

Flower traits of plant species and floral resource users in tropical dry evergreen forest on Coromandel Coast of India

K. ANIL & N. PARTHASARATHY*

*Department of Ecology and Environmental Sciences, Pondicherry University,
Puducherry 605014, India*

Abstract: We investigated flower traits and floral resource users of 110 plant species in tropical dry evergreen forest (TDEF) on the Coromandel Coast of India. The plant species offered various floral resources (nectar, pollen and floral tissue) to 54 faunal species. Bees were the predominant users of 78% of plant species, followed by butterflies (40% species) and thrips (30% species). The use of floral resource by faunal species was related to one or more flower traits such as size, shape, position, colour, scent, stamen position and blooming time. Among 45 plant families, sixteen families attracted more than three faunal groups each. The co-occurrence of floral resource users was also evident from the highest values of co-occurrence of flies and butterflies on the flowers of a given species. In bee-utilising flowers, *Apis florea* utilised 63% of plant species followed by *Trigone iridipennis* (52% species) and *Apis indica* (32% species). The diversity of floral traits among the plants and dependency of specific faunal groups on them underline the importance of maintaining the highly specialized yet complex relationship between the two for conservation of the tropical dry evergreen forest.

Key words: Floral resource users, flower traits, life-forms, tropical dry evergreen forest.

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Introduction

The biotic community of tropical forests are species rich and complex in their structural organisation and functional ecology. Dependence of faunal species on flower resources of plant species in the forest and *vice-versa* for pollination add to the species richness and complexity of biotic interaction in the forest community which eventually influence functioning of the ecosystem. Flower traits attract some flower visitor species and at the same time act as barrier or even defences preventing the visit of certain other faunal species (Galen *et al.* 2011; Junker 2012). Floral characters such as colour, shape and size play an important role in floral visitation and

pollination (Levin 1968; Waser & Price 1983). In tropical forests, community-level studies describing the relationship between flower traits and visitation types have been reported from the Neotropics (Bawa *et al.* 1985; Kress & Beach 1994), and Asia (Appanah 1993; Momose *et al.* 1998a). In India, some studies have focused on the mode of pollination in species of the wet evergreen forests of the Western Ghats (Devay & Davidar 2003, 2006) and dry forests of the Eastern Ghats (Aluri 1990).

Research on plant biodiversity and ecology (Parthasarathy *et al.* 2008), reproductive traits and flowering phenology (Selwyn & Parthasarathy 2006), fruiting phenology (Selwyn & Parthasarathy 2007) and the sexual and breeding systems of 13

*Corresponding Author; e-mail: parthapu@yahoo.com

common plant species (Nayak & Davidar 2010) of tropical dry evergreen forest (TDEF) have been carried out in the past leaving a gap in community-level plant resource use by faunal community. Therefore, in this study we examined flower traits of plant species and their use by different faunal groups as a resource in TDEF communities on the Coromandel Coast of peninsular India. We focussed on documenting major floral resource users and examining the relationship between flower traits of plant species and floral resource users in the community.

Materials and methods

Study area

This study was conducted in tropical dry evergreen forest located in Villupuram (11°56'N, 79°53'E) and Cuddalore (11°43'N, 79°49'E) districts of Tamil Nadu on the Coromandel Coast of peninsular India. Field surveys were conducted for flower visitors at nine sites of tropical dry evergreen forest (TDEF) on the Coromandel Coast. We selected a total of nine tropical dry evergreen forest sites, as to cover all woody plant species of TDEF. Site Puthupet (PP- 12°03'N, 79°52'E), Oorani (OR- 12°09'N, 79°52'E) and Vada Agaram (VA- 72°10'N, 79°55'E) are located respectively 15, 28 and 32 km north of Puducherry (11°56'N, 79°53'E) and six other sites Kuzhandhai-kuppam (KK- 11°43'N, 79°38'E), Thirumanikkuzhi (TM- 11°43'N, 79°41'E), Suriyanpet (SR- 11°44' N, 79°38' E), Sendhirakillai (SK- 11°30'N, 79°41'E), Palvathunnan (PT-11°32'N, 79°41'E) and Kothattai (KT- 11°30'N, 79°42'E) are located around 45 to 50 km south of Puducherry. The forest area of each study site ranged from 1.2 ha to 10 ha. The climate data of the nine sites revealed a mean annual temperature of 28.3 °C and a mean annual rainfall of 1,171 mm (www.worldclim.com). The mean number of rainy days in an annual cycle is 55.5. The bulk of the rainfall is received during October–December. Soils are red ferralitic belonging to the Cuddalore sandstone formation of the Miocene period (Meher-Homji 1974). The vegetation of the area is closed-canopy, 2–3 layered tropical dry evergreen forest rich in lianas (Champion & Seth 1968; Mani & Parthasarathy 2006; Parthasarathy *et al.* 2008). The canopy is about 10–12 m in height, dominated by large trees of *Pterospermum canescens* and *Lannea coromandelica*. The sub-canopy is composed of smaller trees of *Memecylon umbellatum*, *Canthium dicoccum* and *Garcinia spicata*. Major

lianas included *Strychnos lenticellata*, *Combretum albidum*, *Reissantia indica*, *Pyrenacantha volubilis* and *Capparis zeylanica*. The major native perennial herbs present in the forest were *Ecbolium viride* and *Sansevieria roxburghiana* (Parthasarathy *et al.* 2008).

Data collection and analysis

Flower traits of 110 plant species (60 trees, 45 lianas and 5 herbs) and their flower resource users were studied from August 2012 to July 2014 covering flowering stages of all the plant species of TDEF. Two to four individuals of rare and sub-dominant species and up to 10 individuals of common and dominant species were observed to record flower traits and visiting faunal species using a binocular and captured in camera. Observations were conducted for 8–9 hours over three-day period during peak flowering time. The total number of visits of each floral resource user was noted during two intervals of 15 minutes during three days of the study period (6.30–18.30). In addition to these regular observations, three days of observations were made throughout the night (18.30–6.30) in order to determine the visitors of night blooming flowers. The number of floral resource users of each plant species was noted during the study period. Flower traits studied included size, shape, position, colour, scent, stamen position, and blooming time. Besides our observations, relevant literature and regional flora (Gamble & Fischer 1915–1935) were referred to confirm the categorization of floral traits. The vertebrate floral resource users were identified to the species level. Among insects, the honeybees were identified up to species while others were classified into genus level or groups such as morpho-species 1, 2, etc. Pearson correlations (Junker *et al.* 2013) were performed to evaluate the association between flower traits and floral visitors. The co-occurrence of floral resource user on a given species was determined using Jaccard's index (Ramirez 2004).

Results

Flower traits and floral resource users

Flower traits of 110 plant species of the TDEF are summarised in Supplementary Table (Table S1). Though flower colour ranged over a spectrum of 6 colours, about 45% species had white colour and 31% had yellow flowers.

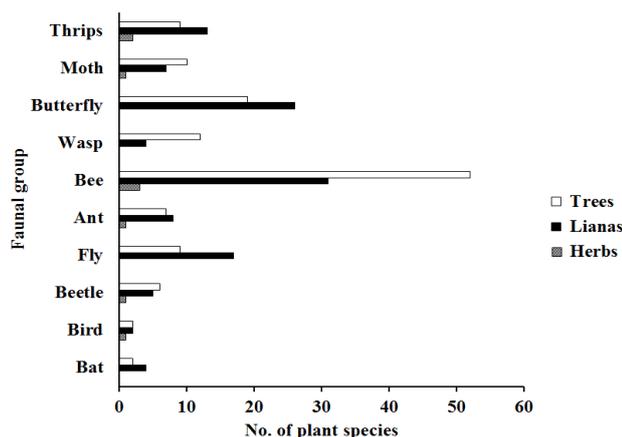


Fig. 1. Relative importance of different faunal visitors of 110 plant species classed by plant life-forms (trees, lianas and herbs) in tropical dry evergreen forest on the Coromandel Coast of India.

About 64% of plant species had faint-scented flowers followed by 21% fair-scented and 16% strong-scented species. Over 97% of species offered nectar followed by pollen (32.7%) and floral tissue (14.5%) (Table S1). Ten categories of floral visitors viz., bat, bird, beetle, fly, ant, bee, wasp, butterfly, moth and thrips used floral resource of plant species (Table S2). The bees were the most common floral resource users which accounted for 78% of floral visitation, followed by butterflies (40%) and thrips (30%). The floral resource users of trees, lianas and herbs are given in Fig. 1.

Bat flowers: Four species of Capparaceae and one species each of Sapotaceae and Barringtoniaceae were visited by bats (Table S1). They mainly feed on nectar and pollen. Bat flowers of lianas were mostly strong-scented, night blooming and large-sized and rotate-shape (Table S3). Bat visited two evergreen tree species with green and white-coloured flowers (Table S1).

Bird flowers (Fig. 2): Five plant species of 4 families were visited by birds (Table S1). Trees which attracted birds had large-sized, bilabiate and red-coloured flowers (Table S3). Lianas with large-sized and white with pink colour flowers were visited mostly by birds. Birds were the major floral resource users in Loranthaceae (Table S1).

Beetle flowers (Fig. 2): Twelve species of 11 families were visited by beetles. They visit flowers for nectar, pollen and/or other floral tissues. Beetles were often associated with spadix inflorescence of the aroid herb *Therriophonum minutum*.

Fly flowers (Fig. 2): Dipterans, mainly floral

nectar users, were attracted to 27 plant species of 17 families. Flowers of trees visited by flies were mostly of tubular shape with white and yellow colours. Fly visiting lianas flowers were small-sized and rotate; most of them belonged to Asclepiadaceae. The spadix inflorescence of *Therriophonum minutum* with faint smell attracted flies, besides beetles.

Ant flowers: Ants were attracted to 16 plant species of 11 families. They were the most frequent visitors to flowers with accessible nectars, *Camponotus* ants were the major floral resource users of herbs like *Sanseveria roxburghiana*. Ant flowers were brightly coloured in trees and large-sized in lianas.

Bee flowers (Fig. 2): Flowers of 86 plant species were mainly visited by bees during day time. Among 110 plant species, in more than 65% flowers opened in day time. Trees with white-coloured flowers with exposed stamens were major attraction while green-coloured flowers were least attractive to the bees (Table S3). In general, fair-scented flowers were visited by bees.

Wasp flowers: Wasps were common resource users of flowers with exposed nectar. Sixteen species of 10 families were visited by wasps. In case of tree species, wasp flowers were small and cauliflorous (Table S3). Flowers of lianas especially belonging to Vitaceae family were visited by wasp.

Butterfly utilising flowers (Fig. 2): Butterflies mainly feed on nectar. Flowers of 45 species of 28 plant families having rotated shape and strong-scent were visited by butterflies (Table S3).

Moth flowers: Seventeen species were visited by moths. Moths were active in night and attracted towards strong-scented salver-form flowers both in trees and lianas (Table S3). In TDEF, *Sanseveria roxburghiana* was the only night-blooming herb visited by moths.

Thrips flowers: Thrips are very small insects with winged adults. Adult thrips feed on pollen and floral tissues. Flowers of 24 species were visited by thrips (Table S1). In case of tree species, flowers were brightly coloured with urceolate corolla and 'included stamens' while in liana, wasps mainly preferred night-blooming large-sized, strongly scented, salver form, white flowers (Table S3).

Other faunal groups: Bugs and weevils were also common flower visitors; they mainly preferred nectar. Squirrels are regular visitors to *Mimusops elengi* flowers and other rodents such as rats visited flowers of the herb *Sanseveria roxburghiana*.

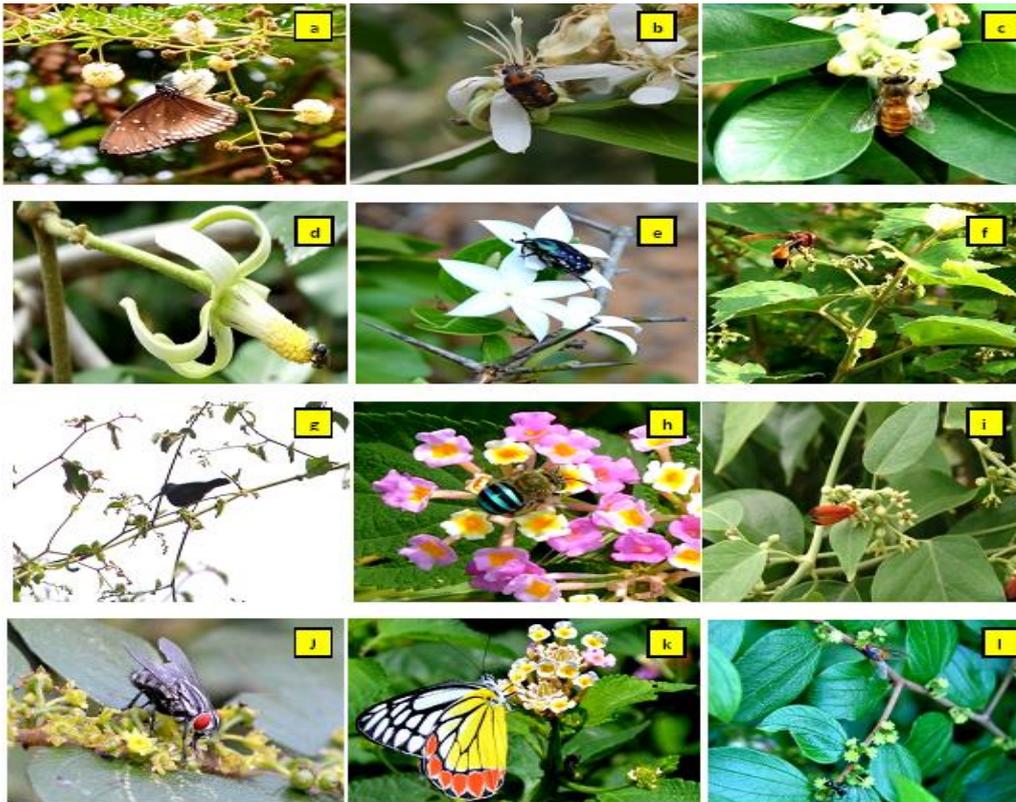


Fig. 2. Various floral rewards (nectar, pollen and floral tissue) utilized by different faunal groups in tropical dry evergreen forest on the Coromandel Coast of peninsular India: (a) Common crow accessing nectar from tubular flowers of *Acacia caesia*; (b) Flower chafer beetle in petals of *Pterospermum canescens*; (c) Rock bee in *Atalantia monophylla*; (d) Dwarf honey bee feeding pollen of *Grewia rhamnifolia*; (e) Flower beetle in corolla of *Carissa spinarum*; (f) Paper-wasp sucking nectar from *Cissus vitiginea*; (g) Loten's sunbird visiting flowers of *Ventilago madraspatana*; (h) Blue-banded bee feeding nectar from *Lantana camara*; (i) Net winged beetle feeding nectar and pollen from *Leptadenia reticulata*; (j) Flesh fly visiting a flower of *Ziziphus oenopia*; (k) Lemon pansy accesses nectar from *Lantana camara*; (l) Visitation of both fly and ant in *Ziziphus oenopia*.

Floral visitor analysis by plant families

Among the total 45 plant families, eight families (Acanthaceae, Boraginaceae, Caesalpinaceae, Cordiaceae, Dioscoreaceae, Flacourtiaceae, Loganiaceae and Salvadoraceae) were exclusively visited by bee species and one family each by birds (Loranthaceae) and butterflies (Ochnaceae) (Table S4). Species belonging to 16 families were attracted by more than three faunal groups. The other (19) families were visited by just two or three different faunal groups. About 22% of families (10 families) was visited by a single faunal group (bee, butterfly or bird).

Co-occurrence of floral resource users

Most floral resource users co-occurred with bees. Co-occurrence of fly-butterfly was most frequently observed (36% of similarity). Co-

occurrence of bee-butterfly (33.7%), bees-fly (25.8%) and bee-bat (0.02%) was very much limited. Flowers of 27% of plant species in TDEF were visited exclusively only by bees (Table S2). Three species (*Ochna obtusata*, *Crateva magna* and *Ampelocissus tomentosa*) were visited only by butterfly species and one species each by birds (*Dendrophthoe falcata*), beetles (*Olox scandens*) and wasps (*Premna latifolia*).

Discussion

Floral resource users are chiefly attracted by flower traits. Most of them utilise nectar, pollen and floral tissue (Momose *et al.* 1998b) and act as an agent of pollination, an important process for successful reproduction and growth of plant species in the forest. Blooming time also influenced the visit of floral resource user. For instance,

moths visited night-blooming flowers and butterfly utilised day-blooming flowers; species like *Apis dorsata* was able to forage both types of flowers (Dyer 1985). In general white flowers was most preferred by different faunal groups in the TDEF, an observation corroborated by Devy and Davidar (2003) in tropical wet evergreen forest of Kakkachi, Indian Western Ghats.

Cynopterus sphinx, the only bat species that utilizes floral resource in TDEF has been reported to be a pollinator in Kakkachi, Western Ghats (Devy & Davidar 2003). Bats have also been reported in dipterocarp forest, Malaysia (Momose *et al.* 1998a). According to Corlett (2004), in Oriental region birds mainly preferred large-sized, coloured flowers. This is in agreement with our observation in the TDEF. Sunbirds which utilised the floral resource of Loranthaceae (*Dendrophthoe falcata*) in TDEF, was also observed in Lambir forest, Malaysia (Momose *et al.* 1998a). At our sites, the number of bird and bat was less than those reported from other tropical forests (e.g. Bawa *et al.* 1985; Kato 1996). The spadix inflorescence of *Theriophonum minutum*, simple mainly visited by beetles in TDEF, was also reported from the Oriental region by Corlett (2004). In the open forest of northern India, *Theriophonum crenatum* (Araceae) was reported to release a 'cow dung smell' that attracts a single species of *Ceratopogon* (Ceratopogonidae: biting midges) (Dakwale & Bhatnagar 1997); in our study sites *Theriophonum minutum* was attracted by blister beetle (*Mylabris pustulata*). *Camponotus* sp. utilised the flower nectar of *Sanseveria roxburghiana* and acted as a pollination agent of the herb *Euphorbia geniculata* (Reddi & Reddi 1984). Wasps were frequent visitors to the small, white, cup-shaped flowers of *Allophyllus serratus*, a similar behaviour was reported by Aluri *et al.* (1998). Butterflies were the second major faunal group visiting rotate-shaped and strong-scented flowers in tropical dry evergreen forest but in Malaysian dipterocarp forest, they preferred orange colour and brush-like or tubular flowers (Momose *et al.* 1998b). Moth species mainly utilised white, scented, tubular flowers in TDEF as also reported by Raju *et al.* (1997) and Momose *et al.* (1998a). Thrips utilised the yellow urceolate flowers which had too small entrances for other visitors (Corlett 2004) and served as pollinators of *Aglaia* in the Western Ghats (Devy & Davidar 2003) and *Diospyros* in Australian rainforests (Williams *et al.* 2001).

Co-occurrence of different faunal groups on the flowers ensures pollination in the event of loss or absence of certain pollinator species (Bond 1994) and increases the capability of reproduction in plant species. About 68% species in TDEF had multiple floral visitors and the remaining 32% had exclusive visitors. A high proportion of multiple floral visitors enhance community stability and organisation (Ramirez 2004). Floral resource users in TDEF showed different degrees of both specialisation and generalisation. Bees, butterflies, thrips, flies and wasps often visited the same plant species but in some cases, they shared many plant species. Bees visited flowers of majority of species while other faunal groups such as butterfly, bird, beetle and wasp exclusively visited few plant species (Table 1).

The proportions of specialised or exclusive visitors are high in diverse forests (O'Brien 1980; Ramirez 2004). TDEF being a low-diverse forest than the wet evergreen forest of the Western Ghats, butterfly, bird, beetle and wasp showed poor degree of specialization. Flies and butterflies exhibited high degree of co-occurrence in this study probably due to some flower traits that attracted both of them. Proctor *et al.* (1996) also found that butterfly species seem to be associated with bee since both prefer coloured, funnel-shaped flowers. Bat co-occurred more with moth and bird flowers in TDEF. Co-occurrence of bats and moth species (Herrera 1999) and birds (Proctor *et al.* 1996) in flowers of many plant species has been related to similarity in their nocturnal habit and morphological characters of flowers (Herrera 1999).

The findings of the present observational study of floral resource users and floral characters of plant species in tropical dry evergreen forest points out that the flower-visiting faunal species not only add species richness to the community, their interaction has potential to influence ecosystem structure and its functioning. Therefore, data on plant resource use by faunal communities are valuable in understanding the complex web of biotic interactions in forest ecosystem and useful in biological conservation.

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Supporting Information

Additional Supporting information may be found in the online version of this article.

Table S1. Flower traits and floral resource use by various faunal groups in tropical dry evergreen forest on the Coromandel Coast of India

Table S2. Faunal groups that visited flowers of 110 plant species in tropical dry evergreen forest on the Coromandel Coast of India.

Table S3. Pearson correlation between floral traits and floral resource users in tropical dry evergreen forest on the Coromandel Coast of India. Below the diagonal correlations pooled for 110 plant species are presented.

Table S4. Faunal group visiting flowers of 45 plant families in the tropical dry evergreen forest.