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Pollination biology of five *Leucas* spp. (Lamiaceae) in Southern Western Ghats

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Abstracts
The genus *Leucas* shows remarkable differentiation in floral traits among related species. Pollination systems and pollinator syndromes were diverse among five studied species of genus *Leucas* (Lamiaceae). Pollination biolosgy of the morphologically diverse genus *Leucas* was investigated by means of field observations as well as laboratory tests. Detailed studies were carried out regarding flowering phenology, anther dehiscence, pollen viability, pollen morphology, and stigma receptivity. The long corolla tubed flower *L. sivadasaniana* frequently visited by *Macroglossum lepidum* being the potential pollinator of that particular species. Here proboscis length well corresponded to corolla tube lengths of *Leucas* spp. Other short corolla tubed *Leucas* members (*L. chinensis, L. ciliata, L. angularis,* and *L. biflora*) were frequently visited by Hymenopterans. Our study concluded that corolla tube length of flower and proboscis length of insects correlated with each other.

Keywords: *Lamiaceae, Leucas spp, corolla tube.*

1. Introduction

Pollination systems in plants vary from being highly generalized to highly specialized [8, 14]. Perhaps the most common pollination systems are those in which flowers are visited by a variety of animal visitors, yet show some degree of evolutionary specialization for pollination by a subset of these visitors [1, 7, 8, 9]. Pollination specialization has long been considered an important process underlying the evolution of floral diversity. Consequently floral traits have been viewed as adaptations to attract specific pollinators and to enhance the efficiency of pollen transfer and out crossing [3, 13]. Diversification of angiosperms is associated with pollination by animals, in particular insect [3]. Co-evolution can promote specialized foraging behaviour, consequently leading to changes in both floral and insect traits. There are four orders of insect pollinators whose association with plants is often evident in the floral traits: Coleoptera, Diptera, Hymenoptera and Lepidoptera [5].

Huck [6] reviewed pollination in Lamiaceae and described about the pollination mechanisms and pollination syndromes of Lamiaceae. Recent studies on pollination mechanisms of the South African genus *Plectranthus* well documented by Potgieter [10] et al and propose that the sigmoid-shaped corolla in many members of genus *Plectranthus* it's a adaptation to the curved mouthpart of genus their bee pollinators. In the other studies on the genus *Syncolostemon* [2] showed that a variety of pollinator groups, ranging from sunbirds to long-proboscid flies, day-flying hawkmoths and bees, were active on species that have a range of corolla tube sizes. Here we documenting on pollination traits of the genus *Leucas* and pollination syndromes. Here we are documenting on pollination traits of the genus *Leucas* and pollination syndromes [11].

2. Materials and Methods

Field observations and collections were made during flowering seasons of 2010 and 2013.

2.1 Study sites: Field work was conducted at Wayanad region of Southern western Ghats Vythiri (N 11° 33' 0" and E 76° 2' 59"), Kalpetta (11.622550°N 76.081250°E), Mookambika wild life sanctuary, Kudajadri hills (3°51′39″N 74°52′29″E) and Munnar(10°05′21″N 77°03′35″E). The collected plant was preserved in the Calicut university botanical garden (planted) for laboratory studies.

2.2 Observations: Flowers of *Leucas* spp were observed during the day time and notes were made on the diversity of insect visitors, type of floral reward utilized and insect behavior on the flowers.

2.3 Length Measurements: Measurements of proboscis length were done from the tip up to the attachment of the proboscis to the face of insect. Corolla tube –lengths of the selected species were measured from the base (at the junction to the calyx) to the mouth of corolla**.** The distance between upper and lower lip of each species was measured by using plastic scale.
Flowering phenology and flower phenology was observed, anther dehiscence was checked by using hand lens. Pollen morphology was studied under microscope (Leica CM, 1100). The number of pollen grains per flower was calculated as suggested by Shivanna & Rangaswami [11]. Pollen viability was checked by using tetrazolium solution. The stigma receptivity were done according to Shivanna and Rangaswami [12] laboratory manual. The results were expressed as standard deviation (mean±S.D).

3. Results and Discussion

Detailed studies were carried out in the flower morphology and reproductive ecology of five *Leucas* spp (Table 1, 2, 3 and Fig 1).

3.1 Phenology

The flowering phenology varies among *Leucas* spp. In the studied species floral characteristics and phenology were shown in Table 1. The flowers were zygomorphic and the corolla has a well-developed upper lip and lower lip were landing place for insects, an adaptation of family Lamiaceae. The tubular portion of the corolla contains nectar. The flower opening time also varied among *Leucas* spp.

Table 1: Floral characters of five *Leucas* species observed during 2010 and 2013.

Studied species	*L. chinensis*	*L. ciliate*	*L. angularis*	*L.sivadasaniana*	*L. biflora*
Flowering period	August-December	November-January	March-July	January-March	October-January
Inflorescence	Verticillaster	Verticillaster	Verticillaster	Verticillaster	Verticillaster
Flower type	Regular, bisxual	Regular, bisexual	Regular, bisxual	Regular, bisexual	Regular, bisexual
Colour	White	Upper lip brown cloured	White	White	White
Odour	Abscent	Abscent	Abscent	Abscent	Abscent
Nectar	Present	Present	Present	Present	Present
Anthesis time	4-5am	5-6am	4-5am	5.30-6.30am	5-6am
Anther dehiscence	4.30-5am	6-6.30am	3-4am	6-6.30am	5.30-6.30am
Anther no	4	4	4	4	4
Ovules	4	4	4	4	4
Pollen/ anther	334	422	292	592	450
Pollen shape	Spherical, tricolpate	Spherical, tricolpate	Spherical, tricolpate	Spherical, tricolpate	Spherical, tricolpate
Pollen size	26.55±0.055	28.75±0.084	24.90±0.195	31.80±0.114	29.84±0.045
Stigma receptivity	12-13.00hrs	10-11.00hrs	11-12.00hrs	9-10.00hrs	10-11.00hrs
Fruit type	Nutlet	Nutlet	Nutlet	Nutlet	Nutlet
Ovule seed ratio	4:4	4:4	4:4	4:4	4:4

Table 2: Floral characters

Traits(cm)	*L. chinensis*	*L. ciliate*	*L. angularis*	*L. sivadasiniana*	*L. biflora*
Tube length	1.1±0.0545	1.00±0.084	0.9±0.114	2.10±0.055	1.20±0.195
Gap between upper lip and lower lip	0.8±0.114	0.3±0.055	0.5±0.055	1.00±0.084	0.6±0.055
Style length	1.5±0.055	1.1±0.195	1.2±0.195	2.20±0.055	1.70±0.114

3.2 Floral tube length

The corolla tube length was found to vary among species *L. sivadasiniana* has average tube length of 2.10 cm, *L. chinensis* 1.1 cm, *L. ciliata* 1cm, *L. biflora* 1.20cm, and *L. angularis* has only 0.9cm length corolla tube (Table 2 and fig 1).

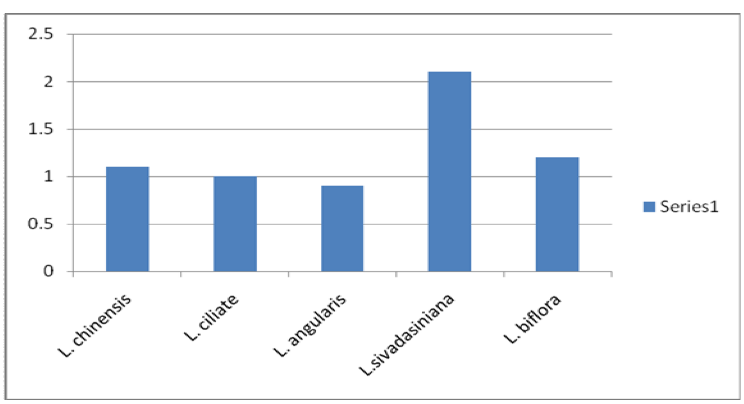

Fig 1: Floral tube length

Table 3: Flower visitors and proboscis length

Species	Pollinator	% of visits	Proboscis length(cm)
L.sivadasaniana	*Macroglossum lepidum*	75	2.5±0.055
	Apis sp –pollen collecting	62	0.5±0.084
	Amegilla sp -pollen collecting	51	0.6±0.195
	Apis cerana -pollen collecting	48	0.5±0.114
L.chinensis	*Amegilla* -pollen collecting	78	0.6±0.084
	Apis florae -pollen collecting	66	0.5±0.055
	Apis cerana -pollen collecting	42	0.5±0.114
L.biflora	*Amegilla* -pollen collecting	62	0.6±0.045
	Apis cerana -pollen collecting	48	0.5±0.114
L.angularis	*Amegilla* -pollen collecting	66	0.6±0.045
	Ceratina sp -pollen collecting	48	0.5±0.071
	Apis cerana -pollen collecting	39	0.5±0.055
L.ciliata	*Amegilla* sp1 -pollen collecting	75	0.6±0.045
	Amegilla sp2 -pollen collecting	52	0.6±0.084
	Apis cerana -pollen collecting	48	0.5±0.114
	Xylocopa sp	33	0.7±0.055

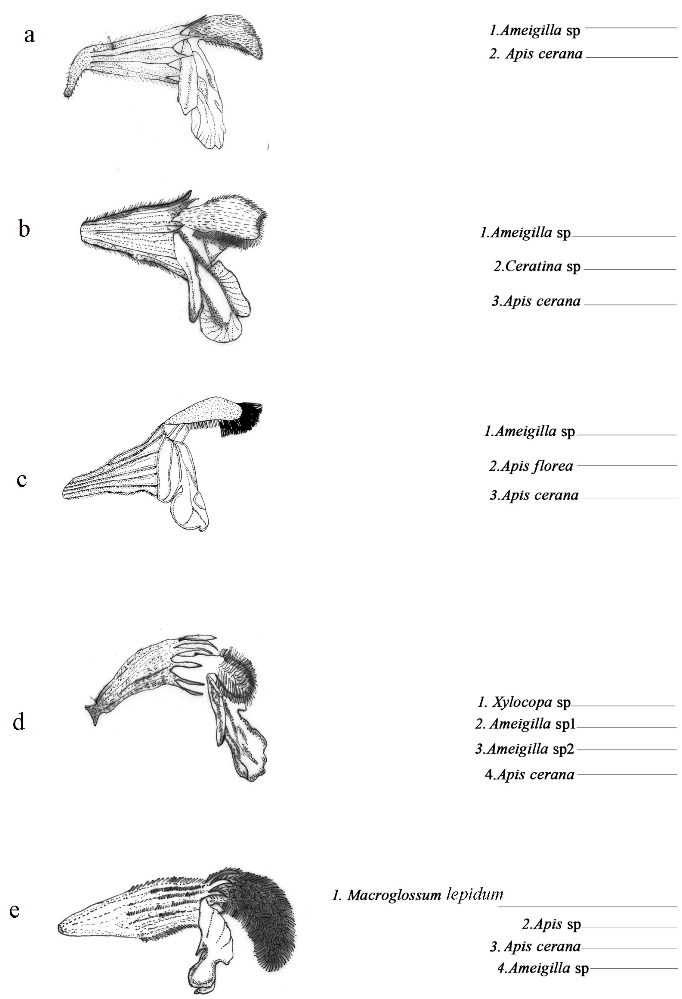

Plate 1. Floral visitors of different *Leucas* spp and correlation between corolla tube length and insects proboscis length. a. *L.biflora.* b. *L. angularis.* c. *L.chinensis.* d. *L. ciliata. L. sivadasaniana.*

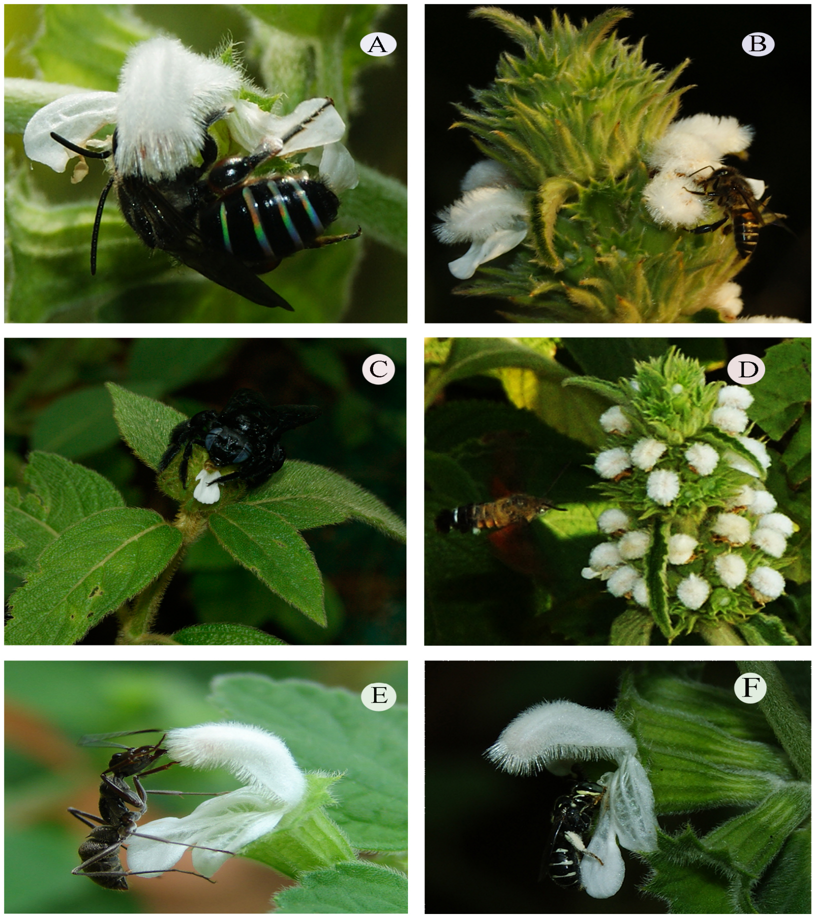

Plate 2. A, *Ameigilla* sp probing nectar from *L. chinensis*. B, *Apis cerana* foraging on *L. sivadasaniana.* C, *Xylocopa* sp feeding on *L. ciliata.* D, *Macroglossum lepidum* on *L. sivadasaniana*. E, *Componotus parius* on *L. chinensis*. F, *Ceratina* sp on *L. chinensis*.

3.3 Flower visitors

Details of floral visitors were shown in Table 3 and Plate 2. According to our study we found that visitors were Hymenopterans and Lepidoperans. The Hymenopterans were recorded highest rank among them. Among the Hymenopterans *Ameigilla* sp, *Apis cerana, Apis florae, Ceratina* sp were recorded as frequent visitors on *Leucas* species Honey bees were observed as pollen collectors (*Apis* spp). The insect visitors were shown altogether different strategies, some insect species like *Trigona irridipenis* were considered as nectar robbers. The ant *Componotus parius* was recorded as pollen robbers in *L. chinensis.* The long corolla tubed *L. sivadasiana* was frequently (78%) visited by day flying hawk moth *Macroglossum lepidum.*

3.4 Pollen attachments

According to the foraging strategy the pollen attachments were varied among insects. Most of the Hymenopterans were landing on the lower lip and inserted proboscis in to corolla for nectar. So pollen adhering was occurred on the dorsal side of the insects. But the foraging behavior of hawk moth was different. The hovering nature of hawk moth was never landed on the flower. So pollen depositions were found on long proboscis.

3.5 Pollination

We found that all *Leucas* members were shown similar kind of reproductive constructions. The bilabiate structure were favoring of insect species. The anthers were hidden in the upper lip and insects were landed on lower lip. While accessing nectar from flower pollen got dusted on insects back (nototribic). The long corolla tubed species *L. sivadasaniana* was frequently visited and pollinated by *Macroglossum lepidum* similarly short corolla tubed flowers of *L. angularis* and *L. ciliate* were pollinated by short proboscid species like *Ameigilla*, *Ceratina* and *Apis cerana.* The study was mentioned about the evolution of corolla tube and foraging strategy of insects. Our study concluded that corolla tube length of flower and proboscis length of insects correlated with each other in the genus *Leucas*.

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