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FLOWER-FEEDING BY BUTTERFLIES : MUTUALISM OR PARASITISM

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INTRODUCTION

Insect groups such as Hymenoptera, Diptera, Coleoptera, Thysanoptera, Lepidoptera are dependant on angiosperm flowers for food. While foraging at the flowers, these insects promote pollination, be it autogamy, geitonogamy or xenogamy. But as to the role of butterflies (Rhopalocera of Lepidoptera) in pollination some studies as of Grant & Grant (1965), Levin & Berube (1972), Smith & Snow (1976), Cruden & Hermann-Parker (1979), Bawa *et al.* (1983) demonstrated a mutualistic relationship between butterflies and the flowers, while some studies as of Wiklund *et al.* (1979) could see no reciprocal relationship and the butterflies as a group are considered to have evolved to occupy a parasitic mode of life feeding on floral nectars without pollinating them.

RESULTS

Forty species of butterflies, 8 belonging to Papilionidae, 12 to Pieridae, 8 to Nymphalidae, 3 to Danaidae, 5 to Lycaenidae, 2 to Hesperiidae, one each to Acraeidae and Satyridae of Visakhapatnam were found to be obligate nectar feeders. These butterflies were found foraging on 67 nectar plants spread over 28 plant families.

Based on the flower structure, the flowers were categorised into three major classes as (1) Zygomorphic, (2) Open and bowl shaped and, (3) Tubular flowers. Taking into consideration the position of essential organs relative to the other floral parts, these were again subdivided into (A) Zygomorphic flowers with the essential organs placed adjacent to or lying on the lower corolla lips, (B) Zygomorphic flowers with the essential organs oriented towards upper lip, (C) Open flowers with essential organs centrally positioned, (D) Open flowers with exposed numerous stamens, (E) Tubular flowers with the essential organs inserted, (F) Tubular flowers with the essential organs exserted, (G) Flowers with essential organs rather elongated and oriented horizontally. The type of flower represented by each of the 67 nectar plants utilised by the butterflies, whether or not contact between the butterfly body parts and the essential organs of flowers should be established, and whether butterflies mediate pollination or not are indicated in the accompanied figure.

Behaviour of butterflies : At group 'A' flowers the butterflies land on the exserted essential organs and insert their proboscides to take up nectar. In this case contact between the essential organs of flowers and head and legs of butterfly surely takes place.

At group 'B' flowers, the butterflies land on the lower lip of the corolla and insert their proboscis into the tube; the proboscis and head make contact with the essential organs.

At group 'C' flowers, the butterflies alight on the fully expanded petals and forage; they may walk around the essential organs to sip nectar secreted around them. The basal part of the proboscis and head gain contact with the essential organs. In *Santalum album* and *Murraya koenigii* where the flowers are in cymes, the butterflies land on one flower and forage on the other flower of the cyme. During this process, proboscis, head, legs and wings touch the essential organs.

In group 'D' flowers, when foraging at the nectary situated at the base of the essential organs, the butterfly mouthparts, head, legs and wings get into contact with the exposed essential organs.

In group 'E' flowers, when the butterflies forage, the proboscides come into contact with the essential organs.

In group 'F' flowers, while the butterfly sucks nectar from the corolla tube, the exserted essential organs make definite contact with the proboscis and head. In head inflorescence the essential organs get into contact with the legs and wings also, because the butterfly walks over on inflorescence to cover all the opened flowers.

In group 'G' flowers, the spatial separation between the elongated essential organs and the nectarial tube not only exclude other insects but also provide good landing platform to the butterflies and facilitate the contacts between essential organs and wings.

Wing positions at foraging : Butterflies when foraging on flowers, keep their wings in various positions as (1) wings fluttering, (2) wings spreading, (3) wings vertical but half-open, (4) wings vertical and closed.

Wings fluttering : The Papilionidae members as *Atrophaneura, Papilio* and *Graphium* hover on flowers and flutter their wings continuously while foraging. The fluttering generates vibrations which cause pollen dispersal.

Wings spreading : Some butterflies keep their wings fully spreading while foraging at flowers. *Danaus chrysippus, Melanitis leda ismene, Euthalia garuda, Hypolimnas misippus, H. bolina, Precis lemonias, P. hierta, P. orithya, Phalanta phalantha, Acraea violae* and *Eurema hecabe* display this type of wing positioning. While these butterflies forage on flowers arranged in cymes, umbels and in head inflorescences, the wings get contact with the adjacent flowers.

Wing vertical but half-open : Species of *Precis almana* (some times *P. lemonias, P. hierta), Anaphaeis aurota, Colotis fausta, C. eucharis, C. danae* keep their wings half-open at forage. In these cases also the wings may come into contact with the essential organs of adjacent flowers of an inflorescence.

Wings vertical and closed : *Danaus limniace, Euploea core, Castalius rosimon, Euchrysops cnejus, Jamides celeno, Apharitis vulcanus, Rapala iarbus sorya, Delias eucharis, Cepora nerissa, Catopsilia crocale, C. crocale pomona, C. pyranthe, Pelopidas mathias, Borbo cinnara,* sometimes *Danaus chrysippus, Hypolimnas misippus, Acraea violae* and *Eurema hecabe* completely close their wings and keep them upright while foraging. They stand on flower or on inflorescence to forage when the legs contact with the exserted essential organs.

Time spent : Data relating to the average time spent and the average number of visits per minute collected for 28 species of butterflies which were most often seen at the flowers are included in Table 1. From these data are calculated the average time spent per flower and average number of visits per minute by each of the family of butterflies studied (Table 2).

DISCUSSION

Whether a butterfly species actually serves as a pollinator or merely thrives as herbivore exploiting the community floral resource can now be decided on the basis of the results described earlier. The floral mechanism found in each of the 67 species of plants visited by butterflies is not one and the same. The position of essential organs relative to other floral parts and the foraging position of butterflies relative to the anthers and the stigma vary from species to species. Consequently, contact of essential organs of a flower cannot be established at a fixed point on the butterfly's body. Moreover, in most cases it was found that more than one butterfly species visits a particular floral host, and more than one plant species serves as floral hosts to a particular butterfly species. A particular butterfly may not be equally effective in pollinating all its floral hosts, and in some it may even fail to mediate any pollen transfer because of differences in floral features between/among different species. Different butterflies visiting a particular floral host may not be equally effective in carrying out pollination in all the hosts, and some may even be irrelevant to pollination because of difference in body size, and behaviour at the flower. Thus, the pollinating potential of a butterfly species may be said to depend on the floral architecture and behaviour of the butterfly at the flowers.

The flowers of the 67 plant species that were found as being visited by butterflies at Visakhapatnam have been categorised into types A-G on the basis of flower structure, symmetry, position and orientation of pollen presenting and pollen receiving structures. In the zygomorphic flowers of group 'A', the small butterflies as *Castalius rosimon* and *Jamides celeno* directly land on the posteriorly placed essential organs, and cause pollination.

In *Justicia* and *Adathoda* representing group 'B' flowers, the flowers are horizontally oriented and the lower part of the corolla provides an alighting platform. When small butterflies like *Castalius rosimon* land on the lower part of the corolla of *Justicia*, *Euploea core* on *Adathoda* and push head into the mouth of tube, the head region and the marginal ends of intact vertical wings of butterflies gain contact with the essential organs, and may result in pollination.

Any insect-visitor can obtain nectar from an open shallow flower. The insect here alights either on the corolla or right on the essential organs when its head or its underside gets dusted with pollen. This condition is met with the group 'C' flowers represented by *Sida*, *Tribulus*, *Antigonon* etc.

Some flowers do not provide platform for the insects to alight and the visiting insect is forced to land on the most exposed structures possibly the stamens, and thereby receiving pollen during the act of alighting on the flower (cf. Kevan 1975). Such condition is noted when butterflies forage on the 'D' type flowers represented by *Albizzia*, *Capparis* etc.

When butterfly passes its slender proboscis into the tubular part of the flower with essential organs concealed, contact between the essential organs and the proboscis surely takes place (*cf.* Robertson 1924; Percival 1965; Proctor & Yeo 1972). Such type of device is seen in flowers of the 'E' type represented by *Duranta*, *Stachytarpeta*, *Citheroxylon*, *Catharanthus*, *Ixora* etc.

In certain tubular flowers, the narrow

entrance to the floral tube may be partially occluded by either the enlarged stigma or the anthers or by folding of the petals. In such flowers only strong and long tongued insects can force their way to the nectary and in doing so cause pollination (*cf.* Kevan 1975). This type of mechanism is encountered in some flowers of the 'F' type such as *Sapindus, Randia, Borreria* etc. The capitulae of Asteraceae and an Umbellate type of inflorescence provide an open surface on which the insect may settle and the insect crawling over it in search of nectar will visit one flower after another and may pollinate a number of flowers (*cf.* Fritsch & Salisbury 1948; Kevan 1975). Flowers of the 'F' type represented by several Asteraceae, and some 'C' type flowers such as *Murraya* with the umbellate type of inflorescence are pollinated in this way.

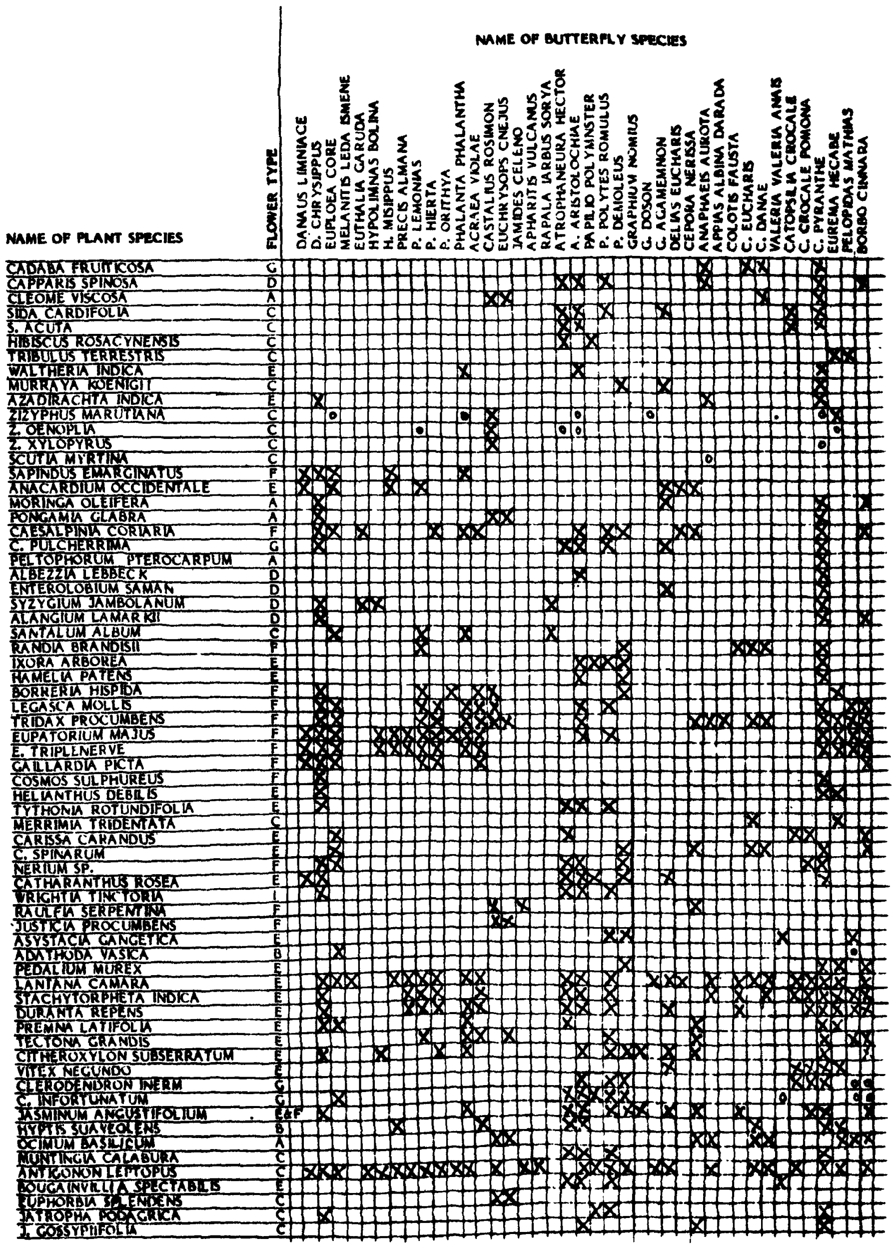
Horizontally oriented flowers possessing rather elongated staminal filaments and style (sometimes gynandrophore) facilitate comfortable landing of butterflies. Such a device also excludes other potential flower visitors (Percival 1965). Flowers of 'G' type represented by *Cadaba fruticosa, Caesalpinia pulcherrima, Clerodendron inerme* and *C. infortunatum* are designed in this way and it is certain that contacts between the essential organs and wings are established when the butterfly visits the flowers. In the flowers of *Cadaba fruticosa* and *Caesalpinia pulcherrima* nectar is placed in special container — a nectarial tube and the spatial separation of this and the essential organs is of positive value for the correct use and placing of proboscis (Faegri & Pijl 1969; Cruden & Hermann-Parker 1979). These taxa are solely visited and pollinated by butterflies only.

The foraging behaviour of pollinators has profound consequences on the breeding structure of populations and population systems, and on the incidence of inter-specific pollination and thus has a profound effect on the amount and organisation of genetic variation within plants (Levin 1978). If this is accepted the foraging behaviour of butterflies assumes greater importance. They have the tendency to visit a few flowers on a plant and fly away. They may visit another conspecific plant or altogether a different species in that foraging bout. This kind of behaviour contributes to the maximisation of xenogamy, and greatly increases the neighbourhood size, or increases the gene flow. Cruden & Hermann-Parker (1979) on *Caesalpinia pulcherrima,* Schmitt (1980) on *Senecio,* Subba Reddi *et al.* (1981) on *Tribulus terrestris,* Subba Reddi *et al.* (1983) on *Sapindus emarginatus,* Reddi and Subba Reddi (1983) on *Jatropha gossypiifolia* also observed the drifting behaviour of butterflies.

There are several plants visited and pollinated not by one group of insects, but by different groups. In such cases even if butterfly pollination is of a small proportion, the plant population would be at a great advantage because the gene flow is considerably increased.

There may be certain cases where butterflies may not be effective as pollinators but do visit such plants for nectar. Such relationships assume much importance when treated in the context of community or ecosystem. The capability of the butterfly to obtain nourishment from a plant species which it does not benefit, helps to maintain it until a right plant which indeed requires its services comes into bloom (see Baker 1963; Baker *et al.* 1971).

The number of visits made by insects, attracted by nectar or other means, is directly related to the amount of pollen carried and transferred (Proctor & Yeo 1972) and this is one way of assessing the pollinating efficiency of different insects. The number of visits per minute and the time spent/flower coupled with the behavi-



RELATIONSHIP BETWEEN DIFFERENT PLANT SPECIES AND BUTTERFLY SPECIES AT VISAKHAPATNAM

X = THE FLOWERS ARE VISITED AND POLLINATED BY BUTTERFLIES; O THE FLOWERS ARE VISITED BUT NOT POLLINATED.

our at flowers suggest that the Papilionidae are of paramount importance as pollinators and the families that follow in the descending order of significance are Pieridae, Nymphalidae, Danaidae, Hesperiidae and Lycaenidae.

SUMMARY

The paper presents an attempt to verify through examining a larger body of data whether there the relationship between butterflies (adults) and their nectar plants is mutualistic or parasitic. Observations on 40 species of butterflies (Papilionidae 8, Pieridae 12, Nymphalidae 8, Danaidae 3, Lycaenidae 5, Hespariidae 2, Acraeidae 1 and Satyridae 1) foraging on one or the other of 67 nectar plants at Visakhapatnam indicated that contact between butterflies and essential organs results from the floral architecture and butterfly behaviour. The body parts of butterflies which contact the essential organs vary; they may be proboscides, wings, legs and head. Data on the frequency of visits per unit time and the length of the time spent at flowers by butterflies of different families indicated that Papilionidae may constitute the most significant pollen vectors followed by Pieridae, Nymphalidae, Danaidae, and Hespariidae in the order. On the whole, the study led to a conclusion that flower feeding by butterflies is not without reciprocation and the extent of reciprocation depends on floral structure and butterfly behaviour. The relationship between *Cadaba fruticosa* and such butterflies as *Colotis eucharis, C. danae* and *Anaphaeis aurota*, between *Capparis spinosa* and the butterfly *Anaphaeis aurota* and that between *Clerodendron infortunatum* and such butterflies as *Papilio polymnster, P. polytes romulus, Atrophaneura hector, A. aristolochiae* is undoubtedly mutualistic.

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TABLE 1

The average length of time spent at flowers and average number of flowers visited per minute by different butterfly species.

Name of the butterfly	Time spent/ flower (sec) (R)	Time spent/ flower (sec) ($\bar{X}$)	No. of visits/ minute (R)	No. of visits/ minute ($\bar{X}$)
Danaus limniace	6–12	10.2	2–8	3
Danaus chrysippus	3–22	9.3	1–8	4 7
Euploea core	1–9	5.0	2–8	4.4
Hypolimnas misippus	4–9	6.4	3–13	6.7
Hypolimnas bolina	2–12	7.2	—	—
Precis almana	6–14	8.7	4–8	6.0
Precis hierta	2–40	10.5	1–10	5.0
Precis lemonias	3–31	13.7	2–6	4.0
Phalanta phalantha	2–27	9.3	1–12	5.0
Acraea violae	4–18	10.4	3–8	5.0
Castalius rosimon	4–30	15.5	1–6	2.8
Euchrysops cnejus	5–49	11.3	1–4	2.3
Jamides celeno	12–17	14.6	1–6	3 0
Atrophaneura hector	1–5	2.6	12-32	22 0

Atrophaneura aristolochiae	2–5	2.8	6–40	19.0
Papilio polytes romulus	1–4	2.7	14–26	19.0
Papilio demoleus	1–3	2.0	6–62	25.0
Papilio polymnstor	1	1.0	36–46	42.0
Graphium agamemnon	1–3	2.1	12–35	22.0
Cepora nerisa	4–7	5.9	3–7	6.0
Anapheis aurota	3–5	4.0	4–14	9.0
Colotis eucharis	1–4	2.4	6–34	15.0
Colotis danae	2–7	3.0	3–17	10.0
Catopsilia crocale	2–11	5.5	4–18	9.0
Catopsilia crocale pomona	1–15	6.7	1–18	7.0
Catopsilia pyranthe	3–16	6.7	4–18	8.0
Eurema hecabe	2–15	6.4	1–17	8.0
Pelopidas mathias	5–20	13.0	2–8	4.0
Borbo cinnara	5–26	13.3	1–6	3.0

TABLE 2

The average length of time spent at flowers and average number of flowers visited per minute by different butterfly families.

Family	Time spent/ flower (sec.)	No. of visits/ minute
Papilionidae	2.4	19
Pieridae	6.3	6
Nymphalidae	9.7	5
Danaidae	8.2	4
Lycaenidae	13.8	3
Hespariidae	13.1	3

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