RELATIONSHIP BETWEEN FLORAL CHARACTERS AND FLORAL VISITORS OF SELECTED ANGIOSPERMIC TAXA FROM KALAKAD MUNDANTHURAI TIGER RESERVE, SOUTHERN WESTERN GHATS, INDIA

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Introduction

Plant-pollinator community oriented interaction is the first step for defining pollinator and plant 'guilds' and for assessing specialization and generalization trend among them (Smith- Ramírez *et al.*, 2005). These studies have a wide application in ecosystem restoration and enable to understand the complexity and organization of pollinator relationship. It also promotes conservation efforts effectively (Johnson and Steiner, 2000; Kremen and Rickett, 2000; Kirk and Gilbert, 2009). Forests with different floral vegetation harbour different assemblage of floral visitors and their interactions are greatly influenced by composition of regional biota (Kato *et al.*, 2008). Community level characterization of pollinators of any Tropical forest site has not been thoroughly studied so far (Shatz, 1990) because of the difficulties in accessing the tall canopy trees in these forests (Lowman and Nadkarni, 1995). In India, few investigations were attempted in this aspect. Krishnan (1994) revealed that the understorey shrub community in mid-elevation site of Agasthiyamalai region use diverse pollinator groups. Devy (1998) reported the intricate relationship between social bees and their food plants. Recently, the pollination modes of 86 tree species at mid-elevation forest of Kakachi, Tirunelveli district were studied. Of which, 75% of trees are specialised to a single pollinator group such as bee, beetle or moth and the remaining with diverse pollinator group. Most of these studies were restricted to Western Ghats because of its richness in endemic flora and fauna and also this region has been identified as one of the hotspots and gains an importance of conservation (Ramesh *et al.*, 1997a). Agasthiyamalai Hills situated in southern end of Western Ghats is the region where luxuriant wet evergreen forests are found in the mid-elevated range of 900 – 1300 msl (Devy and Davidar, 2003). The present investigation focused only in the Mundanthurai Range of Kalakad Mundanthurai Tiger Reserve (KMTR), which is part of Agasthiyamalai Biosphere Reserve, southern Western Ghats with the following objectives:

To examine the diversity, abundance, and frequency of floral visitors; to study the floral characters that may account for visiting pattern of floral visitors; to assess the most potential pollinator among floral visitors for each plant species and to determine the plant species that are potential for maintaining the diversity of forest pollinators.

Materials and Methods

Mundanthurai Range (between 08°31'38.26" N and 08°48'09.96" N Latitudes, 077°10'15.09" E and 077°21'37.69" E Longitudes) is situated on the eastern slope of Agasthiyamalai Biosphere Reserve which is one of the important ranges in Kalakad–Mundanthurai Tiger Reserve (KMTR), Tirunelveli district, Tamil Nadu with an area of 270.43 km^2. This range covers a wide array of forest types such as southern tropical thorn forests (200 m), Southern tropical dry deciduous forests (300 m), Grasslands at lower altitude (500 m), Southern tropical moist deciduous forests (500 m), Southern tropical semi evergreen forests (700 m), Southern tropical wet evergreen (rain) forests (800 – 1500 m), Subtropical Montane forests (>1500 m) and Grasslands at higher altitude (Gopalan and Henry, 2000).

The present study on the floral visitors is a part of the major study of the diversity, distribution, pollen morphology of trees and shrubs of Mundanthurai Range, KMTR, carried out from January, 2008 to December, 2010. A total of 27 species of trees and shrubs were observed in this investigation. The floral visitors of all 27 plant species were observed periodically for 5 – 20 minutes during the peak flowering period and the number of observations for a day depended on the weather conditions of that day (Sunny, Cloudy, Rainy and Windy). The time duration of visitor in a flower, the frequency of floral visitors for every 5 - 20 minutes as well as their numbers in a branch was also recorded. Interactions were recorded only when the floral visitors probing for nectar or eating/collecting pollen as well as their behaviour on the flower, especially having contact with both anthers and stigma. Only such behaviours were

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considered as evidence of interaction, that the visitor is a pollinator. Floral visitors were observed, photographed and authenticated through literature sources (Chapman, 1969; Mani, 1982; Arnett and Jacques, 1985 and Ali, 2002) and also by experts. The Floral characters such as sex expression, floral colour, scent, shape and symmetry for these plant species were noted in the field. The plant specimens were collected from the field and identified through floras and related software (Beddome, 1869–73; Bourdillon, 1908; Gamble, 1916–35; Ramesh *et al.*, 2007). Herbarium specimens were deposited at French Institute of Pondicherry, Pondicherry and Research Centre, St. John's College, Palayamkottai.

Results and Discussion

Among 27 species of plants, belonging to 24 genus and 21 families, 20 species were trees, 4 were shrubs, 2 lianas and 1 reed. Twelve species out of 27 are found to be endemic to southern Western Ghats (Ramesh *et al.*, 1997b). Species such as *Elaeocarpus venustus*, *Homalium travancoricum* are vulnerable (Ramesh *et al.*, 1997b) and *Vepris bilocularis* is rare (Ahmedullah and Nayar, 1986). The most common form of sex expression was hermaphroditic (74%), followed by polygamous (11.1%), dioecious (7.4%), monoecious and monogamous (3.7% each). The dominant flower colour was cream (29.6%) followed by white (22.2%), yellow (14.8%), pink (11.1%), brown, red and green (7.4% each). Actinomorphic floral symmetry was (88.9%), followed by zygomorphic (11.1%). The dominant flower shapes were dish and cup-shaped (29.6% each), followed by tubular (22.2%), brush (14.8%) and head (3.7%). Floral scent was mostly imperceptible (37%) followed by pleasant (29.6%), fruity, sweetish and rancid (11.1% each) (Table 1). Floral visitors of 27 plant species were grouped in to 12 functional/taxonomical groups. 40.7% of plants species are visited by beetles followed by flies (37%), bees (33.3%), ants (18.5%), butterflies (14.8%), birds (11%), moths and mosquitoes (7.4% each), cockroach, insect larvae, spider and small insects (<2 mm) (3.7% each) (Table 2).

Beetle

Generally beetles are not considered as an active pollinator. However, in this study, 40.7% of plant species such as *Canthium travancoricum, Diospyros foliolosa, Elaeocarpus venustus, Mimosa pennata, Litsea* sp., *Osbeckia aspera, Vepris bilocularis* and *Zanthophyllum ovalifolium* are visited by beetles belong to the families Cerambycidae, Chrysomelidae, Meloidae and Phalacridae. Corlett (2004) reported that most of the beetles thrive on the trees at canopy level and seems to be arboreal inhabitants, that may be due to the requirement by the beetle for the direct sunlight to raise thoracic temperature for flight. This study reveals that the flowers of *Diospyros foliolosa, Elaeocarpus venustus* (Fig.1f), *Litsea* sp. (Fig.2p) and *Vepris bilocularis* (Fig.2y) are mostly distributed at the canopy level where as species such as *Canthium travancoricum, Mimosa pennata* (Fig.1o), *Osbeckia aspera* (Fig.2s) and *Zanthophyllum ovalifolium* their flowers are completely exposed to direct sunlight even though their flowers are not at canopy level. The flowers visited by beetle were producing odour like fruity, sweetish and pleasant and similar observation was reported by Williams and Adam (1994). The strong emission of odour in beetle-visited plants are due to the elevation of floral/inflorescence temperature that enhance the volatilization of floral odour (Seymour and Schultze-Motel, 1997). In this study, the beetle visited flowers did not exhibit nectar guides and the usual floral colours are creamish, yellow and occasionally white and pink with yellow anthers as in *Elaeocarpus venustus* (Fig.1f) and *Osbeckia aspera* (Fig.2s) (Faegri and van der Pijl, 1979; Yumoto, 1987 & 1988). Beetle associated with plants that offer only pollen as reward and the flowers are usually open (Devi and Davidar, 2003). Though the frequency of visit by beetles are very less (once in 15 – 20 minutes), the mean time spent on each flower varies between 18 sec and more than 5 minutes. More time on a single flower is mostly due to the feeding of anthers, about 62% of beetles are found to be feeding on the floral parts during observation. Similar observations were made on *Shorea megistophylla* in Sri Lanka, Elaterid beetles consuming pollen, Chrysomelid and Scarabaeid feeding on the stamens and corolla (Dayanandan *et al.*, 1990). Corlett, (2004) also reported that pollen and nectar feeding is widespread among beetles.

Fly

In this study, diverse group of flies belong to families such as Calliphoridae, Heleomycidae, Anthericidae, Sciaridae, Syphidae, Tipulidae and Muscidae visits nearly 37% of plant species which includes *Elaeocarpus serratus, Euphorbia santhapaui* (Fig. 1i), *Homalium travancoricum, Litsea* sp. (Fig. 2p), *Olea paniculata* (Fig. 2r), *Symplocos cohinchinensis, Syzygium tamilnadensis* (Fig. 2x), *Viburnum punctatum, Zanthoxylum ovalifolium* and an Unidentified member of the family, Lauraceae (Fig. 2a,b,c). Among fly visited flowers, brush-shaped inflorescence were noted in species such as *Homalium travancoricum, Litsea* sp., Unidentified (Lauraceae), cup-shaped flowers were observed in species such as *Elaeocarpus serratus, Olea paniculata, Symplocos cohinchinensis,*

Syzygium tamilnadensis, Viburnum punctatum and *Zanthoxylum ovalifolium* and disc-shaped flowers in *Euphorbia santhapaui*. Cream, yellow, green and white are the commonly noted floral colours with mostly rancid, imperceptible and occasionally pleasant floral scent were noted among the plant species. Corlett (2004) revealed that most flies are confined to open flowers with exposed nectars because of their short proboscis and many flowers use deceit to attract flies that are normally associated with decaying organic matter. Most plant species shows less frequency of visitors except in Unidentified (Lauraceae), where the frequency is moderate. Species such as *Litsea* sp., *Symplocos cohinchinensis, Syzygium tamilnadensis, Viburnum punctatum* attract *Sciaria* sp. The abundance of *Sciaria sp.* was more in a single inflorescence of *Litsea* sp. was observed. The time spent by this group of flies is more than 5 minutes in a single flower by getting pollen and nectar as floral rewards. This shows that these tree species may be pollinated by the members of Sciaridae. Chaturvedi (1993) also reported that members of one of the two fly families, Sciaridae are involved in the pollination of three *Ceropegia* (Asclepiadaceae) species in the Western Ghats. Flies belong to the family Calliphoridae, Heleomycidae, Muscidae, Syrphidae, Tipulidae were feeding only nectar and their interactions were not much the essential floral parts. Similar observations were also made by Proctor *et al.* (1996); Wikramaratne and Vitarana (1985); Devi *et al.* (1989) and House (1989). Corlett (2004) also reported, mostly fly take liquid foods for which their suctorial mouth parts are adapted. Many species can also suck up small solid particles such as pollen suspended in saliva. The mean time spent by these visitors is mostly less than 5 seconds. This highlights the minimal availability of floral reward from *Elaeocarpus serratus, Euphorbia santhapaui, Homalium travancoricum* and *Zanthoxylum ovalifolium* to these visitors. Aluri (1990) and Bhatia *et al.* (1995) revealed that members of calliphoridae and muscidae are apparently the major pollinators of *Avicennia officinalis* and *Mangifera indica* in Southern India. The flowers of *Olea paniculata* were visited by Tipulidae (Crane fly), (Fig. 2r) in low frequency and the nectar feeding was with the aid of long proboscis. The fly of the same family was also observed as a pollinator of an orchid *Habenaria parviflora* in Southeastern Brazil (Singer, 2001). Based on the observations, the flies are not considered as potential pollinator, although they visit plants in diverse (Endress, 2001).

Bee

Plants such as *Canthium travancoricum* (Fig. 1b), *Diospyros foliolosa* (Fig. 1c), *Erythroxylon obtusifolium* (Fig. 1g), *Hiptage benghalensis, Homalium travancoricum* (Fig. 1n), *Mimosa pennata, Osbeckia aspera, Schefflera wallichiana* (Fig. 2t) and *Vernonia travancorica* (Fig. 2z), are visited by bees such as *Apis dorsata, Apis cerana, Amegilla* sp., *Trigona* sp. and *Xylocopa* sp. belonging to the family Apidae. In this study, the frequency of bees shows greater variation depending upon the species, floral shape and availability of floral reward. *Apis dorsata* was more abundant in *Vernonia travancorica*, confined only to the canopy level, similar observations were made by Kato (1996). Appanah (1990); Devy and Livingstone (2001) reported their preference for canopy tree species from other rainforest sites. Floral rewards of *Vernonia travancorica* was also shared by *Apis cerana* in less number, along with *Apis dorsata*. Devy and Livingstone (2001); Devy and Davidar (2003) observed that *Apis cerana* is an important canopy pollinator with *Apis dorsata* in the rainforests of the Western Ghats. This condition was also observed in peninsular Malaysia (Appanah, 1990), in the rainforest canopy of the Western Ghats, India (Devy and Livingstone, 2001) and in canopy of dipterocarps, Sri Lanka (Dayanandan *et al.*, 1990). The frequency of *Apis dorsata* was very low in *Erythroxylon obtusifolium* when compared to other two species. Mean time spent by *Apis dorsata* on each flower of *Erythroxylon obtusifolium, Mimosa pennata* and *Vernonia travancorica* ranges from 3.6 to 10.8 seconds this is due to the variation in flower size. In this study, preference of pollen by *Apis dorsata* was observed in *Mimosa pennata*, whereas in *Erythroxylon obtusifolium* and *Vernonia travancorica*, the pollen gets deposited on the body surface while the bee feeding nectar pollen (Rasheed and Harder, 1997). Based on their behavioral pattern and their interaction with the flowers, *Apis dorsata* was considered as one of the potential pollinators of these plants. In this study, *Diospyros foliolosa* (Fig. 1c), *Erythroxylon obtusifolium* and *Schefflera wallichiana* (Fig. 2t) were visited by *Apis cerana*. The abundance of this species was greater towards *Diospyros foliolosa* when compared to other two species which is due to the availability of copious amount pollen and nectar as floral reward. Similar observations were also made on the other two species. Mean time spent by *Apis cerana* on each flower ranges from 4.4 second in *Erythroxylon obtusifolium* to maximum of 6.4 seconds in *Schefflera wallichiana*. Corlett (2001) revealed that *Apis cerana* was the numerically dominant visitor to 55% of 83 woody species studied and probably a major pollinator for most of these species.

The stingless bee, *Trigona* sp. was observed as

Table 1

A list of Angiospermic taxa observed in Mundanthurai Range with their ecological properties, floral characters and floral reward.

S. No.	Plant Name	Family	Distribution	Altitude (m)	Habitat	Habit	Flowering Phenology	Floral Symmetry	Sex Expression	Floral Shape	Floral Color	Floral Scent	Floral reward
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	*Acronychia pedunculata* (L.) Miq.	Rutaceae	IM	619	TWEF	T	Dec	Ac	Po	Di	Cream	Fruity	N
2	*Canthium travancoricum* Hook.f.	Rubiaceae	En	330	TDEF	T	Jun	Ac	He	Tu	Cream	Weak pleasant	P&N
3	*Diospyros foliolosa* Wall. ex A. DC	Ebenaceae	En	260	TDEF	T	May & Nov	Ac	Po	Cu	yellow	Sweetish	P & N
4	*Elaeocarpus serratus* L.	Elaeocarpaceae	IM	1100	TWEF & TSEF	T	Aug-Oct	Ac	He	Cu	Brownish red	Rancid	N
5	*Elaeocarpus venustus* Bedd.	Elaeocarpaceae	En	1140	TWEF	T	Dec	Ac	He	Cu	White	Weak pleasant	P
6	*Erythroxylon obtusifolium* (Wight) Walp.	Erythroxylaceae	SI & SL	780	TDEF	ST	Oct	Ac	He	Di	Cream	Imperceptible	P
7	*Euonymous dichotomous* B. Heyne ex Roxb.	Celastraceae	En	440	TWEF	ST	Mar-Aug	Ac	He	Di	Brownish orange	Imperceptible	N
8	*Euphorbia santapaui* A.N. Henry	Euphorbiaceae	En	1156	TWEF	S	May-Sep (Oct)	Ac	Mo	Di	Yellow	Imperceptible	P
9	*Hedyotis purpurascence* Hook.f. var *pallida* Gamble	Rubiaceae	En	1140	TWEF	S	Aug-Nov	Ac	He	Tu	Purple	Pleasant	P
10	*Helicteres isora* Linn.	Sterculiaceae	IM	250	TDEF	S	Sep-Nov	Zy	He	Tu	Red	Weak pleasant	N
11	*Hiptage bengalensis* (L.) Kurz	Malphigiaceae	IM	610	TSEF	L	Mar	Zy	He	Cu	White	Rancid	P
12	*Homalium travancoricum* Bedd.	Flacourtiaceae	En	260	TWEF	T	Jan	Ac	He	Br	Cream	Rancid	P
13	*Mimosa pennata* (L.) Willd.	Mimosaceae	IM	280	TDEF	L	Nov-Apr (Sep)	Ac	Po	He	Cream	Weak pleasant	P
14	*Litsea* sp.	Lauraceae	-	1180	TWEF	T	Oct	Ac	He	Br	Yellow	Imperceptible	P
15	*Ochlandra travancorica* (Bedd.) Benth. ex Gamble	Poaceae	En	1140	TWEF	R	Dec	Ac	He	Di	Green	Imperceptible	P
16	*Olea paniculata* R. Br.	Oleaceae	IM	1140	TWEF & TSEF	T	Aug	Ac	He	Tu	White	Pleasant	N
17	*Osbeckia aspera* (L.) Blume	Melastomataceae	SI & SL	320	TDEF	S	Apr-Aug (Jan)	Ac	He	Di	Purple	Imperceptible	P
18	*Schefflera wallichiana* (Wight & Arn.) Harms.	Araliaceae	SI & SL	640	TWEF	T	Feb-Jun (Oct)	Ac	He	Di	Brownish	Imperceptible	P & N
19	*Spathodea campanulata* P. Beauv.	Bignonaceae	WA	950	TWEF	T	Oct-Dec	Zy	He	Tu	Red	Weak pleasant	N
20	*Symplocos cochinchinensis* (L.our.) Moore	Symplocaceae	IM	1140	TWEF	T	Oct-May	Ac	He	Di	White	Imperceptible	N
21	*Syzygium mundagam* (Bourd.) Chitra	Myrtaceae	En	400	TWEF	T	Apr-Aug (Sep)	Ac	He	Br	White	Weak pleasant	P
22	*Syzygium tamilnadensis* Rathakr. & Chitra	Myrtaceae	En	1060	TWEF	T	Oct	Ac	He	Cu	Cream	Imperceptible	P&N
23	*Vepris bilocularis* Engl.	Rutaceae	En	619	TWEF	T	Jan-Apr (Jun)	Ac	Di	Cu	Cream	Fruity	N
24	*Vernonia travancorica* Hook.f.	Asteraceae	En	1234	HASF	T	Dec-Feb	Ac	Ho	Tu	Pink	Sweetish	P&N

Contd....

1	2	3	4	5	6	7	8	9	10	11	12	13	14
25	*Viburnum punctatum* Buch.-Ham. ex D. Don	Caprifoliaceae	IM	1180	HASF	T	Oct	Ac	He	Cu	White	Sweetish	P&N
26	*Zanthoxylum ovalifoilium* Wight	Rutaceae	IM	1140	TWEF	T	Dec	Ac	Di	Cu	Cream	Fruity	N
27	Unidentified	Lauraceae	-	1140	TWEF	T	Oct	Ac	He	Br	yellow	Imperceptible	N

Distribution: Endemic (En), Indomalaysia (IM), South India & Sri Lanka (SI & SL) Habitat: Tropical Dry Evergreen Forest (TDEF), Tropical Wet Evergreen Forest (TWEF), Tropical Semi Evergreen Forest (TSEF), High Altitude Shola Forest (HASF); Habit: Tree (T), Small Tree (ST), Shrub (S), Liana (L), Reed (R); Floral Symmetry: Actinomorphic (Ac), Zygomorphic (Zy); Sex Expression: Dioecious (Di), Monoecious (Mo), Hermaphrodite (Hr), Polygamous (Po), Homogamous (Ho); Floral Shape: Brush (Br), Cup (Cu), Disc (Di), Head (He), Tubular (Tu), Floral Reward: Pollen (P), Nectar (N).

Table 2

A list of Angiospermic taxa observed with their recorded flower visitors (from most abundant to least), their time duration in a flower, numbers of observed visits of flower visitors sorted by functional group, and estimated pollinator type.

S. No.	Plant Name	Recorded flower visitor	Functional Group	(1)	(2)	(3)	(4)	(5)
1	2	3	4	5	6	7	8	9
1	*Acronychia pedunculata* (L.) Miq.	Formicidae (*Crematogaster* sp)	Ant	+	10.2 ± 0.51	2.6 (Low)		VI
2	*Canthium travancoricum* Hook.f.	Apidae (*Apis cerana*)	Bee	+		6 ± 0.24	5 (Moderate)	PO
		Apidae (*Xylocopa* sp.)	Bee	+		5.6 ±0.22	2.3 (Low)	PO
		Cerambicidae	Beetle	+	2 min 43 sec		0.3 (Low)	PR
		Papilionidae (*Graphium doson*)	Butterfly	+		3.8 ±0.16	6.3 (Moderate)	PO
3	*Diospyros foliolosa* Wall. ex A. DC	Apidae (*Apis cerana*)	Bee	+++		5.8 ±0.38	20.6 (High)	PO
		Apidae (*Amegilla* sp.)	Bee	+		1.8 ±0.16	4 (Low)	PO
		Hesperiidae (*Hasora chromus*)	Butterfly	++		10.2 ±0.26	7.6 (Moderate)	PO
		Chrysomelidae	Beetle	+	1 min 32 sec		0.3 (Low)	VI
		Formicidae	Ant	+		70.8 ±0.47	1.6 (Low)	VI
		Salticidae	Spider	+	12 sec		0.3 (Low)	VI
			Larva	++	5 min		1 (Low)	PR
4	*Elaeocarpus serratus* L.	Calliphoridae	Fly	+++		2.6 ±0.10	9.3 (Moderate)	PO
5	*Elaeocarpus venustus* Bedd.	Phalacridae	Beetle	+	5 min		0.3 (Low)	PO & PR
6	*Erythroxylon obtusifolium* (Wight.) Walp.	Apidae (*Apis dorsata*)	Bee	++		3.6 ±0.22	4 (Low)	PO
		Apidae (*Apis cerana*)	Bee	+		4.4 ±0.22	1.6 (Low)	PO
7	*Euonymous dichotomous* B. Heyne ex Roxb.		Unid	+	3 min 29 sec		0.3 (Low)	VI
8	*Euphorbia santapaui* A.N. Henry	Formicidae	Ant	++		19.8 ±0.55	7.3 (Moderate)	PO
		Syrphidae	Fly	+		3.2 ±0.26	4.3 (Low)	PO
9	*Hedyotis purpurascence* Hook.f. var *pallida* Gamble	Phalacridae	Beetle	+		92.6 ±0.67	2 (Low)	PO & PR
10	*Helicteres isora* L.	Dicruridae (*Dicrurus* sp.)	Bird	++		4.4 ±0.22	5.3 (Moderate)	PO
		Sturnidae (*Sturnus malabaricus*)	Bird	++		3.6 ±0.22	2 (Low)	PO
11	*Hiptage bengalensis* (L.) Kurz	Blattodea	Cockroach	+++		70.8 ±0.74	5.3 (Moderate)	PO & PR
		Apidae (*Trigona* sp.)	Bee	++		4.4 ±0.22	4.6 (Low)	PO
12	*Homalium travancoricum* Bedd.	Apidae (*Trigona* sp.)	Bee	++		5.4 ±0.22	6.3 (Moderate)	PO
		Calliphoridae	Fly	+++		2 ±0.14	4.3 (Low)	PO
		Syrphidae	Fly	++		2.2 ±0.16	3.6 (Low)	PO
13	*Mimosa pennata* (L.) Willd.	Apidae (*Apis dorsata*)	Bee	++		13.4 ±0.60	7.6 (Moderate)	PO
		Meloidae (*Mylabris* sp.)	Beetle	+	2 min 34 sec		0.3 (Low)	PO & PR
		Nymphalidae (*Euploea core*)	Butterfly	++		11 ±0.54	3 (Low)	PO

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1	2	3	4	5	6	7	8	9
14	*Litsea* sp.	Sciaridae (*Sciaria* sp.)	Fly	+++	5 min		1 (Low)	PO
		Phalacridae	Beetle	+	5 min		0.3 (Low)	PO
15	*Ochlandra travancorica* (Bedd.) Benth. ex Gamble	Crambidae	Moth	+	4 min 41 sec		0.3 (Low)	VI
16	*Olea paniculata* R.Br.	Tipulidae	Fly	++		14.2 ±0.38	3.6 (Low)	VI
17	*Osbeckia aspera* Blume	Apidae (*Xylocopa* sp.)	Bee	+		6.2 ±0.29	2.3 (Low)	PO
		Chrysomelidae	Beetle	+	5 min		0.3 (Low)	PR
18	*Schefflera wallichiana* (Wight. & Arn.) Harms.	Apidae (*Apis cerana*)	Bee	+++		6.4 ±0.22	10 (Moderate)	PO
		Zosteropidae (*Zosterops palpebrosus*)	Bird	+++		3 ±0.14	6 (Moderate)	PO & PR
19	*Spathodea campanulata* P. Beauv.	Pycnonotidae (*Pycnonotus* sp.)	Bird	+++		3.4 ±0.22	6.6 (Moderate)	PO
20	*Symplocos cochinchinensis* (Lour.) Moore	Sciariidae (*Sciaria* sp.)	Fly	++		10.8 ±0.47	4 (Low)	PO
21	*Syzygium mundagam* (Bourd.) Chitra		Beetle	+		26.8 ±0.93	1.6 (Low)	PO
		Nymphalidae (*Tirumala limniace*)	Butterfly	++		10 ±0.44	2.6 (Low)	PO
		Arctiidae (*Amata* sp.)	Moth	++		29.6 ±0.22	2 (Low)	PO
22	*Syzygium tamilnadensis* Rathakr. & Chitra	Sciaridae (*Sciaria* sp.)	Fly	+		16.6 ±0.38	2.6 (Low)	PO
		Chrysomelidae	Beetle	++		20.4 ±0.57	2 (Low)	PO
23	*Vepris bilocularis* Engl.	Chrysomelidae	Beetle	+	2 min 18 sec		0.3 (Low)	PO
		Formicidae (*Crematogaster sp.*)	Ant	+		9.8 ±0.55	2.6 (Low)	VI
24	*Vernonia travancorica* Hook.f.	Apidae (*Apis dorsata*)	Bee	+++		10.8 ±0.65	6.6 (Moderate)	PO
		Apidae (*Apis cerana*)	Bee	++		5.6 ±0.22	3.6 (Low)	PO
25	*Viburnum punctatum* Ham ex D. Don	Formicidae	Ant	+		8.2 ±0.38	2.3 (Low)	PO
		Sciaridae (*Sciaria sp.*)	Fly	++		20.6 ±0.57	2.3 (Low)	PO
26	*Zanthoxylum ovalifoilium* Wight	Phalacridae	Beetle	+	18 sec.		0.3 (Low)	VI
		Muscidae	Fly	++		3.4 ±0.22	2.6 (Low)	PO
		Cullicidae	Mosquito	+		9.4 ±0.64	3.3 (Low)	VI
27	Unidentified (Lauraceae)	Culicidae	Mosquito	+++		10.8 ±0.47	9.3 (Moderate)	VI
		Calliphoridae	Fly	++		4.2 ±0.26	5 (Moderate)	PO
		Heleomycidae (*Suillia* sp.)	Fly	++		2.8 ±0.16	2.3 (Low)	PO
		Athericidae	Fly	+		4.4 ±0.22	3 (Low)	PO

1: Abundance of visitor in a flowering branch: + :< 10, ++: between 10 & 30, +++ : >30; 2: Time duration of a visitor in a flower (in min.); 3: Mean time duration of a visitor in a flower (in Sec.) ± SE; 4: Mean Frequency of floral visitor every 5 minutes: Low - < 5, Moderate – 5 to 10, High - >10; 5: Pollinator (PO)/ Predator (PR)/ Visitor (VI)

the most common visitor of *Hiptage bengalensis* and *Homalium travancoricum* (Fig. 1n), the mean time spent by *Trigona* sp. in *Hiptage benghalensis* is 4.4 seconds and in *Homalium travancoricum* is 5.4 seconds. The flowers are mostly open and the floral rewards are in ease access to *Trigona* sp., which was collecting pollen as well as nectar as their reward. Most of the flowers pollinated by these bees are small and disc-shaped, with unprotected nectar (Inoue *et al.*, 1990; Momose *et al.*, 1998a). *Trigona* species was the major pollinator for one of the four dominant dipterocarp species, *Shorea siamensis* in dry deciduous dipterocarpus forests of Thailand (Ghazoul and McLeish, 2001). A species of *Xylocopa* was observed collecting pollen alone from *Canthium travancoricum* and *Osbeckia pennata*, where the mean time spent by these solitary bees are 5.6 sec and 6.2 sec respectively. This support the findings of Michener (2000) stating that solitary bees are often specialist for pollen but rarely for nectar. Several observations were made that *Xylocopa* has the ability to extract pollen from porose anthers by 'buzzing' (Gross, 1993; Murali, 1993; Endress, 1997) from the species of *Melastoma* (Gross, 1993), *Dillenia* (Endress, 1997), *Cassia* (Murali, 1993) and from non-porose anthers of *Peltophorum pterocarpum* (Aluri and Reddi, 1996). *Amegilla* sp. is another solitary bee, usually very active and the only bee visitor that spent least time (1.8 seconds) to collect floral rewards from *Diospyros foliolosa*. Based on the observations, flowers visited by bees provide both nectar and pollen as reward in copious amount and all the bee species are considered as pollinators to their respective plant species.

Ant

Flowers of *Acronychia pedunculata, Diospyros foliolosa, Euphorbia santapaui* (Fig. 1i), *Vepris bilocularis* and *Viburnum punctatum* are visited by ants belonging to the family Formicidae. The frequency of the visitor is low in *Acronychia pedunculata, Diospyros foliolosa, Vepris bilocularis* and *Viburnum punctatum* whereas it is moderate in *Euphorbia santapaui*. The mean time spent in the flowers of *Acronychia pedunculata* (10.2 seconds), *Diospyros foliolosa* (7.2 seconds) and *Vepris bilocularis* (9.8 seconds) are less, therefore ants are not considered as potential pollinators. Usually ants visit these flowers for nectar and their interactions are in such a way that there is no contact established between the visitor and the reproductive parts. Though these ants appear to be pollinators, they are more properly classified as 'nectar thieves' (Inouye, 1980), because their small bodies can reach the nectar of most flowers without touching the anther at all (Barth, 1985). In *Euphorbia santhapaui* (19.8 seconds) and *Viburnum punctatum* (18 seconds), the mean time spent on each flower is more. The floral blossoms are usually open type and the floral rewards are easily accessible by these visitors. The deposition of pollen on the body surface of these visitors was also observed which indicates that these visitors could be potential pollinators. Reddi and Reddi (1984) also reported the contribution of Formicidae member, *Camponotus* in the pollination of herb, *Euphorbia geniculata* in India.

Butterfly

Butterflies are usual visitors of open or tubular flowers but their role in the pollination are rarely studied in India (Balasubramanian, 1989; Devy and Davidar, 2003). In this study, *Canthium travancoricum, Diospyros foliolosa, Mimosa pennata* and *Syzygium mundagam*, were visited by butterflies such as *Graphium doson* (Common Jay) (Fig. 1a), *Hasora chromus* (Common Banded Awl) (Fig. 1d), *Tirumala limniace* (Blue Tiger) (Fig. 2w) and *Euplea core* (Common Crow) belonging to three families Hesperiidae, Nymphalidae and Papilionidae were observed. Hawkeswood (1985) and Appanah (1990) reported that the species of *Acacia* (Mimosaceae) and *Syzygium* are visited by butterflies of the family Nymphalidae. The flowers of *Canthium travancoricum* and *Diospyros foliolosa* are tubular and cup-shaped whereas the inflorescence/flowers of *Mimosa pennata* and *Syzygium mundagam* are open brush-shaped. Nectar was most conspicuous in all these flowers confined to the base, around stigma. Nectar provides water, sugar and amino acids for adult butterflies (Boggs, 1987). Hence, nectar is the major floral reward provided to the above mentioned visitors. Although the frequency of these visitors was less and moderate, the mean time spent by these visitors greatly varies depending upon the flower shape as well as the availability of nectar. For instance, in tubular flowers of *Canthium travancoricum* (3.8 seconds), in head inflorescence of *Mimosa pennata* (10 seconds), in cup shaped flowers of *Diospyros foliolosa* (10.2 seconds) and in brush-shaped flowers of *Syzygium mundagam* (11 seconds). Based on their interactions, these visitors are considered as one of the pollinators of *Canthium travancoricum, Diospyros foliolosa, Mimosa pennata* and *Syzygium mundagam*. Devy and Davidar (2003) also reported that butterflies visit many flowers and are considered major pollinators of 4 woody species in the mid-elevation rainforest of the Western Ghats, India.

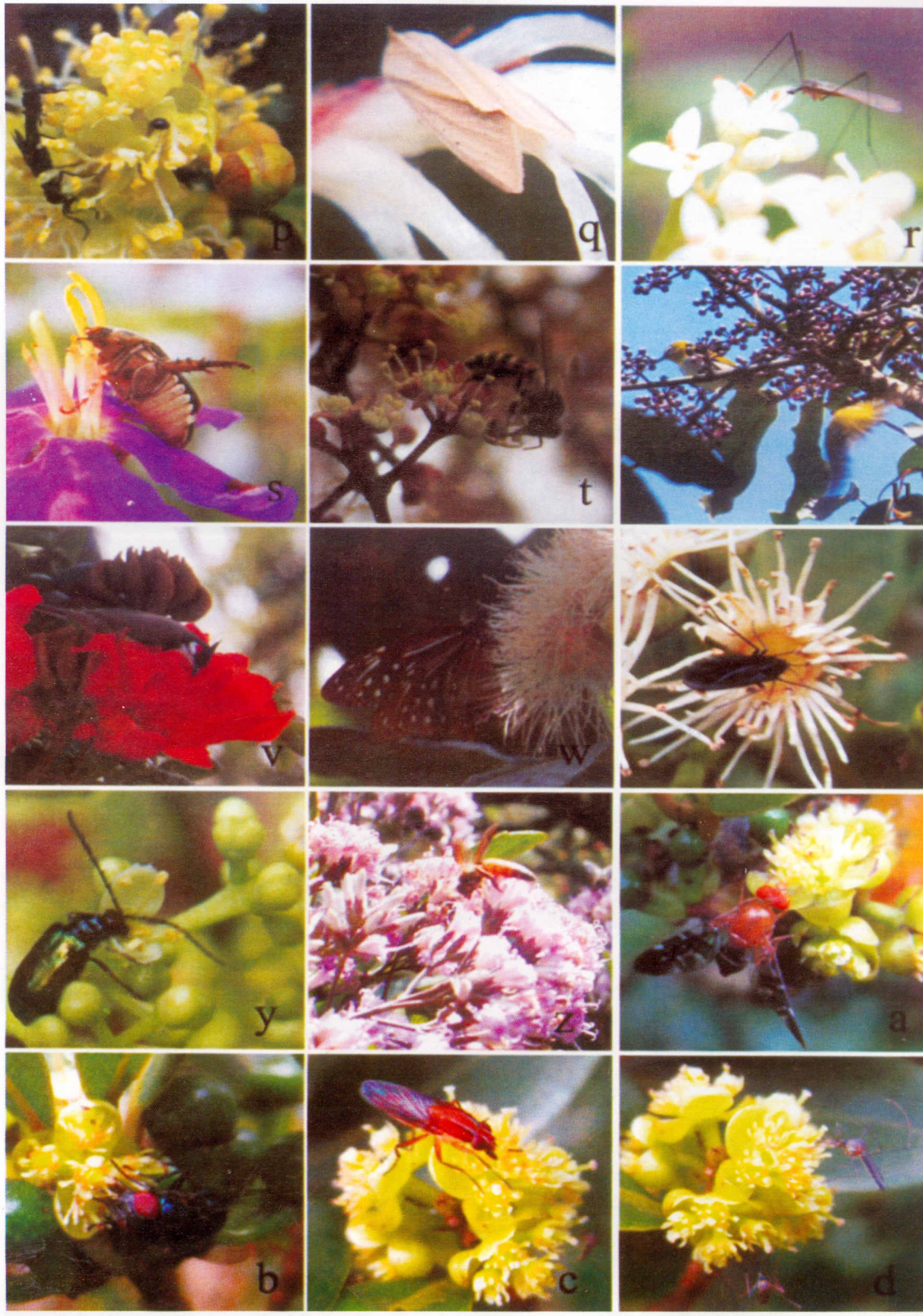
Bird

Flowers of *Helicteres isora* were visited by

Fig. 1

Floral visitors of flowers observed at Mundanthurai Range (a) *Canthium travancoricum* visited by a papilionid butterfly, Graphium doson (b) *Canthium travancoricum* visited by *Xylocopa* sp. (c) *Diospyros foliolosa* visited by *Apis cerana* (d) *Diospyros foliolosa* visited by a *hesperid* butterfly, *Hasora chromus* (e) An unidentified larva feeding on the floral parts of *Diospyros foliolosa* (f) *Elaeocarpus venustus* visited by a *phalacrid* beetle (g) *Erythroxylon obtusifolium* visited by *Apis dorsata* (h) *Euonymus dichotomous* visited by an unidentified insect (i) *Euphorbia santapaui* visited by a formicid ant (j) *Euphorbia santapaui* visited by a syrphid fly (k) *Hedyotis purpurascence* visited by a phalacrid beetle (l) *Helicteres isora* visited by a black drongo, *Dicrurus* sp. (m) *Hiptage bengalensis* visited by a cockroach (n) *Homalium travancoricum* visited by *Trigona* sp. (o) *Mimosa pennata* visited by a meloid beetle, *Mylabris* sp.

Fig. 2



Floral visitors of flowers observed at Mundanthurai Range (p) Litsea sp. visited by a sciarid fly (Sciaria sp.) and a phalacrid beetle (q) Ochlandra travancorica visited by a crambid moth (r) Olea paniculata visited by a tipulid fly (s) a chrysomelid beetle feeding the anther of Osbeckia aspera (t) Schefflera wallichiana visited by Apis cerana (u) Schefflera wallichiana visited by an oriental white-eye, Zosterops palpebrosus (v) Spathodea campanulata visited by a red whiskered bulbul, Pycnonotus sp. (w) Syzygium mundagam visited by a nymphalid butterfly, Tirumala limniace (x) Syzygium tamilnadensis visited by a sciarid fly, Sciaria sp. (y) Vepris bilocularis visited by a chrysomelid beetle (z) Vernonia travancorica visited by Apis dorsata (a - d) An unidentified species of Lauraceae visited by an athericid fly, calliphorid fly, a heleomycid fly, (Suillia sp.) and mosquitoes.

Dicrurus sp. (Drongo) (Fig. 1l) and an endemic bird species *Sturnus malabaricus* (Chestnut-tailed Starling). The flowers of *Schefflera wallichiana* are visited by *Zosterops palpebrosus* subsp. *nilgiriensis* (Oriental White-eye) (Fig. 2u) and the flowers of *Spathodea campanulata* are visited by *Pycnonotus jocosus* (Red whiskered Bulbul) (Fig. 2v). Based on the observations all these three flowers are rich in nectar as well as pollen. Unlike *Helicteres isora*, the flowers of *Spathodea campanulata* and *Schefflera wallichiana* are at the canopy level. The flowers of *Helicteres isora* and *Spathodea campanulata* are bright red in colour, tubular in shape with wide floral tube whereas the flowers of *Schefflera wallichiana* are open disc-shaped and brownish red in colour. Faegri and van der Pijl (1979) reported that bird pollinated flowers are varied in form and include the brush, gullet and tubular types as well as some flag blossoms of the Fabaceae. They produce large volumes of nectar and often bright red in colour with wider floral tube. Corlett (2004) predicted that nectar feeding seems to be more widespread in the families such as Corvidae (particularly, *Corvus, Dicrurus* and *Oriolus*) and Sturnidae (many genera) and among babblers (Sylviidae-Timaliini, many genera). In this study, all the bird species obtained nectar as major floral reward. The frequency of *Dicrurus* sp. and *Pycnonotus jocosus* are high in *Helicteres isora* and *Spathodea campanulata* whereas the frequency of *Sturnus malabaricus* and *Zosterops palpebrosus* are low in *Helicteres isora* and *Schefflera wallichiana*. The mean time spent in flower by all these visitors are less than 5 seconds. Based on the observations; *Zosterops palpebrosus* visit the flowers when the ambient is sunny and leave the flower when it is cloudy. Roberts (1992) and Steinheimer (1999) reported that the members of Zosteropidae visit flowers throughout the oriental region and some species have brush-shaped tongues but their short bills preclude legitimate access to the nectar in long-tubed flowers which they tend to rob. Ali and Ripley (1999) reported though the white-eye 'largely responsible for cross pollinating a wide variety of flowers' they seem to be much less important in most of the regions than the more nectarivorous, long-billed sunbirds. In this study, the flowers of *Schefflera wallichiana* are open with exposed nectar that enables *Zosterops palpebrosus* to gain easy access to the floral reward. Based on the behavior as well as the interaction with the flower, this bird may be one of the potential pollinators of *Schefflera wallichiana*. Santharam (1996) reported that the jungle babbler (*Turdoides striatus*) was the main pollinator among many avian visitors to *Helicteres isora*, in degraded forests in the Western Ghats. In this study, discolouration of forehead by pollen deposition was noted on the forehead of *Dicrurus* sp. while visiting *Helicteres isora* which indicate that *Dicrurus* sp. is one of the potential pollinators of *Helicteres isora*. Discolouration of forehead due to pollen deposition was also widely reported in various species (Roberts, 1992; Steinheimer, 1999).

Moth

A diurnal moth species *Amata* (Arctiidae) was observed to be visiting the flowers of *Syzygium mundagam* and a member of Crambidae visiting the flowers of *Ochlandra travancorica* (Fig. 2q). *Amata* sp. was observed to be feeding nectar from the brush-shaped blossoms of *Syzygium mundagam* in low frequency and the mean time spent by these visitors in a flower was 29.6 seconds. Similar observations were made by Hopper (1980) in *Syzygium tierneyanum* from the subtropical lowland littoral rainforests of Kuranda, Northern Queensland. Based on their interactions, this species is considered to be one of the potential pollinators of *Syzygium mundagam*. The frequency of Crambidae in *Ochlandra travancorica* was low and the mean time spent on the flower was 4 minutes and 41 seconds. Though this moth spent much time in the flower, it never shows any symptoms of interaction with the flower. Hence this insect was just considered as the visitor and not the pollinator.

Cockroach

A member of Blattodea was observed visiting the flowers of *Hiptage benghalensis* (Fig. 1m). Presence of Cockroach was also noted in *Uvaria elmeri* (Annonaceae) (Nagamitsu and Inoue, 1997), on the male and female heads of *Artocarpus odoratissimus* in Sarawak (Momose *et al.*, 1998a, b) and in the flowers of *Clusia sellowiana* (Clusiaceae) from French Guiana (Vlasa´kova´ *et al.*, 2008). The flowers of *Hiptage benghalensis* are white, zygomorphic and producing mild rancid odour. Floral scent is one of the factors that attract these visitors which are also reported by Nagamitsu and Inoue (1997); Momose *et al.* (1998a, b) and Vlasa´kova´ *et al.* (2008). The abundance of visitor per inflorescence was usually more than 2 individuals. Although the frequency of this visitor was moderate, the mean time spent by each visitor in a single flower is 63.4 seconds by feeding anthers along with pollen. Corlett (2004) reported cockroach feed on stigmatic exudates and the anthers and some cockroaches carried pollen on their head. Based on the deposition of pollen on the abdomen while feeding as well as its contact with the stigma of the flower, cockroach may considered as one of the pollinators of *Hiptage benghalensis*.

Mosquito

Flowers of *Zanthoxylum ovalifolium* and an

unidentified Lauraceae member (Fig. 2d) were visited by mosquitoes belonging to the family Culicidae. Abundance of mosquitoes per inflorescence was more in unidentified (Lauraceae), whereas the frequency was moderate in both the plant species. The flowers of unidentified (Lauraceae) and *Zanthoxylum ovalifolium* are usually open, dull-coloured, and with nectar secreting. The visiors are completely depended on the floral nectar as their reward. Mean time spent by these visitors is between 9.4 and 14.2 seconds depending upon the availability of nectar. Based on their behaviour, these visitors are not considered as potential pollinators. Inouye (2010) reported that mosquitoes are stealing nectar without acting as pollinator based on the mismatch between their morphology and most flowers. Though not many reports on mosquitoes are available as pollinators, in *Habenaria obtusta* (Orchidaceae), mosquitoes are reported as pollinators (Thien, 1969).

In this study, other visitors were also observed that include insect larvae (Fig. 1e), feeding floral parts, spider belongs to the family Salticidae on *Diospyros foliolosa* and small insects (Fig. 1h) which are less than 2 mm in length visiting on *Euonymus dichotomous* camouflaging floral colour were also observed spending more time on these flowers. These are simply visitors and not considered as pollinators since they did not have any contact with the essential floral parts.

Conclusion

This study signifies that most of the high altitude tree species posses dull-coloured flowers and are not specialized in their floral structure. Although the diversity of fly was more among the floral visitors, bees are considered to be the potential pollinators for most of the tree species. The beetles as well as cockroach visited flowers are found to be rich in pollen as reward that is mostly utilized for their consumption. Bird visited flowers are mostly brightly coloured with wide open corolla tube and offer enormous quantity of nectar as reward. Most of the plant species in this study support diverse floral visitors such as mosquitoes, moths, ants, spiders, etc. although these visitors associated with the flower they are not considered as effective pollinators. Hence, studies like this are most essential in understanding the complexity, interaction as well as the influence of diverse life forms with plant community and the distribution of rare as well as endemic plant species in the forests.

Acknowledgements

The authors thank Mr. R. Sundararaju, IFS, Principal Chief Conservator of Forests and Chief Wildlife Warden, Mr. D. Venkatesh, Deputy Director, Ambasamuthram Range, Tamil Nadu Forest Department, for providing permit to carry out this research project in the Tiger Reserve, Dr. R. Raveen, Assistant Professor, Department of Zoology, Madras Christian College, Chennai, for identification of floral visitors and Dr. S. Ravi Shankar and Dr. W. Arisdason, Assistant Professors, Department of Plant Biology and Plant Biotechnology, Madras Christian College, Chennai, for their suggestions in manuscript preparation. The Principal and Head, Department of Plant Biology and Plant Biotechnology, St. John's College, Palayamkottai are also thanked for their support.

SUMMARY

Diurnal floral visitors of 27 woody Angiosperms were observed from Kalakad Mundanthurai Tiger Reserve (KMTR), Southern Western Ghats, Tirunelveli District, between 2008 and 2010. The foraging profiles of floral visitors as well as the flower characters were analysed. It was found that although visitor profiles were sometimes consistent with classic pollination syndromes, these syndromes were unreliable predictors of floral visitors. The majority of flowering plants was unspecialized in their morphology, and consequently hosted a diverse array of visitors. Bees being the potential pollinators visited species with purple or pink flowers that are not strictly confirm to the melittophilous syndrome. Bright coloured, tubular flowers were associated with birds, with more accessible nectar. Ants were noted as nectar thieves in some plants. Altitude was a major factor in determining visitors, with flies being the most abundant visitors of many plant species, while others received very few potential pollen vectors.

Keywords: KMTR, Trees, Floral Reward, Floral Visitor, Pollinator

कालक्काड़ मुण्डन थुरई बाघ संरक्षित क्षेत्र, दक्षिण पश्चिमी घाट प्रदेश, भारत के कुछ चुनी हुई संवृत बीज जातियों की पुष्प विशेषताओं और उनके पुष्प- आगन्तुकों के मध्य का सम्बन्ध

पी॰ सेल्वा सिंह रिचर्ड, एस॰ अब्राहम मुथुकुमार व एच॰ मल्लेशप्पा

सारांश

कालक्काड मुण्डनथुरई बाघ संरक्षित क्षेत्र दक्षिण पश्चिमी घाट प्रदेश, जिला तिरूनेलवेल्लि में 27 काष्ठीय संवृत्त बीजाओं पर दिन में आने वाले प्राणियों का 2008 और 2010 में प्रेक्षण किया गया। फूलों से चारा ग्रहण करने वाले आगन्तुकों के पार्श्वचित्र और पुष्पों की विशेषताओं का विश्लेषण किया गया। देखा यह गया कि यद्यपि आगन्तुकों के पार्श्वचित्र कभी-कभी शास्त्रसम्मत परागण प्रणाली से मेल खाने वाले रहे, किन्तु ये प्रणालियां पुष्पीय आगन्तुकों के अविश्वसनीय

पूर्वसूचक ही निकली। पुष्प पादपों का अधिकांश भाग अपनी रचनाकारिकी में अविशिष्ट था और परिणामत: वह अनेक तरह के आगन्तुकों को प्रश्रय देता था। मक्खियां संभावी परागणकर्ता होने के कारण बैंगनी या हल्के गुलाती रंग वाली पादप जातियों पर जाती थी जो कठोरत: मक्षिका प्रिय प्रणाली से मेल नहीं खाते। चटक रंग वाले नलीदार फूल पक्षियों से जुड़ते हैं जिनका मकरन्द ज्यादा प्राप्य किस्म का होता है। चीटियों को कुछ पादपों की मकरकन्द चोर कहा जाता है। आगन्तुकों को विनिश्चित करने में ऊंचाई एक मुख्य कारक रहता है और मक्खियां बहुत सारे पादपों की सर्वाधिक प्रचुर आगन्तुकाएं रहती है जबकि अन्य बहुत कम संभावी पराग संवाहक प्राप्त कर पाते हैं।

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