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# POLLINATION ECOLOGY OF *TRIUMFETTA RHOMBOIDEA* (TILIACEAE)

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Abstract – In *Triumfetta rhomboidea,* the floral characteristics such as showy petals, nectar and pollen, short period of anthesis schedule, self-compatibility, brief period of stigma receptivity, medium pollen/ovule ratio and delayed autonomous selfing suggest that it is facultative autogamous with the option kept open for outcrossing. The natural fruit set and seed set rates reflect the functionality of this breeding system. *T. rhomboidea* flowers are actinomorphic and conspicuously yellow. Despite the existence of five nectaries at the base of ovary, nectar is secreted in traces only. The pollen is copiously produced at plant level and it is a source of protein and amino acids. Bees use both nectar and pollen while wasps and butterflies use only nectar; all effect pollination. A nymphalid butterfly, *Junonia orithya* uses this plant as a larval host plant. Animals and humans disperse dry, indehiscent fruits effectively during dry season. Fruits expose seeds only after the decomposition of fruit coat during rainy season and then the seeds germinate and establish new plants.

Keywords: *Triumfetta rhomboidea*, facultative autogamy, entomophily, rain-assisted autogamy

## Introduction

Collevatti et al. (1998) provided a detailed account on breeding and pollination of *Triumfetta semitriloba*. The plant is a perennial facultative autogamous weed shrub occurring in tropical America. It attracts anthophorids, apids, colletids and halictids, megachilids, formicids, chalcidids, chrysidids, vespids, bruchids, chrysomelids, hemipterans and butterflies to its flowers but only apoid species are effective pollinators. Chrysomelid beetles act as flower herbivores damaging the floral parts including sex organs and hence is affecting the reproductive success of the plant. Janzen (1981) reported that the moth, *Hylesia lineata* during its larval phase feeds naturally on the foliage of diverse plant species but it does not feed on broad-leaf plants in its habitat. *Triumfetta lappula* is an important larval host plant for this moth in Costa Rica. *Triumfetta rhomboidea* is a perennial $C_3$ herb (Zwarg et al., 2012) native to old-world tropics but found throughout the tropical region (Iqbal et al., 2010). The plant is used in traditional medicine for the treatment of tumours, gonorrhea and leprosy (Sivakumar et al., 2010). Root is tonic styptic, galactogogue, aphrodisiac, cooling, useful in dysentery and as diuretic. Pounded roots are given in the treatment of intestinal ulcer. Leaves, flowers and fruit are mucilaginous demulcent and astringent (Jeyaprakash et al., 2011; Devmurari et al., 2010; Parul et al., 2012). The butterflies *Acraea vivianna* and *A. eponina* use this plant species as larval host plant (Jiggins et al., 2003). The cotton mealybug, *Phenacoccus solenopsis* is polyphagous, has high reproductive potential and uses a number of weeds including *T. rhomboidea* as host plants (Vennila et al., 2013). The responses of the plant during pre-flowering, flowering and post-flowering stages to coal-smoke pollution have been studied by Iqbal et al. (2010). These authors reported that it is a good indicator of pollution and also has the ability to modify its metabolic activities for survival in polluted environment. The intent of the present study is to evaluate the floral traits of *T. rhomboidea* to characterize the pollination syndrome and its suitability to the local pollinator fauna to effect pollination. The study is also intended to evaluate

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fruit and seed set rates and finally to examine seed dispersal aspects. Finally, the study also focuses on the importance of *T. rhomboidea* as a food plant for the lycaenid butterfly, *Junonia orithya* and the gastropod, *Euplecta decussata*.

## Materials and methods

*Triumfetta rhomboidea* (Tiliaceae) growing seasonally in Visakhapatnam (17°42'N Longitude and 82°18'E Latitude), Andhra Pradesh, India, was selected for study during 2012-2014. Twenty five fresh flowers were used to record the floral details such as flower shape, colour, odour, sex, symmetry, floral mechanism, calyx, corolla, stamens and style and stigma. Anthesis schedule was recorded by observing twenty five marked mature buds in the field. Similarly, the same mature buds were followed for recording the time of anther dehiscence. The pollen presentation pattern was also investigated by recording how anthers dehisced, whether all anthers in a flower dehisce simultaneously or not and the same was confirmed by observing the anthers under a 10x hand lens. Pollen output was determined by taking twenty un-dehisced anthers from ten plants. The anthers collected from twenty five flowers were placed in a Petri dish. Later, each time a single anther was taken out and placed on a clean microscope slide (75 x 25 mm) and dabbed with a needle in a drop of lactophenol-aniline blue. The pollen mass was drawn into a band, and the total number of pollen grains was counted under a compound microscope (40x objective, 10x eye piece). This procedure was followed for counting the number of pollen grains in each anther. Based on these counts, the mean number of pollen produced per anther was determined. The mean pollen output per anther was multiplied by the number of anthers in the flower to obtain the mean number of pollen grains per flower. Another set of dehisced anthers was collected in a Petri dish and the pollen removed from these anthers was examined under microscope for recording the pollen grain features. The procotols mentioned in Mondal et al. (2009) were followed for identifying amino acid types present in the pollen grains. The protocol described in Sadasivam & Manickam (1997) was followed for the extraction of protein from the pollen samples using phosphate buffer of pH 7.4 and then Lowry et al. (1951) was followed for estimating the protein content in the sample. The pollen-ovule ratio was determined by dividing the average number of pollen grains per flower by the number of ovules per flower (Cruden, 1977). The nectar volume was not measured due to its availability in traces at flower level. Ten flowers each from five individuals were used to test stigma receptivity. It was tested with hydrogen peroxide from mature bud stage to flower closure/drop as per Dafni *et al.* (2005). Further, the receptivity was also observed visually whether the stigma is shiny, wet or changing colors or withering.

The insect species were observed visually and by using binoculars. The hourly foraging visits of each insect species were recorded on 4 occasions and the data was tabulated for further analysis. A patch of five hundred flowers were selected to record the foraging visits of insects. The data obtained was used to calculate the percentage of foraging visits of each category of insects per day to know the relative importance of each category of insects. The insects were observed on a number of occasions for their foraging behavior such as mode of approach, landing, probing behavior, the type of forage collected, contact with essential organs and inter-plant foraging activity. A nymphalid butterfly, *Junonia orithya* uses *T. rhomboidea* as a larval host plant feeding on leaves and petals. Casual observations were made on the larva to know the extent of its feeding on petals.

Two hundred flowers on twenty plants were tagged prior to anthesis and followed for fruit and seed set for two weeks. The resulting fruit and seed output were pooled up for calculating fruit and seed set rates. Fruit maturation period, the fruit and seed characteristics were recorded. The role of wind, rain water and humans in fruit and seed dispersal was examined. The aspects of seed germination and establishment of populations were observed briefly.

## Results

### Plant phenology and Flower morphology

*T. rhomboidea* is an erect annual weedy herb or undershrub which grows up to 1.5 meters in open ruderal locations. The stem is much branched and covered with stellate hairs mixed with simple hairs. The leaves are 3-7 costate, shape variable, rhomboid-ovate, stellate or simple hairy to glabrescent, palmately 3-lobed and acute at the apex. The plant appears following first rains in June, carpets the soil with numerous individuals and forms mostly pure stands, occasionally has scattered occurrence, and disappears in February (Fig. 1a). The other concurrently growing plants along with this weed include *Sida acuta, S. cordata, S. cordifolia, Asystasia gangetica, Merremia tridentata* and *Pedalium murex*. It flowers during September-January. The flowers are borne in axillary cymes and form clusters at nodes. A cluster consists of 30-33 flowers and several such clusters are borne on each

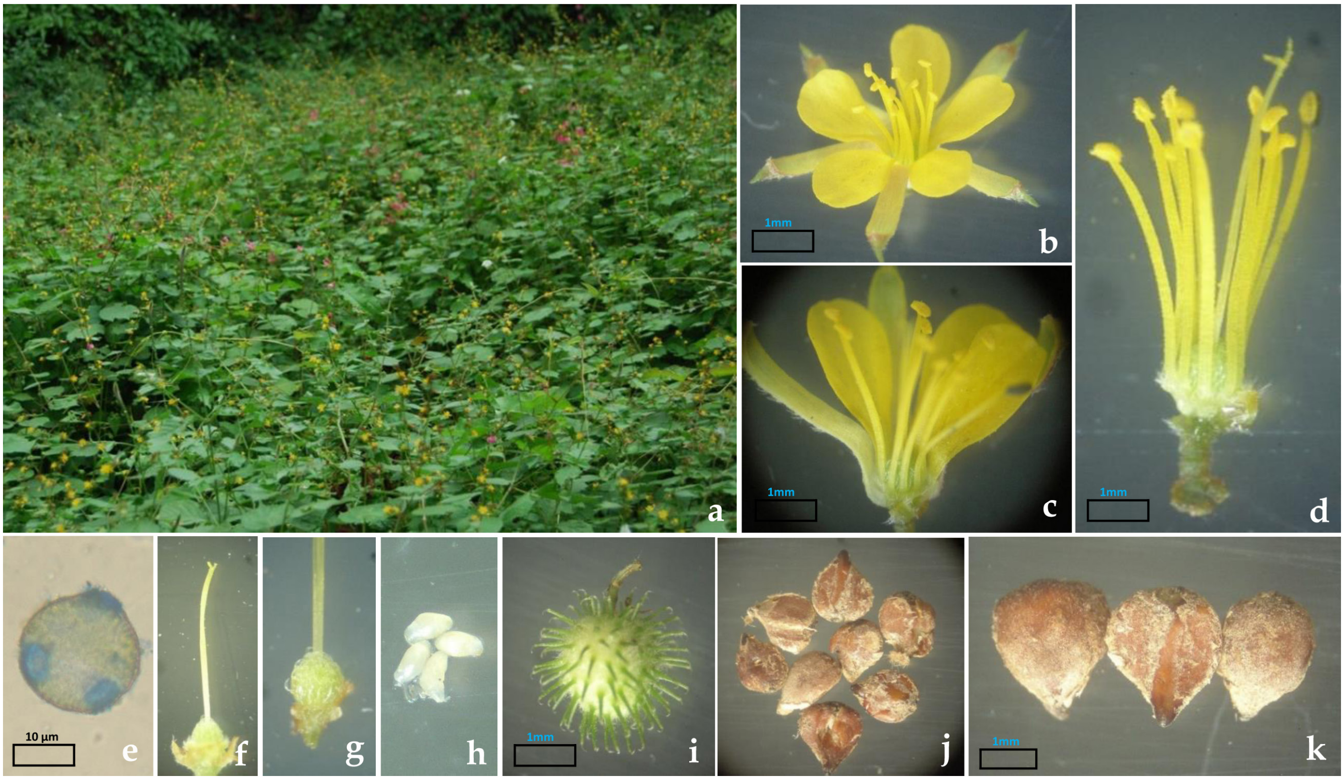

Figure 1. *Triumfetta rhomboidea*: a. Habit, b. Flower, c. & d. Positions of stamens and stigma, e. Pollen grain, f. Ovary, style and stigma, g. Ovary, h. Ovules, i. Young fruit, j. & k. Dry seeds.

branch. An individual plant produces 469 ± 81 flowers. The flowers are small, 6 mm long and 7 mm wide, stellate or star-shaped, yellow, bisexual and actinomorphic. The sepals are 5, free, narrowly elliptical to linear, 6 mm long, 2 mm wide but longer than petals, strongly cucullate, awned at the apex, yellow on the upper surface with pinkish tinge at the tip while they are completely pink on the lower surface. The petals are 5, spatulate, free, 5 mm long, 1 mm wide, yellow, hairy at the base. The stamens are 10, arise from the base, free, papillose, and the filaments are tipped with introrse dithecous anthers. The ovary is tetracarpellary syncarpous covered with hairs and each locule has a single ovule arranged on axile placentation; the style is one and tipped with a bifid stigma (Fig. 1c, d, f-h).

## Floral biology

The flowers open during 13:00-14:00 h. The star-like free petals expose the stigma and stamens following anthesis (Fig. 1b). The stamens are protandrous and anther dehiscence occurs during mature bud stage by longitudinal slits. The pollen output per anther is 313 ± 12 and per flower is 3130 ± 23.2. The pollen-ovule ratio is 783:1. Pollen grains are monads, yellow, spheroidal, sticky, tri-colporate, and 33 µm in diameter with smooth exine (Fig. 1e). The stigma attains receptivity after anthesis and remains receptive for about four hours only; then onwards it shows signs of withering. Nectar is produced in traces and is collected at the base of corolla tube. The pollen contains five essential amino acids and seven non-essential amino acids. The essential amino acids are threonine, valine, isoleucine, lysine and histidine. The non-essential amino acids include alanine, cysteine, cystine, glutamic acid, hydroxyproline, proline and serine. The total protein content per 1 mg of pollen is 333.30 µg.

The flowers during anthesis keep the dehisced anthers and the stigma exposed while the insects effect pollination. The flowers gradually close back by the evening of the same day during which the stigma curls down and contacts the anthers, the movement of which eventually ends up in autogamy. The closing free petals facilitate this movement to occur. The mature buds bagged and followed for a week showed fruit and seed set suggesting that the plant is self-compatible and self-pollinating without vector-mediation. The floral parts except the ovary, style and stigma fall off on the morning of 3rd day of anthesis. Further, on rainy days, the rain drops falling on the flowers splash the dehisced anthers and in effect the pollen flies off and falls on the stigmas, due to which self-pollination occurs.

Table 1. List of insect foragers on *Triumfetta rhomboidea*

| Order | Family | Genus | Species | Common name | Forage sought |
|---|---|---|---|---|---|
| Hymenoptera | Apidae | *Apis* | *dorsata* F. | Rock Honey Bee | Pollen, Nectar |
| | | *Apis* | *cerana* F. | Indian Honey Bee | Pollen, Nectar |
| | | *Apis* | *florea* F. | Dwarf Honey Bee | Pollen, Nectar |
| | | *Trigona* | *iridipennis* Smith | Stingless Honey Bee | Pollen, Nectar |
| | | *Anthophora* | *cingulata* F. | Digger Bee | Pollen, Nectar |
| | Halictidae | *Halictus* sp. | - | - | Pollen, Nectar |
| | Crabronidae | *Stizus* sp. | - | - | Nectar |
| Lepidoptera | Nymphalidae | *Junonia* | *orithya* L. | Blue Pansy | Leaf & Petals |
| | Lycaenidae | *Castalius* | *rosimon* F. | Common Pierrot | Nectar |
| | | *Discolampa* | *ethion* Doubleday & Hewitson | Banded Blue Pierrot | Nectar |
| | | *Neopithecops* | *zalmara* Butler | Quaker | Nectar |
| | | *Chilades* | *laius* Stoll | Lime Blue | Nectar |
| | | *Jamides* | *celeno* Cr. | Common Cerulean | Nectar |
| | Hesperiidae | *Borbo* | *cinnara* Wallace | Rice Swift | Nectar |

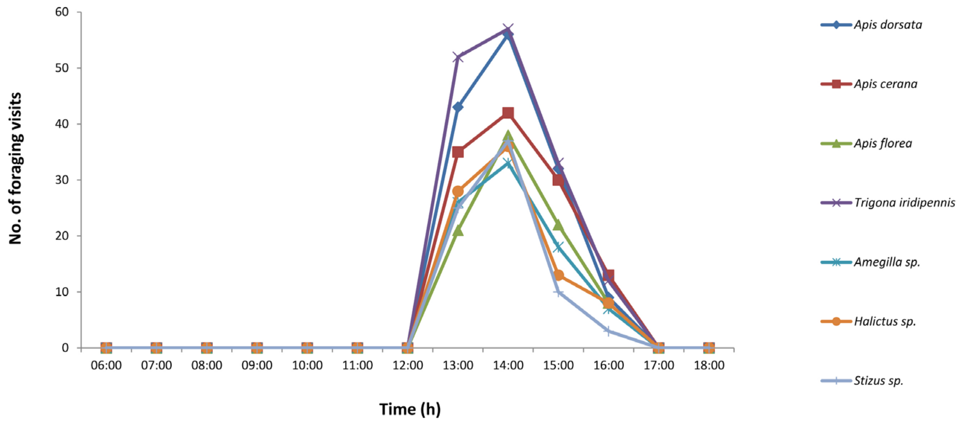

Figure 2. Hourly foraging activity of bees and wasps on *Triumfetta rhomboidea* (average foraging visits recorded on four different days during wet season in 2012 and 2013).

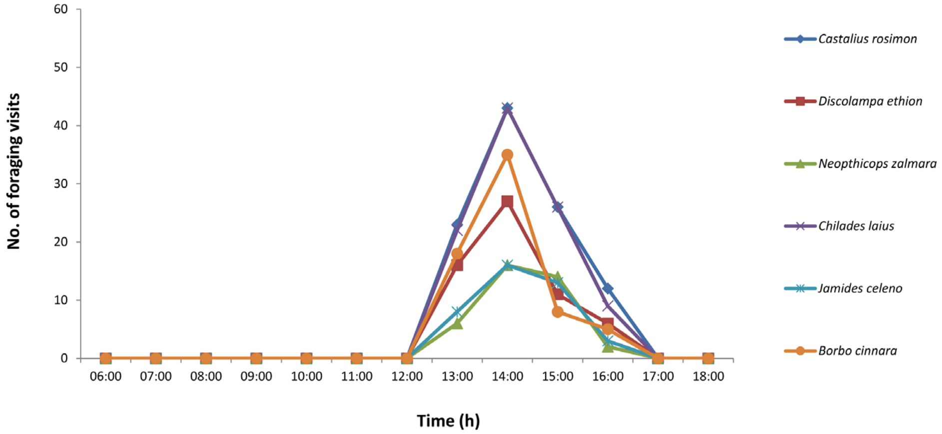

Figure 3. Hourly foraging activity of butterflies on *Triumfetta rhomboidea* (average foraging visits recorded on four different days during wet season in 2012 and 2013).

## Flower visitors and pollination

The flowers were visited regularly during the afternoon period from 13:00 to 16:00 h by bees for both pollen and nectar, and by wasps and butterflies for only nectar (Table 1; Fig. 2, 3). The bees were *Apis dorsata* (Fig. 4a), *A. cerana, A. florea* (Fig. 4b), *Trigona iridipennis* (Fig. 4c), *Anthophora cingulata* (Fig. 4d) (Apidae) and *Halictus* sp. (Fig. 4e) (Halictidae). The wasp was *Stizus* sp. (Fig. 4f) (Crabronidae). The butterflies included members of Lycaenid and Hesperiid families. The lycaenids were *Castalius rosimon* (Fig. 4h, i), *Discolampa ethion, Neopithecops zalmara, Chilades Laius* (Fig. 4j) and *Jamides celeno* (Fig. 4k). The Hesperiid was *Borbo cinnara* (Fig. 4l). Of the total insect visits, bees made 58%, wasps 7% and butterflies 35%. Of the total bee visits, honey bees (*Apis* and *Trigona*) alone made 75%. Among butterflies, the lycaenids made 84% and hesperiids 16% of total visits. The insects approached the flowers in upright position, landed on the corolla and probed for the forage without any difficulty due to open-state and star-like free petals with exposed stigmas and dehisced anthers. The bees collected both the floral rewards in the same visit but they mostly concentrated on pollen collection. The wasp and butterflies probed the corolla base for collecting nectar. At the study area, *T. iridipennis* had its nest close to *Sida* species and regularly collected the pollen during the period when flowers are in open state. The pollen pots of this bee were found to contain pollen of *T. rhomboidea* and *Sida* species. The bees visited numerous flowers across population(s) in search of nectar. The wasp and the butterflies as exclusive nectar feeders made frequent inter-plant visits in quest of more standing nectar crop. Such a foraging behavior was considered as important for effecting and promoting cross-pollination. The bees and the wasp were coated with pollen all over during forage collection while the proboscis and/or forehead part of butterflies were sprinkled with pollen. The presence of pollen on the body of bees and wasps was visible to the naked eye while that of butterflies was confirmed with binoculars. These insects invariably contacted the stamens and stigmas while probing and collecting the forage due to which pollination occurred.

## Leaf and flower predation

A nymphalid butterfly, *Junonia orithya* used *T. rhomboidea* as larval host plant (Fig. 4g). It was found feeding on the leaves and flowers during its larval phase. But, it never visited the flowers for nectar collection. This butterfly was considered to be reducing the reproductive success of the plant to some extent by feeding on the flowers which subsequently fall off without fruit set.

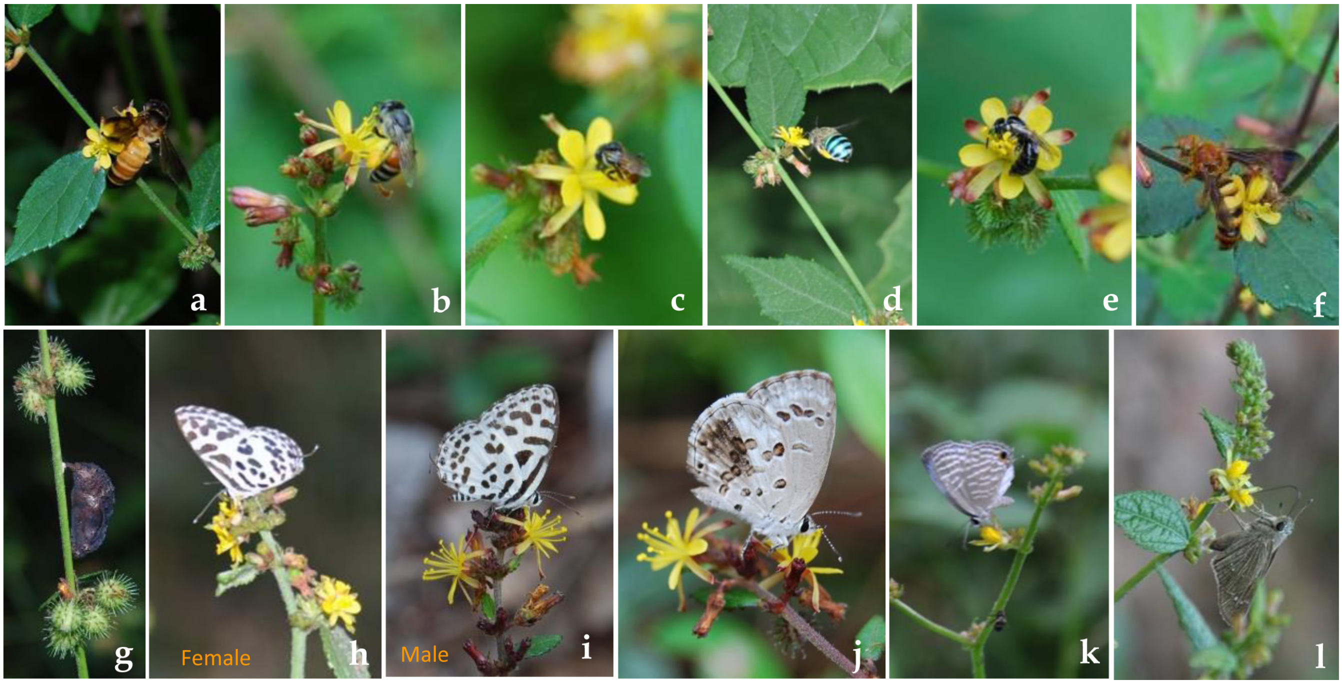

Figure 4. *Triumfetta rhomboidea*: a. *Apis dorsata* collecting pollen, b. *Apis florea* collecting pollen, c. *Trigona iridipennis* collecting pollen, d. *Anthophora cingulata* collecting pollen, e. *Halictus* sp. collecting pollen, f. *Stizus* sp. about to probe the flower for nectar collection, g. Pupa of *Junonia orithya*, h. & i. *Castalius rosimon*, j. *Chilades laius*, k. *Jamides celeno*, l. *Borbo cinnara*

### Fruiting ecology and seed dispersal

The fruit growth and development begins immediately after pollination and fertilization. The fruits mature within two weeks and show colour shifts from green to dark brown towards maturity (Fig. 1i). They are indehiscent globose capsules covered with smooth hooked bristles, small, 6 mm long, 5 mm wide and produce four seeds. Natural fruit set is 96%. The mature fruits fall to the ground during February. As they are adhesive and have bristles, they disperse by attaching to animals and humans. The seeds are semi-ovoid, brown, smooth, 2mm long and get exposed upon decomposition of fruit pericarp (Fig. 1j,k). The seeds germinate to produce new plants during wet season. As the plant is a short-lived annual, it reproduces exclusively by seed.

## DISCUSSION

*Triumfetta rhomboidea* in the present study can be considered a facultative autogamous species, since it is producing ripening fruits and viable seeds even in the absence of pollinators. The floral characteristics such as low investment in showy petals, nectar and pollen, brief period of anthesis schedule and stigma receptivity, self-compatibility, medium level pollen-ovule ratio and delayed autonomous selfing indicate that the plant is facultative autogamous (Faegri and van der Pijl, 1979; Cruden & Miller-Ward, 1981). Delayed autonomous selfing is regarded to be adaptive because it apparently assures seed production when pollinators are scarce or absent, yet allows outcrossing to predominate when they are abundant (Wyatt, 1983). Further, rain-assisted autogamy may also occur due to splashing of rain drops on the anthers which in turn causing the pollen to fly and deposit on the stigma on rainy days (Pansarin et al., 2008); this form of autogamy assumes importance due to its flowering during rainy season. Such a breeding system is a “fail-safe system” to assure the plant to achieve pollination and set fruit and seed in the absence of insects. The natural fruit set and seed set rates recorded in this plant also substantiate the function and success of this breeding system, a character essentially required for annual colonizer species like *T. rhomboidea* to occupy various habitats.

*Triumfetta rhomboidea* flowers are actinomorphic and conspicuously yellow. Despite the existence of five nectaries at the base of ovary, nectar is secreted in traces and hence its analysis was not possible for its chemical constituents in order to relate to the pollinator type or pollination system. The presence of this level of nectar appears to be a strategy by the plant to conserve the nutrient energy and at the same time attract insect visitors for pollination. Collevatti et al. (1998) have reported similar situation in *T. semitriloba*. Actinomorph symmetry with perianth free components allows easy access to pollen and nectar resources, and really attracts several species of insects. Although individual flowers are very small to be attractive from a distance, their showy yellow petals, the distribution of individual plants within patches, and flowering synchronism within-plant and patch may result in a conspicuous resource for bee pollinators (Heinrich and Raven, 1972; Augspurger, 1980).

Heinrich (1975) stated that pollen-rich flowers are specially visited by solitary bees that gather pollen for their nest, and their nectar requirement is lower than for social bees that collect nectar for the colony. Further, Heinrich & Raven (1972) stated that the flower choice may be correlated with body size, which is correlated with energetic requirements of bees. Bees with larger body size need more energy for metabolism and flight, and hence bees of this size may be less frequent than small-sized bees in flowers with low content of nectar. In *T. rhomboidea*, both social and solitary bees visit the flowers frequently and collect both pollen and nectar. All the bees recorded are either small or medium-sized ones and agrees with the generalization stated above. Among social bees, *Trigona iridipennis* builds nests in the sites covered by the luxuriant growth of *T. rhomboidea* and *Sida* species. It uses these plants as important pollen sources and can be seen in the pollen pots of this bee. Solomon Raju et al. (2009) reported that this bee builds nests in the vicinity of *Sida acuta* and the nest site is the stem of *Cycas sphaerica*, a red-listed deficient tree species. They also reported that the bee collects and stores the pollen of *S. acuta* in pollen pots. In the present study, *T. rhomboidea* occurs along with *Sida* species and these plants collectively form a huge of source of pollen for this bee and also for other local pollen collecting bees depending on the match between floral attributes and {cysteine, cystine, glutamic acid, hydroxyproline, proline and serine. DeGroot (1953) reported honey bees require ten essential amino acids out of which six are present in the pollen of these plants and in addition non-essential amino acids are also present. The pollen also has a small amount of protein content. The pollen is thus nutritionally important. Therefore, these bees use *T. rhomboidea* as an important pollen source and their pollen collecting activity although contributing to pollination, may greatly reduce the availability of pollen for pollination purpose. In this situation, the limited and fixed number of ovules per flower, and the bifid stigma with adequate surface area assume importance in the context of achieving pollination performed by bees. In fact, a few pollen grains deposited on each stigma are sufficient to fertilize a single ovule in each carpel and the bifid stigma keeps the captured pollen grains intact in order to enable the latter to germinate and fertilize the ovule (s). The flowers of *T. rhomboidea* also attract a wasp species and butterflies, especially lycaenids for nectar but the traces of nectar at flower level compel these insects to visit several or a number of flowers of the same or different plants within the patch and in different patches. In this process, they promote cross-pollination.

Heinrich (1975) stated that flower constancy may be established by resource presentation (attractiveness), manipulation facility, reward quantity or quality. In line with this, Shettleworth (1984) stated that the said factors provide information about the resources that are associated to certain characteristics of flowers, such as colour, forming an image search, decreasing the cost of flower manipulation or resource recognition. In *T. rhomboidea*, the flower constancy by foragers appears to be conditioned by flowering synchrony that presents conspicuous and abundant pollen and nectar resource at population level, afternoon anthesis by which time the floral rewards in the co-flowering herbaceous flora are mostly exhausted and also the closure of flowers in certain plant species such as *Sida*. Further, yellow flower colour and easy access to the floral rewards fuel the flower constancy of foragers, especially of bees. Therefore, the flower constancy appears to be a preferred foraging strategy than others (Wells & Wells, 1986). Similar flower constancy by bees has been reported in *T. semitroloba* (Collevatti et al., 1998).

In *Triumfetta rhomboidea*, the synchronous anthesis and synchronous presentation of floral rewards may further impose flower constancy. In this case, the flight distance may be shorter for bees collecting pollen and in this situation, autogamy and geitonogamy rate would be higher when bees fly to nearest neighbours or fly within the flowering patch. But, the low nectar production at flower or plant level drives the nectar-collecting bees, and also the wasp and butterflies to visit more flowers and fly longer distances within and between flowering patches the plant. This inter-plant and inter-patch movement would increase the rate of xenogamy. The study suggests that pollen-collecting bees would contribute to more self-pollination while the nectar-collecting bees and other insects to more cross-pollination. Therefore, *T. rhomboidea* is both hymenopterophilous and psychophilous. Collevatti et al. (1998) reported such a situation in *Triumfetta semitroloba* which is visited by a variety of pollen and nectar-collecting insects, but pollinated effectively only by bees. Rathcke et al. (2005) reported that bees pollinate the self-incompatible *Corchorus hirsutus*. Haber & Frankie (1982) reported that *L. candida* is self-incompatible and pollinated primarily by sphingid moths but diurnal visitors including stingless bees, flies and butterflies also visit but they are ineffective pollinators. *L. seemannii* exhibits partial to full self-compatibility in deciduous forest population while it is self-incompatible in evergreen forest population. There is a breakdown of incompatibility, and also an evolutionary shift to diurnal pollination due to scarcity of nocturnal pollinators and hence is pollinated by stingless bees. *L. speciosa* with floral morphology similar to *L. candida* rarely attracts sphingids during its blooming period in the early dry season even though these moths are present in the habitat. This is pollinated largely by opportunistic diurnal visitors. These studies indicate that entomophily is the prime pollination mode in the so far studied members in the subfamily Tilioideae of Malvaceae.

In the subfamily Tilioideae, certain species have been reported to be experiencing leaf, flower and fruit or seed predation. Rathcke et al. (2005) reported that a hemipteran lygaeid *Ochrostomus pulchellus* is a specialist seed predator. Its nymphs and adults pierce the fruit capsules and feed on developing ovaries in *Corchorus hirsutus;* this predation eventually ends up in reduced fruit and seed set. Janzen (1981) reported that the moth *Hylesia lineata* uses *Triumfetta lappula* as its larval host plant. Collevatti et al. (1998) reported that in *Triumfetta semitriloba,* chrysomelid beetles act as flower herbivores damaging the floral parts including sex organs and hence affect the reproductive success in this plant. Vennila et al. (2013) reported that *Triumfetta rhomboidea* is one of the potential larval host plants among a number of weeds used by the polyphagous cotton mealybug, *Phenacoccus solenopsis*. Jiggins et al. (2003) recorded that *T. rhomboidea* is used as larval host plant by the nymphalid butterflies, *Acraea vivianna* and *A. eponina*. In the present study, *T. rhomboidea* is used as a larval host plant by the nymphalid butterfly *Junonia orithya*. This butterfly feeds on the leaves as well as on flowers; Leaf-feeding would affect the photosynthesis activity, which in turn would affect the availability of photosynthate to the flowers, fruits and seeds, while flower-feeding would affect the reproductive success depending on the consumption rate of leaves and flowers. Therefore, *T. rhomboidea* as annual weed is useful as a food plant for the nymphalid butterflies. Ecologically, these herbivores appear to be controlling the spread and distribution of this annual weed.

In *Triumfetta rhomboidea,* mature and dry indehiscent fruits with hooked bristles disperse effectively by animals and humans during dry season. This form of dispersal is predominant in the tropics and has the potential to help restore plant diversity on degraded sites in a reasonable period of time, thereby helping to defray restoration costs (Joseph, 1997). Fruits of *T. rhomboidea* expose seeds only after decomposition during rainy season and then the seeds germinate establish new plants. The self-compatibility favours these plants after long-distance dispersal in the form of fruit (Cox, 1989) and also the delayed autogamy is advantageous as this would maximize the capacity for rapid spread onto a newly available site without precluding the ability to exchange genes with the population at large when one develops (Klips & Snow, 1997). Iqbal et al. (2010) studied the responses of *Triumfetta rhomboidea* to coal-smoke pollution during pre-flowering, flowering and post-flowering stages. These authors reported that the leaves are highly sensitive to pollution load and loose the extent of leaf-area as a function of stomatal responses reflecting upon its overall metabolism and growth. The plant shows an increase in the number of leaves at the polluted site probably as a compensatory mechanism adopted by plants under stress but at the same time it shows significant reduction in leaf size and hence in the total leaf area. In line with this, the total dry weight of the plant also shows a dramatic decrease when compared to control site and this situation is in accordance with the reduced rate of photosynthesis. This report suggests that this plant has the ability to modify its morphological, anatomical characters and even physiological mechanisms in polluted sites and hence serve as a good indicator of pollution. In view of this, this plant would be useful as one of the plants for rehabilitating or restoring ecologically degraded and polluted sites. Further, it has an important role in supporting certain local insects by providing the necessary forage and also negatively supporting certain herbivores by providing foliage and flowers as food sources.

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