Ant foraging on extrafloral nectaries [EFNs] of *Ipomoea pes-caprae* (Convolvulaceae) in the dune vegetation: Ants as potential antiherbivore agents

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Present study focuses on the different groups of arthropods visiting extrafloral nectaries of *Ipomoea pes-caprae* and the interactions among these different groups of arthropods. Diurnal activity patterns of arthropods on nectaries were recorded. This study also reports the presence of similar extrafloral nectaries in other species of *Ipomoea*.

[Key words: Extrafloral nectaries (EFNs), *Ipomoea pes-caprae*, Ant, defence mechanism mutualism]

Introduction

*Ipomoea pes-caprae*, also known as Beach Morning Glory or Goat's Foot, is a common pantropical creeping vine and a principal sand binding plant, belonging to the family Convolvulaceae (Figs 1 & 2). It is a primary sand stabilizer, being one of the first plants to colonize the dune and endures salted air. It grows on almost all parts of the dune but is usually found on the seaward slopes sending long runners down towards the toe of the dune. It is one of the most common and most widely distributed salt tolerant plants, which produce water dispersed seeds that float and are unaffected by salt water, remaining viable for up to six months in sea water. This plant grows in association with other herbs like *Acanthus ilicifolius*, *Canavalia lineata*, *Launea* sp. and *Spinifex squarrosus* and is a useful sand binder thriving under conditions of sand blast and salt spray. It was very common along the sandy shores and nearby areas of Bengal and Orissa till the last decade helping in the formation and stabilization of sand dunes. But in recent years there has been a sharp decline in its population along this stretch largely due to urbanization and natural disasters, which the plant by itself has been unable to overcome. However, it has its own defence mechanism against the herbivore predators feeding on its parts. This is due to the presence of extrafloral nectaries (EFNs).

![Fig. 1 — The plant of *Ipomoea pes-caprae*](image1.jpg)

![Fig. 2 — *Ipomoea pes-caprae* growing in association with *Pandanus fascicularis*](image2.jpg)
Many plant species bear nectar-secreting organs on leaves, stems or bracts, known collectively as extrafloral nectaries. They are nectar-secreting vascularized or non-vascularized structures not directly involved with pollination and are found on virtually all above-ground plant parts. They are especially common on leaves, petioles, young stems, stipules and reproductive structures (e.g. buds, calyx, inflorescence axis, flower peduncles, fruit). Extrafloral nectaries are known in at least 66 plant families and occur on species in taxonomically very distant groups, including ferns and flowering plants and – within the latter group – monocotyledons as well as dicotyledons. Plants bearing EFNs are widely distributed around the world, and more common in tropical than in temperate environments.

The extrafloral nectar attracts organisms that remove, attack, prey upon, or parasitize plant herbivores. This protective role of extrafloral nectar has long been a matter of discussion, but many studies have now proven that it can play an important role in a plant’s indirect defense against herbivores. Many ants have been found to forage preferentially on plants with EFNs and the presence of these ants have been found to reduce the number of herbivorous insects on these plants, thus lessening damage by herbivores. The third major hypothesis for explaining why some EFNs exist is the nutrient enhancement hypothesis i.e. to procure additional soil nutrients.

Insect herbivores may eat virtually all types of plant tissue and herbivore damage may occur at any stage of a plant’s life cycle. However, because herbivores consume both vegetative and reproductive tissue, the impact of herbivory on plant fitness may depend largely on the type of tissue being consumed. Plants have evolved with a number of characteristics, including structural, chemical, physiological and life-history traits in response to this selective pressure exerted by herbivores. One such defense strategy includes mutualistic associations with ants and many plant species have been found to produce domatia (structures that house ant colonies) and/or food rewards (food bodies, extrafloral nectar) to attract ants which in turn provide the plant with some protection against herbivores.

Present study focuses on the ants and other different groups of arthropods visiting the EFNs of Ipomoea pes-caprae and the interactions among these different groups of visiting arthropods. It also aimed to examine the anti-herbivore effect of the visiting ants. The diurnal activity patterns of arthropods on nectaries were recorded. Presence of similar EFNs in other species of Ipomoea were also examined in the present research work.

Materials and Methods

Field work was carried out from 2007 to 2010, along the coastal areas of West Bengal and Orissa, two eastern states of India. The annual temperature in this study area ranges from 17–36°C, and total annual precipitation from 220 to 610 mm. Structure and composition of the vegetation of the dune system in these areas depend on sand movement, protection from wind and salt spray. These factors create a mosaic of vegetation within the dune system. Mobile and stabilized dunes in the lower areas are inhabited mostly by herbaceous plants consisting of Acanthus illicifolius (Acanthaceae), Canavalia lineata (Fabaceae), Launea sp. (Asteraceae), Spinifex squarosus (Poaceae), besides Ipomoea pes-caprae, whereas the neighboring thickets located in the higher parts host a scrub of shrubs and trees like Casuarina equisetifolia (Casuarinaceae), Pandanus fascicularis (Pandanaceae), Prosopis juliflora (Mimosaceae), etc. Prosopis juliflora is an exotic tree introduced in this area to prevent soil erosion. It is known to hold the record for depth of penetration by roots.

Insects were photographed and collected in 70% ethanol and preserved in air tight vials for identification with the help of Zoological Survey of India and available literature. Interactions among different groups of arthropods visiting EFNs were observed and the diurnal activity patterns of arthropods on nectaries were recorded. Plant parts containing the EFNs were collected and slides were prepared to study the structure of the nectaries under the microscope. Extrafloral nectar was also collected with the help of microtips in eppendorf tubes to record the volume of nectar secreted during the different seasons.

Results

Ipomoea pes-caprae bearing notched leaves produces showy, bisexual funnel shaped flowers, with no notable floral odor. But the flowers produce copious amount of nectar from a large circular nectary at the base of the flower and small amounts from glands on the sepal. The primary pollinators have been found to be Xylocopa species (carpenter bees). Insect visitors are attracted to the flowers by the color and ultraviolet light patterns of the corolla. Key reproductive
factors in the life cycle of *I. pes-caprae* are the long-range pollen flow (up to 90 m) and mass germination of water-dispersed seeds.

The plants have a pair of extrafloral nectaries on the petiole of each leaf near the point of blade attachment, which produces nectar (Fig. 3). Red nectaries at the base of young leaves have been found to produce more nectar and attract ants and other visitors but the black nectaries at the base of older leaves produce less nectar and generally do not attract insects. These nectaries were found to be of basin type consisting of a hollow cavity surrounded by few scale-like trichomes (Fig. 4). The cells of the extrafloral nectary have densely staining cytoplasm due to high concentrations of ribosomes and mitochondria, along with quantities of rough and smooth endoplasmic reticulum with abundant vesicles, and an inconspicuous vacuole, and large nuclei. There are many plasmodesmata connecting these cells through radial and basal cell walls. Phloem usually ends close to the nectaries.

Gland activity (i.e. availability of EFNs and visitation by ants) in the study site was influenced by seasons. The secretion of extrafloral nectar was maximum prior to the rainy season i.e. in May-June (nectar volume was ± 0.6 µl) and were constantly visited (day and night) by a variable ant assemblage as well as other non-ant visitors. Nectar secretion was minimum during winter months of November-January (nectar volume was ± 0.02 µl) (Fig. 7).

The EFNs of *I. pes-caprae* were found to be visited by many foraging ants as well as many ‘non-ant’ visitors like beetles, wasps, jumping spiders and flies (Fig.6). Ants visited the EFNs of *I. pes-caprae* on a round-the-clock basis patrolling the upper and the lower leaf surface and stem. Associated ant assemblage was formed by eight species distributed in

Fig. 3—The extrafloral nectarines of *Ipomoea pes-caprae* (a&b) on the petiole at the base of the leaf (c) nectar oozing out of the nectar
four subfamilies viz. Formicinae (*Camponotus* sp., *Formica* sp., *Paratrechina* sp.), Myrmicinae (*Leptothorax* sp., *Monomorium* sp., *Solenopsis* sp.), Dolichoderinae (*Dolichoderus* sp.) and Ponerinae (*Pachycondyla* sp.) [Table 1]. Average visitation rate ranged from 1-5 to 7-10 ants per plant. The species composition of the principal ant visitors not only changed markedly from day to night period but also seasonally. Foraging ants were minimum (almost absent) during the winter months i.e. when the extrafloral secretion was minimum. Apart from ants there were many non-ant visitors visiting the EFNs of *I. pes-caprae*. These included wasps, jumping spiders, bugs and beetles.

**Discussion**

The frequency of ant visits and ant species richness visiting the EFNs of *I. pes-caprae* varied during the sampling periods. Species composition also varied during the periods. In general the frequency of ant species (i.e. the number of times an ant species is associated or visiting the EFNs) was higher during the day than at night. Ants of different species were observed to attack herbivorous insects, even when these were much larger than the ants. Ants and the other non-ant visitors visited the EFNs but none were found to visit the nectarines of the flowers. The visits of ants also depended on the volume of glandular secretion of the EFNs which showed a seasonal variation. During winter when the secretion of the EFNs decreased, the frequency of the ants visiting the EFNs also decreased and it is during this period that the plants are seriously affected by the lady bird beetles which largely feed on the flowers and other plant parts (Fig. 7). This supports the protection hypothesis showing increased herbivory when the ants are absent from the plants. Similar support also comes from many experimental studies showing increased herbivore and/or lower seed production when ants are denied access to plants. Exclusion experiments conducted earlier by demonstrated that ants feeding on EFNs of *I. pes-caprae* had increased seed set. However the above did not protect seeds from predation by the bruchid beetle *Megaceras*. Besides the seasonal decrease in secretion of EFNs, another factor which might be responsible for this lack of protection is spatial and temporal variation in the density of ants and herbivores. Many workers have also suggested that EFNs can confer benefits other than, or in addition to, plant protection. Production of extrafloral nectar may encourage ants to nest in or near plants, where ant waste products can provide valuable mineral nutrients to plants.
Fig. 5—Different arthropod visitors to the extrafloral nectaries of Ipomoea pes-caprae (a-c) ants, (d-e) beetles, (assassin bug), (g) wasp, (h) jumping spider
A competition for extrafloral nectar was observed between the ants and the other arthropod visitors including the wasps, jumping spiders, bugs and beetles. Thus the EFNs are prone to exploitation by other arthropods due to the open presentation of extrafloral nectar. An early observation of obvious competition for extrafloral nectar has been reported O’Oowd, who found trigonid bees to consume extrafloral nectar of *Ochroma pyramidale* on plants from which ants had been excluded. Many of these ‘non-ant’ consumers of extrafloral nectar particularly some wasps, beetles and the assassin bugs showed defensive behavior against herbivores. It can serve as a true functional ‘alternative’ to ants in regard to the plants’ protection against herbivores in case of other plants bearing EFNs. Others like the jumping spiders in contrast, only consumed extrafloral nectar without providing the plant with any mutual benefits and thereby behave as parasites. It was observed that the spiders waited till the ants left and then consumed nectar from the EFNs. Such an ‘approach–retreat–approach’ phenomenon has been reported in case of *Phintella vittata* Koch, a salticid spider (Araneae: Salticidae) while taking nectar from EFNs of *Urena lobata* L. (Malvaceae)40.

EFNs were also observed in other species of *Ipomoea*. These include *I. batatas* (L.) Lam., *I. fistulosa*, *I. paniculata* and *I. pestigridis* (Table 2).
Except for *I. fistulosa*, which had crypt type of EFN, the other species had basin type of EFN as in *I. pes-caprae*.

**Conclusion**

Foraging ants and other non-ant foragers thus reduce the number of herbivorous insects on these plants and thus lessens damage by herbivores. Seasonal variation in the amount of extrafloral nectar secretion leads to temporal exclusion of plant-defending ants and other insects from nectaries of *I. pes-caprae*, which prevents from exhibiting their defensive effect during a certain period, thus reducing the overall efficacy of this indirect defence mechanism causing important ecological costs. Diversity of EFNs morphology was observed among the other species. Studies relating to the morphology and distribution of EFNs with their differential visitation by insects can lead to an understanding on the evolution of these glands and their taxonomic value.

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**References**


**Table 2**—Type of extrafloral nectaries in the different species of *Ipomoea*

<table>
<thead>
<tr>
<th>Name of the species</th>
<th>Petiolar nectary</th>
<th>Type of nectary</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>I. batatas</em> (L.) Lam.</td>
<td>+</td>
<td>basin</td>
</tr>
<tr>
<td><em>I. fistulosa</em> Mart. ex Choisy (I. carnea Jacq.)</td>
<td>+</td>
<td>crypt</td>
</tr>
<tr>
<td><em>I. nil</em> (L.) Roth.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>I. paniculata</em> R.Br.</td>
<td>+</td>
<td>basin</td>
</tr>
<tr>
<td><em>I. pes-caprae</em> (L.) R.Br.</td>
<td>+</td>
<td>basin</td>
</tr>
<tr>
<td><em>I. pestigridis</em> L.</td>
<td>+</td>
<td>basin</td>
</tr>
<tr>
<td><em>I. purpurea</em> (L.) Roth</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>I. quamoclit</em> L.</td>
<td>-</td>
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**Fig. 7**—Comparative study of secretion of extra floral nectar in two seasons.


