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Floral ecology and pollination in *Eriolaena lushingtonii* (Sterculiaceae), an endemic and threatened deciduous tree species of southern peninsular India

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Abstract: *Eriolaena lushingtonii* is an endemic and threatened medium-sized deciduous tree species. The flowering is very brief and occurs during the early wet season. The flowers are solitary, remain within the foliage and attract a few bee foragers only in the presence of nectariferous and polleniferous plants such as *Holarrhena pubescens*, *Grewia tiliaefolia* and *Orthosiphon rubicundus* which are common, exhibit gregarious flowering and attract a wide array of insects. In *E. lushingtonii*, the floral characteristics suggest entomophily but it is exclusively melittophilous involving *Apis, Trigona* and *Xylocopa* bees in the study area. The hermaphroditic flowers with the stigmatose style beyond the height of stamens and the sticky pollen grains do not facilitate autogamy but promote out-crossing. The study showed that pollinator limitation is responsible for the low fruit set but it is, however, compensated by multi-seeded fruits. Anther predation by a beetle also affects the reproductive success. Explosive fruit dehiscence and anemochory are special characteristics but these events are not effective during the wet season. The locals exploit the plant for treating snake bites, scorpion sting, making ropes and fuel wood. Therefore, the pollinator limitation, ineffective anemochory, seedling establishment problems and local uses largely contribute to the endemic and endangered status of *E. lushingtonii*.

Keywords: *Eriolaena lushingtonii*, vulnerable, melittophily, explosive fruit dehiscence, anemochory.

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Author Contribution: Prof. A.J. Solomon Raju is Head of the Department of Environmental Sciences, Andhra University, Visakhapatnam. He is the recipient of several national and international awards. He has more than 250 research papers in international and national journals. He is on the editorial board of several international journals. He is presently working on endemic and endangered plant species in southern Eastern Ghats forests with financial support from MoEF and CSIR, and on mangroves with financial support from MoEF. Dr. K. Venkata Ramana is a Research Associate in CSIR Project on Pollination ecology of *Wendlandia glabrata* DC. and *Wendlandia tinctoria* (Roxb.) DC. (Rubiaceae), the rare tree species of Eastern Ghats of Andhra Pradesh. Mr. P. Hareesh Chandra is a Junior Research Fellow working in All India Coordinated Research Project on Reproductive Biology of Rare Endangered and Threatened (RET) Tree species funded by the Ministry of Environment and Forests, Government of India, under the supervision of Prof. A.J. Solomon Raju, Andhra University,

Author Details: AJSR has done part of the field work and write-up of the ms while VR and HC were involved in field work and provided assistance in the preparation of the manuscript.

INTRODUCTION

Eriolaena meaning the "woolly calyx lobes" is a genus of the family Sterculiaceae with 8–10 arborescent deciduous tree and shrub species distributed in India, South East Asia and southern China (Kubitzki & Bayer 2003). Tang et al. (2007) mentioned that this genus has about 17 species but the authors have not given the list; the state of information indicates that the taxonomic aspects have been poorly studied. The genus is characterized by actinomorphic, bisexual flowers lacking staminodes and ovary tipped with a long style and spreading stigmas developing into a woody dehiscent capsule with numerous winged seeds (Hutchinson 1967). The identified species include *E. kwangsiensis, E. glabrescens, E. quinquelocularis, E. spectabilis, E. stocksii, E. candollei, E. wallichii, E. hookeriana* and *E. lushingtonii*. *E. kwangsiensis* is endemic to China, *E. glabrescens* to south Yunnan, Thailand and southern Vietnam while all other species including *E. hookeriana* and *E. lushingtonii* occur in India and elsewhere in tropical and subtropical Asia. *E. hookeriana* occurs in the peninsular India, Maharashtra and Sri Lanka while *E. lushingtonii* is an endemic and endangered deciduous tree species of southern peninsular India where it is restricted to open slopes of moist deciduous forests at 350–900 m (Hutchinson 1967; Kubitzki & Bayer 2003; Tang et al. 2007; Rao & Pullaiah 2007). The chronology of field collection of *E. lushingtonii* in peninsular India has been noted by Rao & Pullaiah (2007). In Andhra Pradesh, the type collection was made by Lushington during pre-independence time from the Nallamalai Hills in Kurnool District. After a lapse of about 70 years, Ellis collected it from Chelama Reserve Forest of Kurnool District on 05 July 1963 and from the adjacent locality Rollapenta on 16 August 1972 in the Nallamalais. In Tamil Nadu, it was collected from the south Srivalliputhur Reserve Forest on 24 July 1965 by E. Vajravelu. Malick (1993) noted the distribution of this species in Karnataka and Kerala. None of these species have been investigated for their reproductive ecology. But, there is one reference to the pollination aspect of *E. quinquelocularis* in a study on the reproductive phenology of a tropical dry forest in Mudumalai in southern India by Murali & Sukumar (1994). In this study, these authors noted that *E. quinquelocularis* is entomophilous and anemochorous. Keeping this state of information in view, *E. lushingtonii* has been studied for its floral ecology and pollination in recognition of its endemic and Vulnerable (WCMC 1998) status and the same is presented and discussed in this paper.

MATERIALS AND METHODS

In Andhra Pradesh, *Eriolaena lushingtonii* occurs in two localities only. A small population consisting of 25 individuals occurs in the dry deciduous forest near Chinarutla Gudem (16^{0}02'N & 78^{0}57'E; elevation 727.5m) which is a part of Nallamalai forest in Markapuram Division, Prakasam District (Images 1a-c). Another population occurs in Nagarjuna Sagar-Srisailam Tiger Reserve (15^{0}53'–16^{0}43'N & 78^{0}30'–79^{0}28'E; 837.4m) which covers an area of 3,568sq.km in the Nallamalai Hill Range. The first population was used for study during May 2010–September 2011. The second population could not be accessed due to entry restrictions.

Twenty five tagged mature buds were followed for recording the time of anthesis and anther dehiscence; the mode of anther dehiscence was also noted by using a 10x hand lens. Five flowers each from ten trees selected at random were used to describe the flower morphology such as flower sex, shape, size, colour, odour, sepals, petals, stamens and ovary. Ten mature but undehisced anthers were collected from five different plants and placed in a petri dish. Later, each time a single anther was taken out and placed on a clean microscope slide (75x25 mm) it was dabbed with a needle in a drop of lactophenol-aniline-blue. The anther tissue was then observed under the microscope for pollen, if any, and if pollen grains were not there, the tissue was removed from the slide. The pollen mass was drawn into a band, and the total number of pollen grains was counted under a compound microscope (40x objective, 10x eye piece). This procedure was followed for counting the number of pollen grains in each anther that was collected. Based on these counts, the mean number of pollen produced per anther was determined. The characteristics of pollen grains were also recorded. Five flowers each from ten trees were used for testing stigma receptivity. It was tested with hydrogen peroxide from mature bud stage to flower drop as per Dafni et al. (2005). Hydrogen peroxide when applied to stigma does not stain but produces bubbles as a result of catalase (peroxidase) presence. The period of bubble production was taken as the duration of stigma receptivity. A sample of 50 just fallen flowers were taken to record the percentage of anther predation by an unidentified beetle. The fruit set rate in open-pollinations was recorded by counting the number of fruits per tree. Fifteen trees were used for this purpose. Regular field visits were conducted to observe the foraging activity of insects but the insects were not regular and consistent in forage collection from *E. lushingtonii*. However, we could record and identify

the foragers from their occasional foraging activity. The insects were observed with reference to the mode of approach, landing, probing behaviour, the type of forage they collect, contact with essential organs to result in pollination, inter-plant foraging activity in terms of cross-pollination, etc. Fruits and seed characteristics were also recorded. Field observations were made on seedling establishment rates. In the entire study area, only 21 out of 214 seedlings were established and growing continually while all others perished subsequently within three weeks. The soil samples were collected from this area for pH, electrical conductivity, organic carbon, Pb, Na, Cd, Cu, Zn, Mn, Fe and soil microbial carbon. The soil analysis was done by the Central Research Institute for Dry land Agriculture, Hyderabad. The plant habit, flowers and fruits were photographed with Nikon D40X Digital SLR (10.1 pixel). Magellan Explorist 210 Model Digital Global Positioning System was used to record the coordinates—latitude, longitude and altitude.

RESULTS

The habitat of *E. lushingtonii* is rocky with black clay soil. The soil is principally transported from other areas during rainy season. Its pH is slightly acidic; salinity, Pb, Cu, Fe, Na, SMBC levels are very low; Mn and organic carbon are very high; Cd and Zn levels are at normal range (Table 1). The soil chemical profile for the analyzed parameters indicated that the slightly acidic pH appeared to be playing an important role in the availability of micronutrients to the plant growth (Rengasamy & Olsson 1991; Doran & Parkin 1996; Moody & Aitken 1997). In such soil environments, the medium-sized deciduous tree species, *E. lushingtonii* occurs naturally. The plant displays leaf flushing during May–June. The flowering event occurs from the 3rd week of June to the 3rd week of July. An individual tree flowers for about two weeks while the flowering duration at population level is about four weeks. The flowers are solitary, pedicellate and borne in the leaf axils hanging downwards or at right angles to the axis (Image 1d). They are large, 25mm long, 42mm wide, yellow, mildly fragrant, hypogynous, actinomorphic and bisexual. The calyx is composed of five pale green 22mm long free linear sepals with stellate-hairs on the outside and villous on the inside. The corolla has five free petals and arranged alternate to sepals; they are golden yellow, reflexed and each petal is 20mm long and 5mm wide. The stamens are 18–20, yellow and fused at their base to form a stamina column. Free filaments arise from the length of the tube and each is 6mm long and surmounted by a 2mm long bilocular, tetrasporangiate anthers with parallel locules. The staminodes are completely absent and the fertile anthers are of varying heights due to varying filament length. The ovary is 5mm long, 4–5 locular and each locule is 6–8 ovuled; the total number of ovules per ovary is 35–40 (Image 2g). The style is 18mm long, brownish, stigmatose and stellately tetra or pentafid at its apex. The stigmatic lobes are equal, pubescent and each of them is 2mm long. The stigmatose style extends far beyond the height of stamens.

The mature buds are open from 0700–0800 hr (Image 1e). The sepals and petals unfold and reflex backwards exposing the entire length of staminal column and style and stigmatic lobes (Image 2a,b). Anther dehiscence and stigma receptivity occur after anthesis; anthers dehisce first by longitudinal slits (Image 2c) while the stigmatic lobes unfold completely about 3 hours later (Image 1f,g). In this state, the stigmatic lobes are semi-wet, pubescent and remain wet for two days (Image 2f). During this period, they are receptive to pollen and it is further confirmed by hydrogen peroxide test. The pollen output per anther is 763±30 and it varies from 13,734–15,260 depending on the number of stamens. The pollen grains are spherical, echinate, panporate, sticky and 58.1µm in size (Image 2d). The pollen-ovule ratio is also not constant due to the varying number of ovules per flower. A flower produces 0.8±0.1 µl of nectar at the base of the ovary, which is firmly held by the pubescent hairs, and the nectar glistens against sunlight. The flowers fall off on the 4th day if not pollinated while in the pollinated ones, the ovary remains and all other flower parts fall off over a period of 4–10 days.

During the entire flowering season, the flowers were occasionally foraged by the honey bees *Apis dorsata, A. cerana* and *A. florea*, the stingless bee, *Trigona iridipennis*, and the carpenter bees *Xylocopa pubescens* and *X. latipes* during day-time especially during the forenoon period due to availability of fresh nectar and pollen.

Table 1. Results of chemical analysis of soil collected from the habitat of *Eriolaena lushingtonii*

Soil sample	pH	EC (ds/m^{-1})	O.C%	Pb (ppm)	Na (ppm)	Cd (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	SMBC (µg/g)	Fe (ppm)
Mean of 5 samples	6.3	0.12	1.48	0.8	9.95	0.02	0.08	0.565	8.81	25.69	2.141

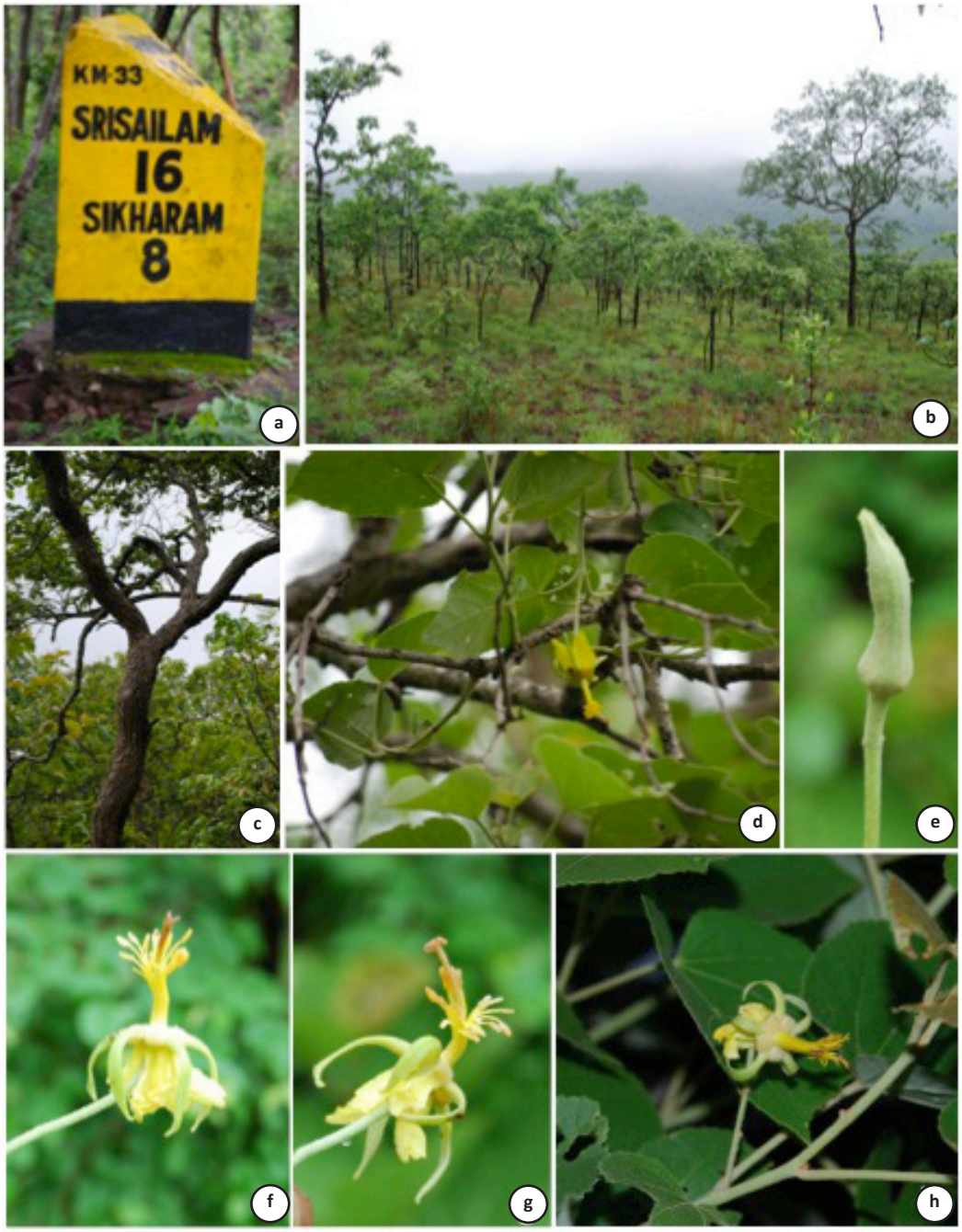

Image 1. ***Eriolaena lushingtonii*****: a- Landmark; b - Habitat appearance during June; c - Trunk; d - Flowering branch; e - Mature bud; f - Flower with unfolding stigmatic lobes; g - Flower with pentafid stigma in receptive state; h - Flower with filaments after feeding of anthers by an unidentified beetle. © Prof. A.J. Solomon Raju**

The carpenter bees were found to be feeding only on nectar while the other bees also on pollen. These bees exhibited two different approaches, the first included an approach of the bee in upright position from the side bypassing the stamens and stigmas for probing the ovary base directly for nectar collection while the second included an approach of the bee in upright position via the stamens and stigmatic lobes for collecting nectar from the ovary base. In both the approaches, the pollen collecting bees after nectar collection ascended to the place of stamens for pollen collection; sometimes these bees first collected pollen and then descended into the ovary base for nectar collection. All the bees except the stingless bees had contact with the stamens and stigmatic lobes while collecting nectar and/or pollen in the same or different visits; such a contact was considered to

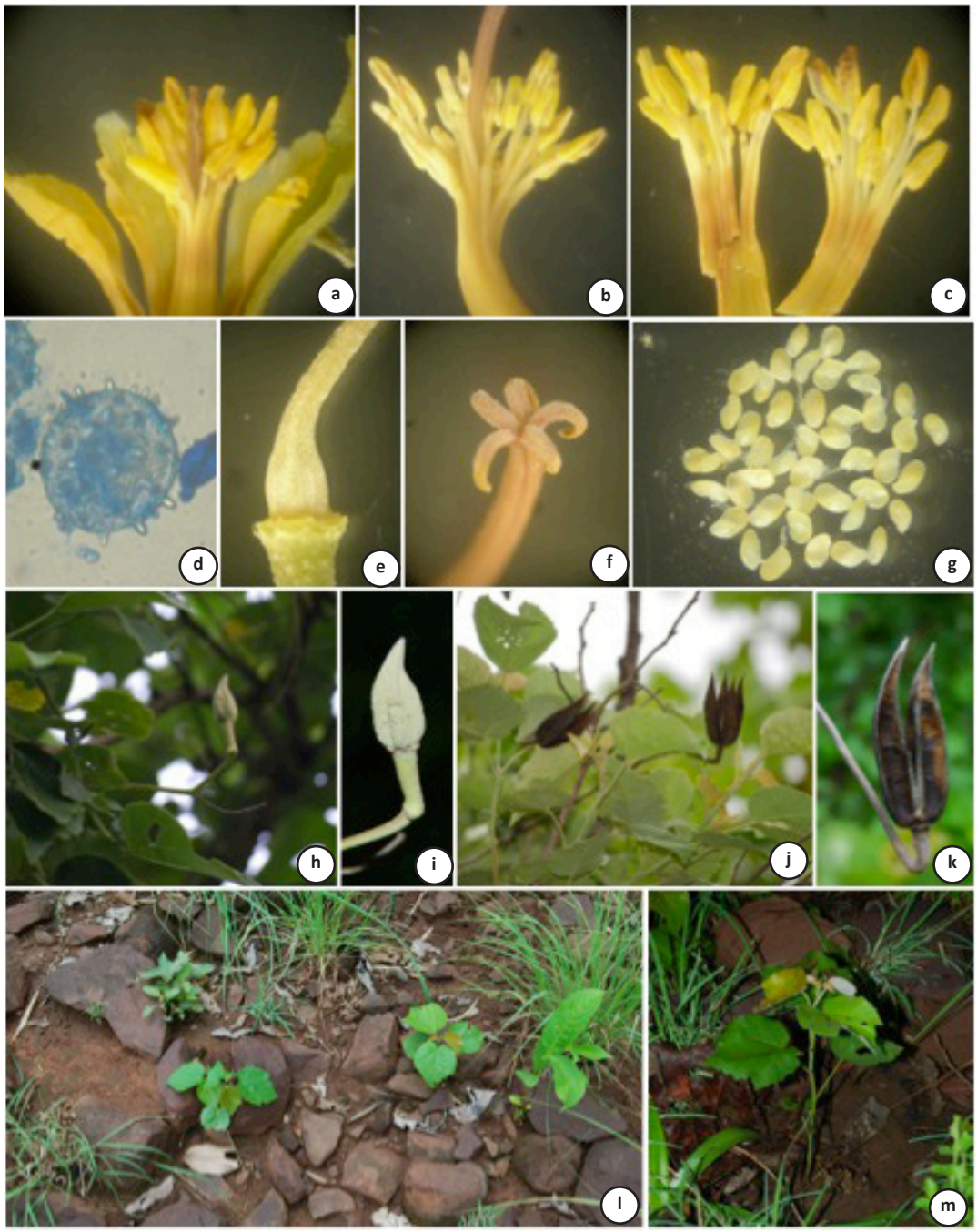

Image 2. *Eriolaena lushingtonii*: a–b - Position of anthers and stigma during mature bud and flower; c - Anthers; d - Pollen grain; e - Ovary; f - Pentafid stigma; g - Ovules; h–i - Fruit; j–k - Explosive dehiscence of fruit; l–m - Seedlings. © Prof. A.J. Solomon Raju

result in pollination. The production of a small number of flowers at tree level was found to be driving the bee foragers from one plant to the other to seek more forage and such a foraging behavior was considered to result in cross-pollination. The stingless bee had contact with the stigmatic lobes occasionally while collecting pollen from the anthers and this contact was considered to be effecting pollination. A beetle (unidentified) feeds on the anthers leaving the filaments and other floral parts intact; the percentage of such flowers accounts for 5% of the sampled flowers (Image 1h).

In the habitat of *E. lushingtonii*, the trees *Holarrhena pubescens* (Apocynaceae), *Grewia tiliaefolia* (Tiliaceae), *Pterocarpus marsupium* and the herb *Orthosiphon rubicundus* (Lamiaceae) were found to be flowering simultaneously. *P. marsupium* is a rare species while

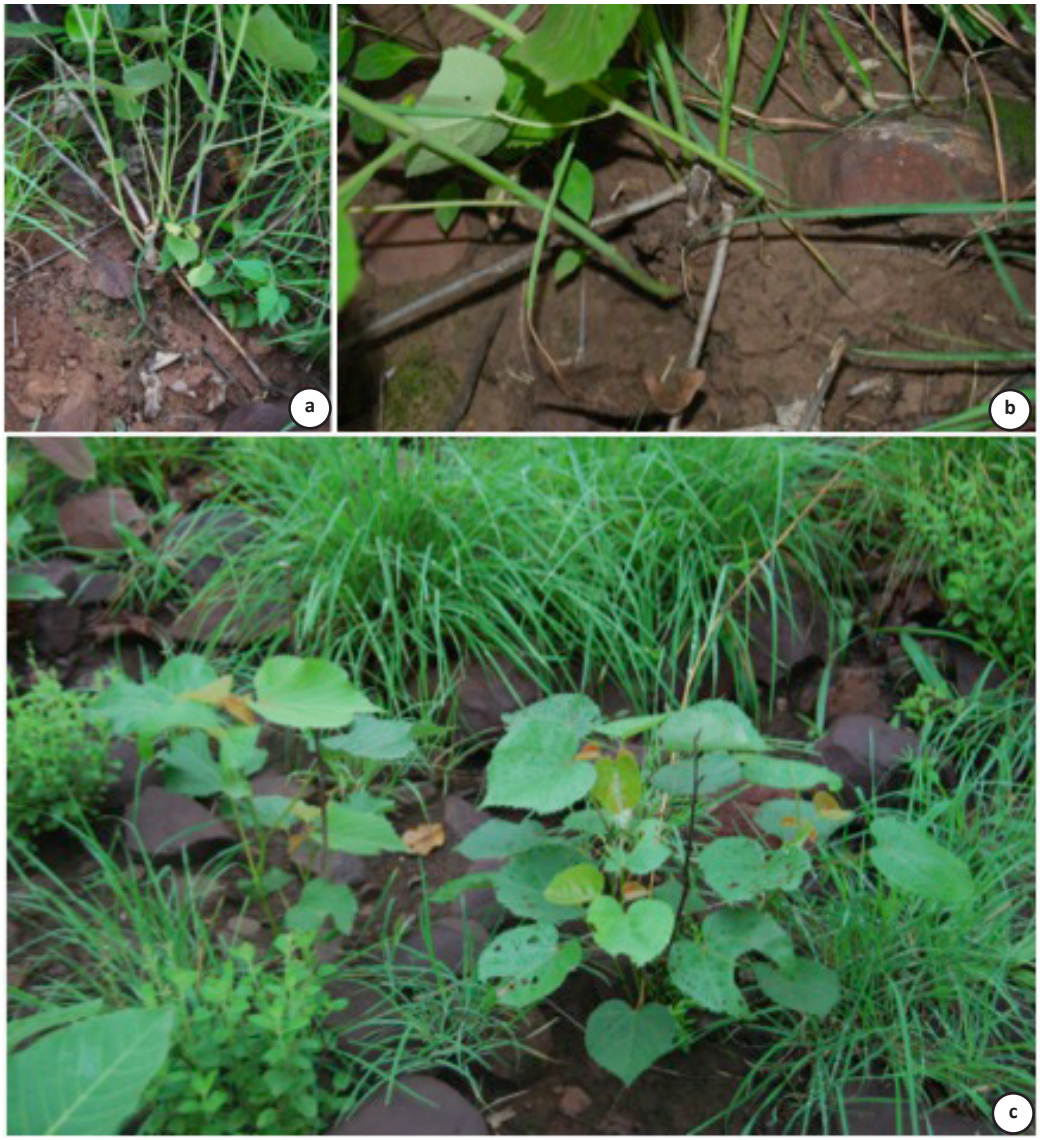

Image 3. *Eriolaena lushingtonii*: a–c - New growth from the underground root stock. © Prof. A.J. Solomon Raju

the other species are common. The flowers are white in *H. pubescens*, white lilac in *O. rubicundus* and yellow in *G. tiliaefolia* and *P. marsupium*. The flowers are borne in small to large clusters or aggregates, anthese during early morning and appear prominently against the foliage in these species. Further, the flowering is profuse in *G. tiliaefolia* and *O. rubicundus*. The flowers of all four species are nectariferous and offer nectar and pollen as rewards to pollinators. With the production of ample floral forage, these plant species attracted a wide array of insects representing bees, wasps and butterflies. With simultaneous flowering of these plant species in the habitat, *E. lushingtonii* with a small number of solitary flowers covered in the foliage was found to be unattractive and hence were visited only occasionally by some bees.

In fertilized flowers of *E. lushingtonii*, the ovary gradually bulges, transforms into fruit and produces seeds (Image2h,i). The total duration from fruit initiation to maturation and dispersal is about four weeks. A tree produces 25–39 capsular fruits. The fruit is a 3.5–3.7 cm long woody 4–5 lobed capsule with 13–22 ascending seeds and wool filling the spaces between them. The seeds possess apical membranous wings which are about as long as the body of the seed. The mature, dry capsules dehisce loculicidally a bit explosively liberating winged seeds into the air (Image 2j,k). The seeds thus released are driven away by the prevailing wind and they germinate readily and produce seedlings (Image 2l,m). The rocky habitat with migrated soils was found to be

unfavourable for seedling establishment even if seed germination is successful. The aged trees cut to ground level and beyond by locals were found to show new vigorous growth continually from the root system left in the ground (Image 3a-c).

DISCUSSION

Eriolaena is a genus distributed exclusively in dry or moist deciduous open forest. Its species flower either in the dry or wet season (Tang et al. 2007). In India, Murali & Sukumar (1994) reported that *E. quinquelocularis*, occurring in a dry forest of Mudumalai in southern India, exhibits leaf flushing and flowering events successively within the dry season. Chetty et al. (2008) noted that in *E. hookeriana*, flowering and fruiting events take place during January–October. *E. lushingtonii* is also a dry deciduous open forest species but shows leaf flushing in late dry season while flowering during the early wet season. Tang et al. (2007) reported that the flowers of all *Eriolaena* species are characteristically yellow. *E. hookeriana*, a dry deciduous species confined to India and Sri Lanka also produces yellow flowers. *E. quinquelocularis*, a dry deciduous species distributed in and outside India also bears yellow flowers which are more conspicuous due to its flowering during the dry season when the herbaceous flora disappear and tree species remain leafless (Murali & Sukumar 1994). In *E. lushingtonii*, the flowering occurs for a brief period during which a few yellow flowers are produced daily at tree level. Further, the flowers are solitary, remain covered in the foliage and hence, go unnoticed by the flower visitors due to emergence of herbaceous flora and leaf flushing in deciduous tree species following rainfall in early June. Such flowering pattern and flower position appear to be disadvantageous for the plant to attract flower visitors, especially in the presence of other simultaneously flowering plant species in the area. The nectariferous and polleniferous plant species, *Holarrhena pubescens, Grewia tiliaefolia* and *Orthosiphon rubicundus* with common occurrence, gregarious flowering and very conspicuously present grouped flowers against the foliage attract a variety of insects comprising of bees, wasps and butterflies while *E. lushingtonii* receives only occasional foraging visits of bees. All the co-flowering plant species and *E. lushingtonii* produce a minute amount of nectar. *G. tiliaefolia* with numerous stamens is a copious pollen producer. *E. lushingtonii* produces a moderate amount of pollen while the other two species a small amount of pollen. The aggregate arrangement of flowers and a profuse flowering pattern appear to play an important role in the co-flowering plant species to compete well with *E. lushingtonii* for flower visitors.

Murali & Sukumar (1994) reported that *E. quinquelocularis* is insect-pollinated in the Mudumalai deciduous forest. In the Nallamalai deciduous forest, *E. lushingtonii* with morning anthesis, exposed dehisced anthers presenting pollen and exposed flower base presenting nectar after anthesis indicates that it is adapted for day-active flower foragers for pollination. In line with this, bees visit the flowers for forage, the honey bees and stingless bees for both the pollen and nectar while carpenter bees only the nectar. The low energy-requiring small bodied stingless bees habitually confine to an individual plant for forage collection while high energy-requiring moderate-sized honey bees and large-bodied carpenter bees fly between plants for more forage collection (Raju 2007). In the present study, *E. lushingtonii* with a small number of solitary flowers at tree level drive even the stingless bees to fly between plants to collect as much forage as possible for meeting their own needs and for their colony members as well. Such a foraging activity by these bees contributes to the maximization of cross-pollination rate. The flowers with 2-day long stigma receptivity have the option to receive pollen and subsequently to achieve pollination by the visiting bees on the second day of anthesis. The floral characteristics of *E. lushingtonii* as detailed previously conform to the entomophilous pollination syndrome (Faegri & van der Pijl 1979). Since only bees are involved in pollination, it can be stated that *E. lushingtonii* is melittophilous in the study area. Sharma (Sharma 1967) stated that *Eriolaena* pollen grains are stenopalynolous and also described the pollen grain characteristics of *Eriolaena* species, *E. wallichii, E. hookeriana* and *E. spectabilis*. These three species exhibit similar pollen morphology and hence have been referred to as *E. wallichii* type by him. The panporate and spinulate characters typify this type of pollen grains. He considered the panporate condition as a climax in the line of apertual evolution. The spherical, echinate and panporate pollen grains of *E. lushingtonii* represent the *E. wallichii* type. Further, the pollen grains are sticky and there is no possibility of their dissemination into the air during the wet season. The sticky and spinulate nature of the grains in this species is an adaptive feature for melittophily and is also advantageous for the bees to load and pack them into corbiculae for transportation to their nest (Gottsberger 1989).

E. lushingtonii with hermaphroditic sexual system and weak protandry facilitates both self- and cross-pollination.

The ability to fruit through both modes of pollination is adaptive but it is essentially insect-dependent since the extension of the stigmatose style beyond the height of stamens and the sticky nature of pollen grains which is further dampened by the high humidity during wet season preclude the occurrence of autogamy. The study indicates that the pollinator limitation appears to be playing a considerable role for the low fruit set, and the fruit number per tree in the entire population stands below forty. However, the low fruit set is compensated to a small extent by the production of several seeds per fruit. The seed set rate could be attributed to the number of fertilized ovules and to the nutrient status of the soil. Further, the flowers attract a beetle which consumes anthers and such flowers do not participate in sexual reproduction. Murali & Sukumar (1994) reported that in *E. quinquelocularis*, the fruits mature within a short duration and this reason could be the investment of more resources in flowers. Further, the fruit dehisce explosively to disseminate seeds into the air and hence the seeds are characteristically wind-dispersed for which the dry season is very effective because of low humidity at that time. All the reproductive events, flowering, fruiting and seed dispersal of this plant occur within the dry season only. In *E. lushingtonii*, fruits mature within a month, dehisce explosively liberating winged seeds into the air and the seeds are wind-dispersed; and hence the plant is anemochorous (Maury-Lechon & Curtet 1998). But, the wet season is not ideal for anemochory due to high humidity and precipitation. However, seed dispersal during the wet season enables seeds to avoid exposure to desiccation during the dry season. The seeds are not dormant due to their immediate germination following their dispersal. But, the seedlings do not grow properly and subsequently wither away. There are very few seedlings that finally establish and produce new plants. The non-establishment of the seedlings could be attributable to several factors. The rocky habitat with migrated soil due to runoff from the uphill areas does not favour the establishment of the seedlings. The soil reaching the habitat does not remain there and is subject to erosion by rainwater. Further, the soil chemical analysis indicates that it contains micronutrients at low or normal range with high organic carbon. But, its slight acidic pH appears to be limiting the availability of micronutrients and the high organic carbon in soils may also tie up the micronutrients in unavailable forms (Sarwar et al. 2010). The quick growth of grass cover is also another factor that is affecting the growth of seedlings of *E. lushingtonii*. The successful establishment and the continuous growth of the seedlings of *E. lushingtonii* into new plants could be related to the existence of some pockets of deep soil within the rocky habitat. The areas where the plants are established have deep soil which enables them to penetrate gradually through crevices and cracks of rocks. The study suggests that the soil layer and its composition, and also robust grass growth have a great bearing on the build-up of population of *E. lushingtonii*. Further, the locals use leaf extract as antidote for treating snake bites and scorpion sting and bark fiber for making ropes. They also cut down the trees to use as fuel wood; new shoots arise from the underground root stock if the latter is intact. Therefore, the pollinator limitation, anther predation, seed dispersal during the wet season, establishment problems and local uses collectively contribute to the endemic and endangered status of *E. lushingtonii*. These aspects are to be taken into account while framing effective conservation and management measures as well as the recovery of the population of *E. lushingtonii*.

REFERENCES

Chetty, K.M., K. Sivaji & K.T. Rao (2008). *Flowering Plants of Chittoor District, Andhra Pradesh, India.* Students Offset Printers, Tirupati, 600pp.

Dafni, A., P.G. Kevan & B.C. Husband (2005). *Practical Pollination Biology*. Enviroquest Ltd., Ontario, 590pp.

Doran, J.W. & T.B. Parkin (1996). Quantitative indicators of soil quality: A minimum data set, pp. 25–37. In: Doran, J.W. & A.J. Jones (eds.). *Method for Assessing Soil Quality.* Soil Science of America, Special Publication No. 49, Madison, Wisconsin, USA.

Faegri, K. & L. van der Pijl (1979). *The Principles of Pollination Ecology*. Pergamon Press, Oxford,

Gottsberger, G. (1989). Floral ecology: Report on the years 1985 (1984) to 1988. *Progress in Botany* 50: 352–379.

Hutchinson, J.B. (1967). *The Genera of Flowering Plants. Dicotyledons*. Vol. 2, Clarendon Press, Oxford, 578pp.

Kubitzki, K. & C. Bayer (2003). Malvaceae, p. 418. In: Kubitzki (ed.). *The Families and Genera of Vascular Plants*: *Flowering Plants Dicotyledons, Malvales and Non-betalain Caryophyllales.* Vol. 5, Springer, Berlin-Heidelberg, New York.

Malick, C. (1993). *Flora of India - Volume 3.* Botanical Survey of India, Calcutta, 417pp.

Maury-Lechon, G. & L. Curtet (1998). Biogeography and evolutionary systematics of Dipterocarpaceae, pp. 5–44. In: Appannah, S. & J.M. Turnbull (eds.). *A Review of Dipterocarps: Taxonomy, Ecology and Silviculture*. Center for International Forestry Research, Indonesia.

Moody, P.W. & R.L. Aitken (1997). Soil acidification under some tropical agriculture systems 1. Rates of acidification and contributing factors. *Australian Journal of Soil Research* 35: 163–173; http://dx.doi.org/10.1071/S96069

Murali, K.S. & R. Sukumar (1994). Reproductive phenology of a tropical dry forest in Mudumalai, Southern India. *Journal of Ecology* 82: 759–767.

Raju, A.J.S. (2007). *Indian Plant Reproductive Ecology and Biodiversity*. Today and Tomorrow's Printers and Publishers, New Delhi, 383pp.

Rao, D.M. & T. Pullaiah (2007). Ethnobotanical studies on some rare and endemic floristic elements of Eastern Ghats-Hill Ranges of South East Asia, India. *Ethnobotanical Leaflets* 11: 52–70.

Rengasamy, P. & K.A. Olsson (1991). Sodicity and soil structure.

Australian Journal of Soil Research 29: 935–952; http://dx.doi.org/10.1071/SR9910935

Sarwar, N., Saifullah, S.M. Sukhdev, H.Z. Munir, N. Asif, B. Sadia & F. Ghulam (2010). Role of mineral nutrition in minimizing cadmium accumulation by plants. *Journal of Science, Food and Agriculture* 90**:** 925–937; http://dx.doi.org/10.1002/jsfa.3916

Sharma, B.D. (1967). Studies of Indian pollen grains in relation to plant taxonomy: Sterculiaceae. Proceedings of Indian National Science Academy 35: 320–359.

Tang, Y., M.G. Gilbert & L.J. Dorr (2007). Hippocastanaeae through Theaceae, pp. 302–330. In: Wu, Z.Y., P.H. Raven & D.Y. Hong (eds.). *Flora of China* - Vol. 12. Science Press, Beijing and Missouri Botanical Garden Press, St. Louis.

World Conservation Monitoring Centre (1998). *Eriolaena lushingtonii*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2. <www.iucnredlist.org>. Downloaded on 08 May 2013.