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POLLINATION ECOLOGY OF *MERREMIA TRIDENTATA* (L.) HALLIER F. (CONVOLVULACEAE)

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Abstract: *Merremia tridentata* is a twining and prostrate herb. The flowers are campanulate, bisexual, weakly protandrous, self-compatible and facultative autogamous. The forager guilds indicate that thripsophily, melittophilily and psychophily are functional pollination syndromes. Ballistichory, anemochory and hydrochory are the seed dispersal modes. Seeds germinate as soon as they reach the ground if the soil has sufficient moisture or else they remain dormant and germinate during the rainy season. Such seed dispersal modes and flexible germination responses enable the plant to invade and colonize new areas. Further, the plant with perennial woody root stock stays alive during the dry season, sprouts back to life during the rainy season to re-start its life cycle. The dual modes of regeneration enable the plant to form extensive herbaceous cover and bind the soil effectively. Therefore, the plant is an important soil binder and useful at controlling soil erosion.

Keywords: Anemochory, ballistichory, facultative autogamy, hydrochory, melittophilily, *Merremia tridentata*, psychophily, thripsophily.

The genus *Merremia* comprises about 70–80 species with a pantropical distribution (Deroin 2001; Demissew 2001) and most of them are sources of pyrrolizidine alkaloids (Jenett-Siems et al. 2005). The genus is characterized by the yellow, funnel-shaped or campanulate corolla, spirally twisted anther thecae (after dehiscence) and non-spiny (non-echinate) pollen grains. Very few species of this genus have been studied for their

reproductive ecology. Raimundez-Urrutia et al. (2008) reported that *M. macrocalyx* is facultatively xenogamous and melittophilous. Kill & Ranga (2000) reported that *M. aegyptia* displays a cornucopia pattern of flowering. It is self-compatible, facultatively autogamous and melittophilous. Maimonia-Rodella & Rodella (1987) reported that *M. cissoides* is self-compatible and mostly pollinated by bees. Willmott & Burquez (1996) reported that *M. palmeri* is hermaphroditic, self-incompatible and sphingophilous.

Santapau & Henry (1973) reported that the genus *Merremia* is represented by 15 species in India. Some of the species recorded include *M. vitifolia*, *M. quinata*, *M. aegyptia*, *M. emarginata*, *M. umbellata*, *M. hederacea*, *M. dissecta*, *M. gangetica*, *M. hastata*, *M. tuberosa*, *M. rajasthanensis* and *M. tridentata*. None of these species have been studied for their pollination ecology. Kaladhar (2010) and Oyen (2013) mentioned that *M. tridentata* is widely distributed in tropical Africa, Asia and Australia. It is widely used in traditional medicine in Africa and Asia. In India, *M. tridentata* as a perennial soil binding creeper shows its dominance among herbaceous flora during wet season. Recently, this creeper has been used as an effective soil binder in rocky and erosion-prone

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soils. Further, it is also planted as an ornamental in parks and gardens. Keeping in view its importance as a soil binder and ornamental creeper, the present study is contemplated to provide details of pollination ecology of *M. tridentata*. The prime objective of the study is to understand its sexual reproduction, pollinators, fruiting ecology and seed dispersal in this species in order to use this information for its propagation in ecologically fragile areas. Further, the work reported in this paper would provide a reference base for further studies on other species of *Merremia* either in India or elsewhere.

MATERIALS AND METHODS

The wild patches of *Merremia tridentata* growing in Visakhapatnam and its surroundings (17.7000000°N & 82.3000000°E) were used for the study. Ten inflorescences which had not initiated flowering were tagged and followed daily to record the duration of flowering, anthesis schedule and the timing of anther dehiscence. Twenty-five fresh flowers were used to record the floral morphological details. Nectar could not be measured and analyzed due to its secretion in minute quantities which was further depleted by thrips during mature bud and flower life. Twenty mature, but undehiscent anthers were collected from different plants and examined for pollen output as per the method described in Dafni et al. (2005). The calculation of pollen output per flower and pollen-ovule ratio was done as per the formulas described in Cruden (1977). The method described in Mondal et al. (2009) was followed for the analysis of amino acid types in the pollen. The protocol described in Sadasivam & Manickam (1997) was followed for the extraction of protein and the Lowry et al. (1951) method was followed for estimating the protein content in the pollen. 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 the procedure described in Dafni et al. (2005). Further, the receptivity was also observed visually whether the stigma was shiny, wet or changing colours or withering. Twenty patches with 125 mature buds were tagged and followed for four weeks to record fruit and seed set rate in open-pollinations. The morphological characteristics of fruit and seed were observed in detail to evaluate their adaptations for dispersal by different means. Field visits were made during dry and rainy seasons to note the aspects of seed germination and production of new plants. Further, field observations were made on the production of fresh growth and sexual reproduction from the perennial woody root stock of the plant.

Insects foraging at the flowers were observed from morning to evening on four different days for their mode of approach, landing, probing behavior and contact with the floral sexual organs. Bees were identified with the representative specimens available with the Department of Environmental Sciences, Andhra University, Visakhapatnam. Butterflies were identified by consulting the book written by Kunte (2007). The foraging visits of insects were recorded using 1x1 m area of flowering patch for 10mins every hour for the entire day on four different days and the data was tabulated to record the foraging pattern and the percentage of visits made by bees and butterflies. The pollen/nectar collection behaviour of insects was carefully observed to assess their role in effecting pollination. Ten specimens of each insect species were captured during the peak foraging period and brought to the laboratory. Each specimen was washed in ethyl alcohol, stained with aniline-blue on a glass slide and observed under the microscope to count the number of pollen grains present. From this, the average number of pollen grains carried by each insect species was calculated to know the pollen carryover efficiency. Raju & Ramana (2017) followed these methods in previous studies on insect foraging activity and their pollen carryover efficiencies.

RESULTS

Phenology

It is an annual or perennial twining and prostrate herb depending on the soil environment (Image 1a). It commonly occurs in open, dry and sandy soils during rainy and winter season. It roots at the nodes and produces several wiry radiating branches from a thick, woody root stock. It measures up to 2m long. It is multi-stemmed and propagates through seeds as well as by vegetative mode. Leaves are sessile, simple, linear to lanceolate and dentate. The plant re-grows from the perennial ground root stock during the rainy season. Individual plants occurring close to each other form extensive mats due to their profuse growth. It appears conspicuous during the flowering period. The flowering occurs early in individuals emerging from the root stock while it is late in those emerging from the seed. The flowering begins in July in the former and August in the latter. The duration of flowering and the life of the plant depend on the soil moisture condition. But, the flowering is profuse during August-September when the soil is sufficiently wet. If the soil is sufficiently wet even during summer season, the plant survives and produces flowers depending on the soil nutrient status. In such plants, the flowering occurs throughout the



Image 1. *Merremia tridentata*: a - habit; b - white flower; c - lemon yellow flower with dark reddish throat. © A.J. Solomon Raju

year. A closer examination of the flowers of different populations indicated that the plants produce two floral colour forms, one exclusively white flowers (Image 1b) and the other lemon yellow with a dark reddish throat (Image 1c). But, individual plants produce only one flower form. The plants of lemon yellow with dark reddish throat flower form are most common. The plants of the two floral colour forms grow either intermingled with each other or grow displaying distinct populations. The number of twining branches per plant is 18.2 ± 6.46 in white flower form and 24.4 ± 10.90 in lemon yellow flower form during the rainy season. The plants of the yellow flower form are more profuse and spreading than the plants of the white flower form. The flowers are pedicellate (17mm long), solitary, densely villous and borne in leaf axils. They appear quite distinct against the foliage. The plants of both the flower forms with profuse spreading branches with many solitary flowers in a scattered appearance is quite attractive during the flowering season.

Flower morphology

The flowers are dichromatic only by corolla colour. Morphometrics for both flower colours are the same and the description provided here relate to both flower morphs unless otherwise stated. The flowers are small (20.8 ± 0.04 mm long, 17.2 ± 0.04 mm wide), white, campanulate, odourless, actinomorphic and bisexual. The calyx has five free sepals but slightly fused at the base; the sepals are green, densely hairy, lanceolate, acuminate, 4.8 ± 0.04 mm long and 2.2 ± 0.04 mm wide. The corolla is campanulate, glabrous, 18.21 ± 0.13 mm long, tubular at base and shallowly five-lobed with more or less broadly triangular lobes. It is completely white or lemon yellow with a reddish throat. The stamens are white, inserted on the corolla, exerted,

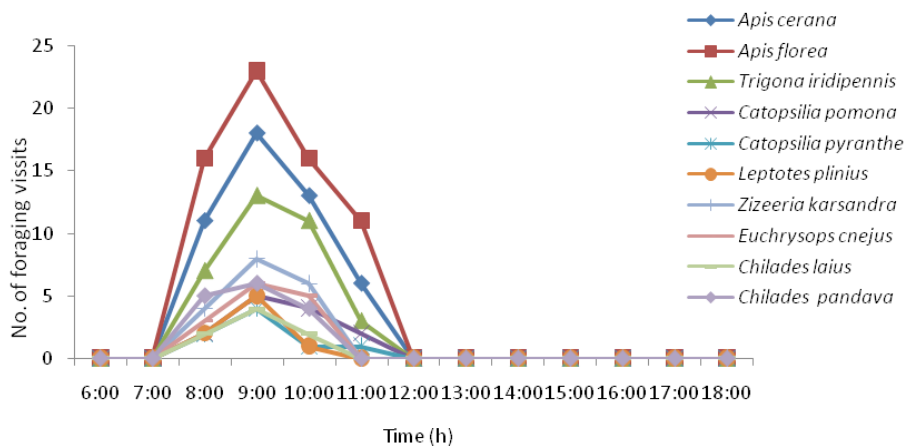
glabrous, filaments filiform and 5.8 ± 0.04 mm long and monomorphic (Image 2a,b). The anthers are white, glabrous, 1mm long and dithecous. The ovary (2.6 ± 0.24 mm long) is light yellow and bicarpellary, bilocular with two ovules arranged on axile placentation in each locule. The style is filiform, light yellow, 6.1mm long and crowned with a sticky, bi-lobed stigma (Image 2d–f).

Floral biology

The dichromatic flowers on different individuals display the same functional characters and the description provided here relate to both. Mature buds open from 07:00–09:00 hr on clear sunny days and from 07:30–09:30 hr on rainy days. The flowers open completely on sunny days while they are partially open on rainy days. The anthesis process from mature bud to fully open flower occurs in a time span of thirty minutes. In mature buds, the corolla is slightly twisted and attains sub-rotate shape after complete opening. The anthers dehisce by longitudinal slits during anthesis and the pollen is presented latroely (the split on the side of the anther positioned towards the other anthers rather than towards the inside or outside of the flower). The number of pollen grains per anther is 265 ± 10.25 and per flower is $1,325 \pm 51.28$ (Image 2c). The pollen-ovule ratio is 331.25:1. The pollen grains are monads, light yellow, sticky initially, powdery later, spheroidal, polyporate, 74.7 ± 1.23 μm and exine smooth with reticulate sculpture. The pollen contains four essential and six non-essential amino acids. The essential amino acids are threonine, valine, isoleucine and lysine. The non-essential amino acids include cysteine, cystine, glutamic acid, hydroxyproline, proline and serine. The total protein content per 1mg of pollen is 285.7 μg . In vitro pollen germination tests were unsuccessful to record pollen viability duration. The stigma becomes receptive at the end of anthesis and remains so until 16:00hr of the same day. The stigma is shiny, sticky, papillate during the receptive phase. The ring-shaped nectary present in the center of the corolla tube, around the base of the ovary secretes nectar in minute quantities during the mature bud stage and it is exposed upon anthesis. It is present in traces in open flowers due to feeding by thrips in buds. Thrips use the growing buds for breeding and emerge by the time the buds bloom. During mature bud, anthesis and post-anthesis, the thrips continually feed on nectar and pollen. The corolla together with the stamens and stigma closes back spirally by 12:30hr on the same day. The pollinated and fertilized flower remains in place while the entire flower falls off in un-pollinated flowers on the morning of the second day.

Table 1. List of insect foragers on *Merremia tridentata*

Order	Family	Genus	Species	Common name	Forage sought
Hymenoptera	Apidae	<i>Apis</i>	<i>cerana</i> F.	Indian Honey Bee	Pollen + Nectar
		<i>Apis</i>	<i>florea</i> F.	Dwarf Honey Bee	Pollen + Nectar
		<i>Trigona</i>	<i>iridipennis</i> Smith	Stingless Bee	Pollen + Nectar
Lepidoptera	Pieridae	<i>Catopsilia</i>	<i>pomona</i> F.	Common Emigrant	Nectar
		<i>Catopsilia</i>	<i>pyranthe</i> L.	Mottled Emigrant	Nectar
	Lycaenidae	<i>Leptotes</i>	<i>plinius</i> F.	Zebra Blue	Nectar
		<i>Zizeeria</i>	<i>karsandra</i> Moore	Dark Grass Blue	Nectar
		<i>Chilades</i>	<i>laius</i> Stoll	Lime Blue	Nectar
		<i>Chilades</i>	<i>pandava</i> Horsfield	Plains Cupid	Nectar
		<i>Euchrysops</i>	<i>cnejus</i> F.	Gram Blue	Nectar

Figure 1. Hourly foraging activity of bees and butterflies on *Merremia tridentata*

Pollination mechanism

The flowers display different positions of the stamens and the stigmas during and after anthesis. Of the five stamens, one stands close to and/or contacts with the stigma due to the attachment of the filament at a different position on the corolla tube throughout flower life. Such a placement of this stamen and the stigma may facilitate autogamy but it is not definite. All other four stamens stand slightly below the stigma preventing autogamy throughout flower life. Such differential positions of stamens in relation to the stigma appear to be facilitating partial selfing during flower life. The closing of the corolla in a spiral manner at noon time facilitates brushing of the stigma against all anthers effecting autogamy. Such a floral mechanism is considered to be a fail-safe strategy by the plant to resort to autogamy in the event of failure of either geitonogamy or xenogamy.

Insect visitors and pollination

The insect foragers were the same to both the flower forms; they visited both the forms without any discrimination but comparably, the yellow flower form was found to be more attractive to them. Thrips were the first feeders of both nectar and pollen. They were found to be contributing to primarily self-pollination by feeding on both pollen and nectar during mature bud and during and after anthesis. The flowers were foraged by honey bees and stingless bees from 08:00–11:00 hr with concentrated foraging activity at 09:00hr, and by pierid and lycaenid butterflies from 08:00–10:00 hr with concentrated foraging activity at 09:00hr (Fig. 1). The bees included *Apis cerana* (Image 2i), *A. florea* (Image 2g,h) (honey bees) and *Trigona iridipennis* (stingless bees). The pierid butterflies were *Catopsilia pomona* (Image 2j) and *Catopsilia pyranthe* while lycaenid butterflies included *Leptotes plinius*, *Zizeeria karsandra*, *Chilades laius*, *Chilades pandava* (Image 2k) and *Euchrysops cnejus* (Table 1). Of the total foraging visits recorded during the

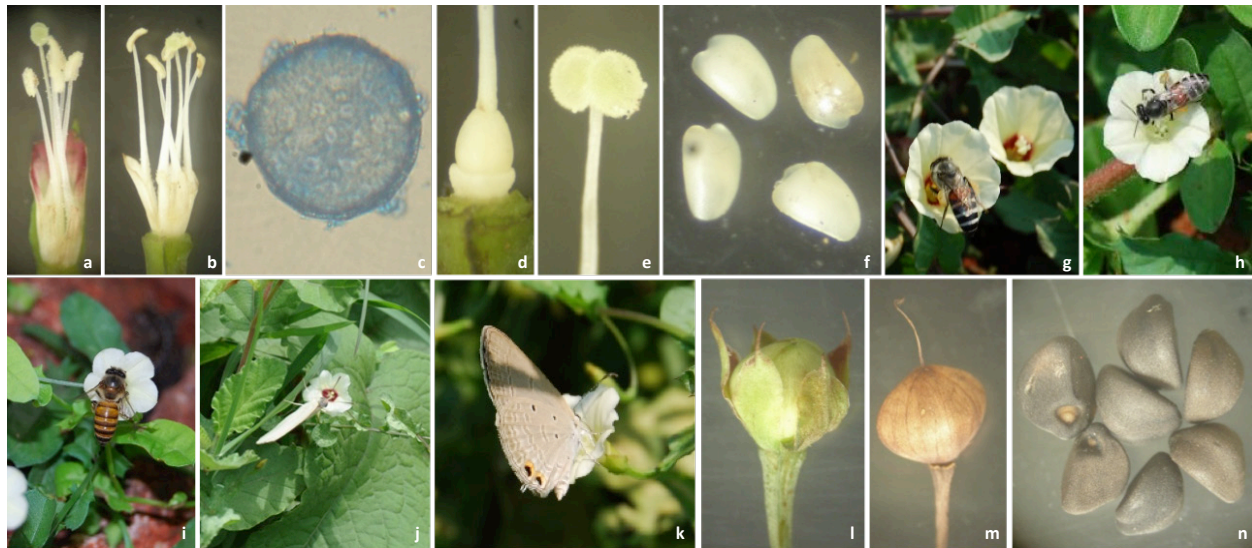


Image 2. *Merremia tridentata*: a - lemon yellow flower stamens and stigma; b - white flower stamens and stigma; c - pollen grain; d - ovary; e - capitata stigma; f - ovules; g - *Apis florea* collecting pollen from lemon yellow flower form; h - *Apis florea* collecting pollen from white flower form; i - *Apis cerana* collecting nectar from white flower form; j - *Catopsilia pomona* collecting nectar; k - *Chilades pandava*; l & m - mature and dry fruits; n - seeds. © A.J. Solomon Raju

observation period, honey bees and stingless bees made 65% while pierid and lycaenid butterflies contributed to 35% (Fig. 2). The bees approached the flowers in upright position, landed on the corolla and probed for pollen and/or nectar. To collect nectar, they inserted their hairy tongue (proboscis) into the corolla throat to access the available nectar; in so doing, the ventral side brushed against the dehiscent anthers and the stigma effecting sternotribic pollination. To collect pollen, the bees approached individual anthers during which only the ventral side and the stigma brushed against the anthers effecting sternotribic pollination. In most of the foraging visits, the bees probed for nectar and pollen while in other visits, they collected either nectar or pollen. The butterflies approached the flowers with head facing the corolla throat; then they inserted the proboscis to collect nectar during which their ventral side and/or proboscis brushed against the anthers and the stigma effecting sternotribic pollination. The bees and butterflies visited 9–14 flowers consecutively and in some cases up to 25 flowers depending on the flower density before leaving the flowering patch. As the flowers were depleted of nectar by thrips, the insects made multiple visits to the same flowers in quest of nectar and/or pollen. The pollen carrying efficiency evaluated by body washings of captured insects indicated that honey bees were more efficient in carrying pollen than stingless bees and butterflies; the average number of pollen grains recorded varied from 68.7–50.8 in case of honey bees and 26.7 in case of stingless bees and from 19.9–12.5

in case of butterflies (Table 2). The insects foraged the flowers in quick succession from one flower to the other on the same and/or different flowering patches in order to collect as much pollen and/or nectar as possible; this inter-plant foraging activity was considered to promote cross-pollination.

Fruiting ecology

In the two flower forms, the pollinated and fertilized flowers grow continually and produce fruits in three weeks (Image 2l,m). Natural fruit set rate is 89.6% and seed set rate is 74.6%. The calyx is persistent and grows further during fruiting phase; it envelops the growing fruit. It is a globose capsule, green initially and brown when mature; it is stalked, non-fleshy, non-hairy, 4–5 mm long and 4–9 mm diameter. A single fruit produces one to four seeds. One-seeded fruit set rate is 5%, two-seeded 8%, three-seeded 37% and four-seeded 50%. The seeds are dull black, smooth, ovoid-trigonous, and 3mm in diameter (Image 2n). The fruit capsules dehisce loculicidally to disperse seeds. The dispersed seeds fall to the ground. They further disperse by wind and rainwater. The seeds germinate and form new plants if the soil is sufficiently wet. But, seed germination occurs mainly during the rainy season when the soil is charged with moisture or rain water. Erratic rainfall and long dry spells during the rainy season terminate the growth and development of seedlings. The old plants with their robust underground woody root system withstand water stress and continue their phenological events

Table 2. Pollen recorded in the body washings of bees and butterflies on *Merremia tridentata*

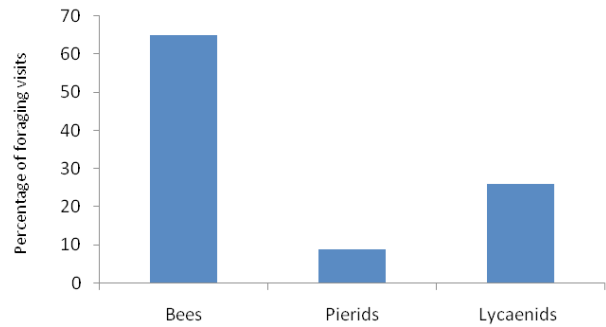
Insect species	Sample size (N)	Number of pollen grains		
		Range	Mean	S.D
<i>Apis cerana</i>	10	26–103	68.7	23.22
<i>Apis florea</i>	10	32–78	50.8	12.27
<i>Trigona iridipennis</i>	10	15–46	26.7	8.82
<i>Catopsilia pomona</i>	10	7–24	14.5	5.31
<i>Catopsilia pyranthe</i>	10	8–29	14.1	6.05
<i>Leptotes plinius</i>	10	5–23	12.5	4.69
<i>Zizeeria karsandra</i>	10	9–21	13.8	3.48
<i>Chilades laius</i>	10	10–23	14.6	4.17
<i>Chilades pandava</i>	10	12–28	19.9	4.63
<i>Euchrysops cnejus</i>	10	6–26	15.2	6.8

sequentially.

DISCUSSION

Merremia tridentata produces several wiry radiating branches from the thick, woody root stock. It grows throughout the year and displays profuse to sporadic flowering depending on the soil moisture and nutrient environment. The plant disappears if the soil is dry but the woody root stock stays alive under-ground to re-start its life cycle when favourable conditions return. Seed production is continuous in plants growing in areas of moist soils; seeds germinate almost immediately if soil environment is favourable but new plants from seeds appear mostly during the rainy season. With these dual modes of regeneration, it shows prolific growth during the rainy season. The plant grows well in open, sandy and dry localities. It is easy to spot in the field with its twining wiry branching habit, large patches and large brightly coloured and campanulate flowers. Two flower forms are distinguished based on corolla colour; one is completely white while the other is lemon yellow with dark reddish throat. Individual plants produce only one flower form. The lemon yellow flower form is most common with profuse growth due to more number of wiry branches than the other one. This study is the first to document the existence of two flower forms in this species. The plants of the two flower forms grow either intermingled with each other or produce distinct populations. The solitary flowers borne in leaf axils project out against the foliage, appear attractive and hence is easy to spot the plant in the field.

In *Merremia*, self-compatibility and self-

**Figure 2.** Percentage of foraging visits of bees and butterflies on *Merremia tridentata*

incompatibility have been reported in the studied species. *M. cissoides* and *M. aegyptia* are self-compatible (Maimonia-Rodella & Rodella 1987) and *M. palmeri* is self-incompatible (Willmott & Burquez 1996). The present study shows that *M. tridentata* is highly self-compatible due to which it shows the highest fruit set and seed set rates in open-pollinations. The low pollen-ovule ratio recorded in this plant also substantiates this claim. The low pollen output is relatable to the pollen size also. Cruden (1977) stated pollen-ovule ratios can serve as a reliable indicator of breeding system. High pollen-ovule ratios are normally associated with obligate out-crossing, moderate pollen-ovule ratios with facultative xenogamy and low pollen-ovule ratios with obligate autogamy. The low pollen-ovule ratio in *M. tridentata* can be taken as an indicator of obligate autogamy. But, the flower behavior differs partially with this indication. In open flowers, one of the five stamens is positioned close to the stigma due to which autogamy may occur but it is not absolute while all other four stamens stand away from the stigma precluding the occurrence of autogamy. However, all five stamens would brush against the bilobed stigma during the closing of the corolla in a spiral manner at noon and in effect, autogamy occurs since the stigma is still receptive and the receptivity ceases long after the closure of the corolla. The delayed autogamy keeps the option open for cross-pollination during flower life and it has obvious fitness benefits in habitats where there is much spatial and/or temporal variation in the availability of pollen vectors (Morgan 2006). This means that when the pollinator availability is constant and adequate, plants can maximize their out-crossed seed set and then use delayed autogamy to fertilize any remaining ovules, while if pollinators are absent the ovules may still be fertilized by autogamy and still retain a high relative fitness if inbreeding depression is low (Pannell 2006). Therefore, the positional aspects of the stamens and stigma during flower life and at the closing

of the corolla and the low pollen-ovule ratio collectively suggest that *M. tridentata* is facultative autogamous.

Merremia tridentata flowers are nectariferous but the nectar is secreted in minute quantities, which is not measurable. It is available during mature bud stage and is utilized by thrips, which use the buds for their breeding. Since the stigma is receptive after anthesis, the nectar and pollen feeding activity of thrips does not contribute to self-pollination before anthesis but contributes mostly to self-pollination after anthesis. Further, the differential positions of stamens in relation to the position of stigma may also reduce the chances of occurrence of selfing within the flowers. The left over nectar present in traces in the flowers compels the actual nectar-feeding pollinator insects to make multiple visits in search of more nectar and in effect, cross-pollination rate is enhanced. Further, the pollen feeding activity by thrips also indirectly increases the flower visitation rate by pollen-feeding pollinator insects. Therefore, such a state of standing crop of nectar before and after anthesis due to foraging activity by thrips is advantageous for the plant to increase cross-pollination rate. This finding is in agreement with the note by Hodges (1995) that an overabundance of nectar may have a detrimental effect on seed set by increasing intra-plant pollinator movement.

In the genus *Merremia*, a few species have been studied for their pollination biology. Raimundez-Urrutia et al. (2008) reported that *M. macrocalyx* displays melittophilous pollination syndrome and is pollinated by bees of Apidae and Halictidae. Kill & Ranga (2000) reported that *M. aegyptia* is pollinated by bees of Apidae and Halictidae. Maimonia-Rodella & Rodella (1987) reported that *M. cissoides* is mostly pollinated by bees. Willmott & Burquez (1996) reported that *M. palmeri* is sphingophilous. In the present study, *M. tridentata* has patchy distribution and its showy bloom may serve as a long distance attractant. The large patches increase the availability of cross-pollen and encourage flower constancy by potential pollinators. The early morning pattern of floral nectar secretion in synchrony with the process of anthesis in this species appears to be an adaptation for foraging activity and subsequent pollination by day-active insects. Despite such an abundance of flowers, even during rainy season, the flowers are pollinated by a few insects only. The flowers are pollinated by honey bees, stingless bees and lycaenid butterflies. These insects foraged the flowers only during forenoon period since the flowers are not available in the afternoon due to closure of the flowers by noon. The bees contribute to sternotribic pollination

while collecting nectar and pollen. The pollen is protein-rich and also a source of four essential and six non-essential amino acids for bees (DeGroot 1953). Similarly, butterflies also contribute to sternotribic pollination while collecting nectar. The body washings of these insects collected after foraging indicated that bees are efficient in carrying more pollen than butterflies and hence bees are the primary pollinators while butterflies are supplementary pollinators. Therefore, the pollinator guilds recorded in this study indicate that thripsophily, melittophily and psychophily exist in *M. tridentata*.

In Convolvulaceae, dormant and non-dormant seeds have been reported. In case of non-dormant ones, recalcitrant seeds have also been documented in this family (Daws et al. 2005). The reports by Sharma & Sen (1975) and Azania et al. (2003) indicate that *Merremia* species have physical dormancy and it might have evolved from species with non-dormant recalcitrant seeds. In this study, *M. tridentata* has been found to produce non-dormant recalcitrant seeds since the seeds germinate as soon as they reach the ground but it occurs only in soils which are sufficiently moist. But, most of the seeds germinate and produce new patches during rainy season and such a situation explains that the seeds are partially recalcitrant and the dormancy factor is related to the state of soil moisture and nutrient environment. In recent years, rainfall is insufficient and also long dry spells exist within rainy season. In consequence, the seedlings are struggling to survive and if there is not enough soil moisture, they do not show any further growth and subsequently perish. However, the re-growth from the well established old root stock withstands rain deficit and produces new plants alleviating the loss of seedlings from the seeds to some extent. Therefore, the observed level of seed dormancy and the production of new plants from the old root stock enable the plant to occupy various habitats to extend and expand its distribution range. In this context, it is appropriate to mention that the capsule form of fruit dehisces loculicidally facilitating seed dispersal to different distances on the ground and the smooth and ovoid-trigonous seeds subsequently disperse through wind and rain water characterizing anemochory and hydrochory. These three modes of seed dispersal benefit the plant to invade and colonize new areas.

In the literature, there is only one report on the natural bio-controlling agent to control the weeds of *Merremia* genus. Raimundez-Urrutia et al. (2008) reported that the bruchid beetle, *Megacerus flabelliger* is the natural controlling agent for *M. macrocalyx*. This beetle uses the seeds for its breeding and hence is

considered to be a natural control for this weed. In the present study, the seeds of *M. tridentata* are not used by any beetle or other insect for its breeding. But, further studies across different regions of its distribution range are recommended to find out whether there is any such natural controlling agent for this weed.

The patchy distribution of *M. tridentata* provides the needed forage to all flower visiting insects almost throughout the year depending on the soil moisture and nutrient status. But, the forage is available mainly during forenoon period since the flowers close back by noon. The plant builds up populations seasonally and then cover the soil, reduce soil erosion during rainfall, and add organic matter to the soil upon withering and decomposition, the aspect of which assumes importance with reference to infiltration and percolation of rain water during rainy season. The study clearly indicates that *M. tridentata* is a successful colonizer, especially of open, sandy dry areas and play many ecological roles in supporting local insects and in the protection of soil cover.

Progressive anthropogenic disturbance of natural habitats is one of the greatest problems for the last few decades. Many environmental agencies direct to stop non-reversible environmental damage and to promote spontaneous restoration. In many cases, programs of environmental management are designed for multiple purposes for which woody species are preferred while shrubs and herbaceous species are less commonly considered for habitat restoration. Bradshaw (1987) stated that restoration of degraded areas would more likely be successful if native species were used. Knapp & Rice (1996) noted that there is a widespread interest in native herbs due, in part, to the recent availability of plant material as well as recognition of the role of native herbal species in the restoration of biological diversity and the conservation of endangered species and habitat. In this context, *M. tridentata* is a promising candidate for the restoration of the ecological niches where they successfully grow and colonize. Needless to say, this plant is an effective soil binder with its clustered root system and spreading form of multi-stemmed branching pattern. Therefore, it is an important herb in the natural and artificial restoration of habitats which are either destroyed or degraded or damaged.

Merremia tridentata is widely used in traditional medicine in Africa and Asia, especially in India. It has ornamental value due to its large and bright showy flowers. It is a good feed material for cattle, sheep and other livestock (Kaladhar 2010; Oyen 2013). This plant has been documented to be useful as a supplementary

feed to the grass *Panicum maximum* in housed sheep during the rainy season in West Africa. It has high protein, low fiber and tannin content and hence has been considered to be worth using as a supplement to *P. maximum* for young West African Dwarf sheep. Further, it is easy to harvest this weed and minimizes the cost of supplying the feed when used (Aschfalk et al. 2002). Since *M. tridentata* is used in traditional medicine and also as fodder, it can be scientifically used in the modern forms of medicine and also as a potential fodder supplement while allowing it to grow in areas where it is not a menace from the human point of view.

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