-septate ascospores. It shows a close resemblance to *Phlyctis himalayensis* (Nyl.) D.D. Awasthi and *P. karnatakana* S. Joshi & Upreti, in having transversely 7-septate ascospores but differs in thallus chemistry. Both *P. himalayensis* and *P. karnatakana* have a K+ red thallus with anonymous lichen compounds in the former and norstictic acid in the latter. Moreover, *P. himalayensis* has a subleprose thallus with comparatively larger ascospores of 60–75 × 6–8 µm. *Phlyctis subhimalayensis* is similar to the New Zealand taxa *P. longifera* (Nyl.) D. Galloway & G. Guzmán

and *P. megalospora* (P. James) D. Galloway & G. Guzmán in having transverse spore septation. However, the latter two species have larger ascospores (55–86 × 5–7 µm and 285–390 × 79–95 µm in size) and presence of stictic and psoromic acids as major thallus compounds, respectively. The chroodiscoid apothecia *Phlyctis subhimalayensis* can be confused with the members of thelotremoid Graphidaceae (e.g. *Chapsa*) and also the non-lichenized genus *Stictis*.

Specimens examined: India, Uttarakhand, Pithoragarh district, Munsiyari, Kalamuni, alt. 2500 m, 2006, on *Quercus semecarpifolia* tree trunk, Y. Joshi & R. Bajpai 06–007019 (LWG); Ginny band, alt. 2500 m, 2009, on bark, D. K. Upreti et al. 09–012423 (LWG). Arunachal Pradesh, west Kameng district, enroute to Sela, 10 km before Sang, 2008, on *Acer nepalensis*, D. K. Upreti, U. Dubey, R. Khare & G. K. Mishra 08–009294 (LWG).

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Fabronia schensiana C. Muell., a new record from Palni Hills, Tamil Nadu, South India

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ABSTRACT

Asthana G. & Yadav S. 2013. *Fabronia schensiana* C. Muell., a new record from Palni Hills, Tamil Nadu, South India. Geophytology 42(2): 159-161.

Fabronia schensiana C. Muell., belonging to the family Fabroniaceae, is a rare taxon and has been reported from Sikkim and Nagaland in Eastern Himalaya and from Kerala in South India. During the study of bryophytes from Palni Hills, Tamil Nadu (South India), the fertile plants of this taxon were collected, growing as corticolous population in Kodaikanal (Observatory Road), which shows its extended distribution in peninsular India from Kerala to Tamil Nadu. The South Indian population has been described and illustrated along with their sporophytic details.

Key-words: Fabroniaceae, *Fabronia schensiana*, corticolous, South India.

INTRODUCTION

Fabronia Raddi is a large genus (represented by about 95 species) and occurs mainly in tropical and warm temperate regions of the world (Vohra 1983, Shabbara & Ghanem 2006). Lal (2005) listed 10 species of *Fabronia* from India, i.e. *F. assamica* Dix., *F. ciliaris* (Brid.) Brid., *F. curvirostris* Doz. & Molk., *F. goughii* Mitt., *F. madurensis* Dix. & Vard., *F. minuta* Mitt., *F. pusilla* Raddi., *F. schensiana* C. Muell., *F. schmidii*, C. Muell. and *F. secunda* Mont. Of these, *F. curvirostris* Doz. & Molk., *F. goughii* Mitt., *F. madurensis* Dix. & Vard., *F. schmidii* C. Muell. and *F. secunda* Mont. are reported from South India (see also Chopra 1975, Nath et al. 2007). However, Daniels (2010) listed 5 species from Tamil Nadu state (three species from Palni Hills and four species from Nilgiri Hills). Among these, *F. madurensis* Dix & P. Vard. is reported from Palni Hills only, *F. pusilla* Raddi and *F. schmidii* C. Muell. are reported from Nilgiri Hills only while *F. gaughii* Mitt. and *F. secunda* Mont. are reported from both Nilgiri and Palni Hills. During bryological exploration of the Palni Hills, the fertile plants of *Fabronia schensiana* C. Muell. have been collected which are described and illustrated here with sporophytic details. This is an Asiatic species which is reported so far from North-east Himalayas, Nepal, China and India (Kerala, Sikkim and Nagaland) only (Gangulee 1978-1980, Vashistha 1998, Lal 2005, Nair et al. 2005, 2007, 2008, Bansal & Nath 2011). The present report shows extension in the distributional range in India in general and in the peninsular India in particular.

TAXONOMIC DESCRIPTION

Fabronia schensiana C. Muell. Nuov. Giorn. Bot. Ital. n. ser. 4: 262.1897

Text-figures 1-11

Description: Plants yellowish green and irregularly branched, 0.5-2.5 cm long and 0.4-0.6 mm wide with leaves, pleurocarpous, corticolous. Branches 5.0-8.0 mm long and 0.8 -1.0 mm wide with leaves. Stem 0.05-0.09 mm in diameter, cells of outer two rows small, slightly thick walled, 7-11 x 2-4 µm, inner cells large, thin walled, 19-26 x 7-11 µm in one row, central cells

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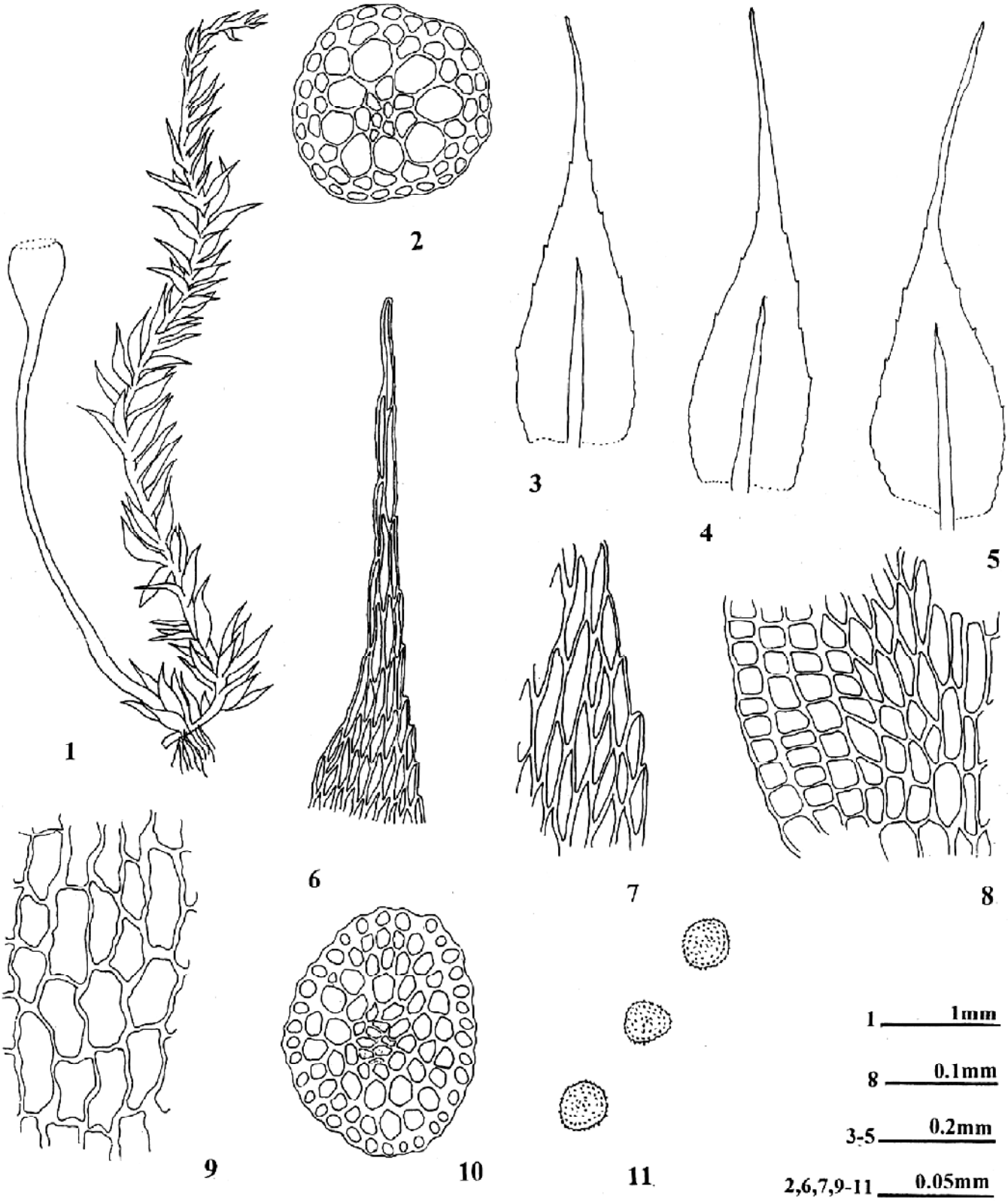

Text-figures 1-11. *Fabronia schenciana* C. Muell. 1. A plant with sporophyte. 2. Cross-section of the stem. 3-5. Leaves. 6. Apical leaf-cells. 7. Marginal leaf-cells. 8. Basal Leaf-cells. 9. Capsule wall (surface view). 10. Cross-section of the seta. 11. Spores. All figures drawn from 20441/08 (LWU).

small, thin walled, 11-15 x 4 µm. Leaves closely arranged, erect, lanceolate, 0.78-0.94 mm long and 0.21-0.25 mm wide, apex gradually narrowed into subulate apex, margin minutely dentate almost throughout, dentitions one celled, subula smooth. Costa single, about ½ of the leaf length. Leaf-cells rhomboidal, apical cells 38-57 x 7-11 µm, tip cells very much elongated, up to 95-133 µm long, middle cells 49-57 x 7-11 µm, basal cells 11-15 x 7-11 µm, rectangular to rhomboid near costa and quadrate - rectangular near margin in 2 or 3 rows. Sporophyte present on short lateral branches. Seta yellowish, erect, 3-4 mm long and 0.08-0.12 mm in diameter. Capsule erect, small, urn shaped, 0.43-0.64 mm long and 0.34-0.43 mm wide. Peristome teeth fragile, disintegrated. Spores small, papillose, 15-19 µm in diameter.

Habitat: Plants grow on bark surface in association with *Metzgeria indica*, *Lejeunia flava* and *Frullania campanulata*.

Specimen examined: South India: Tamil Nadu, Palni Hills, Kodaikanal (Observatory Road), alt. ca. 2314 m, Lat. 10^0 13.776′ N and Lon. 77^0 27.587′ E, P. K. Verma & Afroz Alam, 29 December 2008, 20441/ 08 (LWU).

Range: Nepal, China, India (Gangulee 1978-1980)

Distribution in India: Eastern Himalaya: Sikkim, Nagaland (University Guest House, Mokokchung). South India: Kerala: Wayanad District - Chembra Estate, Idukki District - Munnar; Tamil Nadu: Dindigul District - Kodaikanal (Palni Hills).

DISCUSSION

Fabronia schensiana C. Muell., an Indo-Chinese (Asiatic) species, was described and illustrated by Gangulee (1978-1980). Nair et al. (2005, 2007) described and illustrated this taxon, with vegetative details only, from Kerala, showing its extended distribution from north to south. The present study reveals the presence of this taxon in Tamil Nadu also, which shows its further extension in distributional range. The plants of *F. schensiana* from Palni Hills are fertile with mature sporophyte. They are close to Himalayan population in the size of the plants, leaf, leaf-cells, seta length and capsule size. The South Indian population reported from Kerala is vegetative and has comparatively smaller plants with smaller leaves and leaf-cells. Besides, the dentitions on the margin of the leaves are more prominent as compared to the plants from Palni Hills and Himalayan population (Nair et al. 2005, 2007).

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A checklist of liverworts, hornworts and mosses of Uttar Pradesh, India

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ABSTRACT

Singh S. K. 2013. A checklist of liverworts, hornworts and mosses of Uttar Pradesh, India. Geophytology 42(2): 163-167.

A checklist of 27 species of Marchantiophyta (liverworts), 3 species of Anthocerotophyta (hornworts) and 24 species of Bryophyta (mosses) from Uttar Pradesh is presented here. Currently accepted nomenclature and distribution of each species within Uttar Pradesh are provided.

Key-words: Liverworts, hornworts, mosses, checklist, Uttar Pradesh.

INTRODUCTION

Uttar Pradesh has an area of 243,290 km^2 and constitutes a major part of Gangetic Plains. The state is bordered by Uttarakhand, Haryana and Delhi in the north and north-west, Rajasthan in the west, Madhya Pradesh, Chhattisgarh and Jharkhand in the south and south-east and Bihar in the east. It shares an international border with Nepal in the north. Climatically, the area delimits itself within the subtropical zone and exhibits xeric conditions. The temperatures usually range from 12.5 to 17.5°C in winter and from 27.5 to 32.5°C (sometimes up to 49.9°C) in summer. Rainfall starts generally in the month of June and continues up to September (southwest monsoon). The average rainfall ranges between 99 and 201 cm every year in the eastern part and between 61 and 99 cm in the western part. The periodic failure of the monsoon results in drought conditions.

The area is not much suitable for the growth of bryophytes because most of the forests are degraded probably due to increased human activities for commerce and agriculture and harsh climate. The forests are shrinking and are confined to some small localized areas in the state. Several plant species are facing threat and struggling for their existence. As the bryophytes play important role in nutrient cycling and maintenance of soil at greater extent, their inventory is needed. So far, about 54 species (including infra-specific taxa) of marchantiophytes, anthocerotophytes and bryophytes are recorded from different parts of Uttar Pradesh, but are in scattered form. In the present list, an attempt has been made to bring out all the known species and their up-to-date nomenclature. The distribution within the state is based on published record and its references are provided.

ENUMERATIONS

Marchantiophyta (Liverworts)

Asterella wallichiana (Lehm. & Lindenb.) Pande, K. P. Srivast. & Sultan Khan ex Grolle, Khumbu Himal. 1(4): 262. 1966. [**Aytoniaceae**]. Faizabad (Singh & Kumar 2003 as *Asterella angusta* (Steph.) Mahab. & Bhate), Lucknow (Long 2006).

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