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The Roles of Bees and Hoverflies in the Pollination of *Jacquemontia evolvuloides* (Moric.) Meisn. (Convolvulaceae) in a Semiarid Region

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Abstract

Jacquemontia species are often found in disturbed areas, and their flowers are ephemeral and very attractive to insects. We investigated the interaction between the flowers of *Jacquemontia evolvuloides* and its visitors, with emphasis on potential pollinators, considering morphological, temporal, and behavioral aspects, between September/2009 and August/2010 in an anthropized area in Bahia State, Northeastern Brazil. *Jacquemontia evolvuloides* flowers are diurnal, ephemeral (approximately five to six hours duration), are present throughout the year, and offer nectar and pollen rewards. Because of the floral morphology of *J. evolvuloides* insect visitors have easy access to its resources, and its pollination could be considered generalized. While *J. evolvuloides* flowers are visited by several insects, only small bees (*Augochlora* spp.) and syrphids (*Toxomerus* spp.) appear to play a role in pollination of flowers. Although bees have been considered efficient pollinators of that plant, the significant presence of syrphids (considered occasional pollinators but showing high frequency visitation), may indicate their role as potential pollinators, especially when bees are not abundant in the fall/winter. As such, even in pollination systems that are considered generalized (with flowers allowing easy access to various visitor groups), visitor size may be an important factor for efficient pollination, especially when associated with high visitation frequencies.

Introduction

Many ruderal plants grow in urban and agricultural environments and are considered pests due to their invasive natures (Souza & Lorenzi, 2008), and are usually overlooked for pollination studies. But those plants often display striking floral advertisements (e.g., bright colors) and offer attractants (such as pollen and nectar) that help maintain native and non-native floral visitors, many of which are also important pollinators of local plants. Ruderal species of Convolvulaceae are common in anthropogenic environments, but rarely studied, as is the case of weed species of *Jacquemontia* Choisy (Simão-Bianchini & Pirani, 2005) with significant ornamental potential (Judd et al., 2009). More research is needed to know which species of weeds are beneficial and use them to attract pollinators. These plant species also occur on the edges fields and are important for the maintenance of pollinators (Nicholls & Altieri, 2013; Garibaldi et al., 2016).

Jacquemontia comprises approximately 120 species (Staples & Brummitt, 2007) found throughout the tropical Americas, occurring as natives in several vegetation formations. *Jacquemontia evolvuloides* (Moric.) Meisn. Is widely distributed, occurring mainly in the Cerrado, Atlantic Forest, and Caatinga phytophysiognomies (Bianchini & Ferreira, 2010). Their flowers are very attractive to insects, mostly bees (Piedade-Kiill & Ranga, 2000; Pinto-Torres & Koptur, 2009; Rodriguez et al., 2010; Silva et al., 2010; Kiill & Simão-Bianchini, 2011), as well as to larger animals such as hummingbirds (Machado, 2009).

Information about the reproductive strategies and the pollinators of *Jacquemontia* species is important because, as a ruderal plant, it produces many flowers with colorful corollas and nectar and pollen resources that can contribute to the maintenance of native pollinators in anthropized and agricultural areas (Piedade-Kiill & Ranga, 2000). *Jacquemontia* flowers are ephemeral and last less than 10 hours (Silva et al., 2010), limiting the window of time for collecting resources, a fact that must be taken into account in pollination studies. Considering the importance of ruderal plants in urban areas for the maintenance of local pollination communities, we investigated the floral biology of *J. evolvuloides,* with emphasis on the morphological, behavioral, and temporal aspects of its floral visitors as related to pollinating efficiency.

Materials and Methods

The present study was carried out on the campus of the Universidade Estadual de Feira de Santana – UEFS, in Feira de Santana, Bahia State, Northeastern Brazil (12º11'56''S, 38º58'07''W). The original local vegetation of the area was dryland Caatinga (thorny, deciduous, shrub/arboreal) vegetation, but it is presently supplemented with introduced and invasive plants due to anthropization (Santana & Santos, 1999). The local climate is classified as BSh or semiarid (Köppen's classification), with average monthly temperatures ranging between 20.7 and 26.8 ºC, and total annual rainfall between 500 and 800 mm (SEI, 2011).

Observations were performed on a monthly basis from September to November/2009, January/2010, and from April to August/2010. Climatic data (temperature and relative humidity) were recorded using a digital thermohygrometer at hourly intervals during all of the field observations following anthesis. Rainfall, average temperatures, and relative humidity data were obtained from the UEFS Climatology Station (Fig 1).

Jacquemontia evolvuloides is a creeping, prostrate shrub that usually occurs in cultivated areas, vegetable gardens, and orchards. It forms wide carpets covering the ground that inhibit the growth of other plants (Moreira & Bragança, 2011). It occurs spontaneously in the study area at vegetation borders, in clearings, and along roadsides. Due to the difficulty of individualizing the plants, we considered all of the individuals present in a 15 m x 13 m area (195 m²) during our field observations.

Flowering was recorded monthly by counting all open flowers in the sampling area. To verify any correlations between meteorological variables and the numbers of flowers, a Simple Correlation Test was carried out using SPSS 8.0 software for Windows. To control error accumulations in the confidence intervals for each variable, the Bonferroni correction was used, dividing the level of significance by 4 (p=0.0125). For morphological studies, ten flowers from different individuals were fixed in 70% alcohol and subsequently measured using a digital caliper to determine corolla diameter and length, and the sizes and dispositions of the reproductive structures. These values were used for calculating flower size, which was classified according to Machado and Lopes (2004).

Flower anthesis and pollen availability were recorded (n = 10 flowers) for three consecutive days each month. Stigmatic receptivity was determined by immersing the stigmas in 10% hydrogen peroxide (H_2O_2) (Dafni & Maués, 1998) at hourly intervals starting at the bud phase through closing. The presence of osmophores was determined by immersing the flowers in a 1% neutral red solution for 15 minutes (Dafni et al., 2005). In order to verify flower odor, fresh flowers were stored in a closed recipient for one hour. Ultraviolet pigments were detected in flowers by exposing them to ammonium hydroxide vapors (P.A.) for 30 seconds, and then examining them for color changes (adapted from Scogin et al., 1977). These procedures were carried out with ten flowers throughout the flowering period.

Floral reproductive biology was analyzed through pollination experiments, using 15 flowers in the pre-anthesis stage in each treatment: apomixis, spontaneous and induced self-pollination, manual cross pollination (xenogamy), and control (natural conditions). The flowers used in the experiments were emasculated and bagged, when appropriate, and followed until fruit formation. Pollination success was estimated based on the fruit formation rates of marked flowers. The chi-squared test ($p<0.01$) was used to determine if there were differences among the pollination experiments in terms of fruit formation.

Floral visitors were observed and collected during three days (two days for collecting of individuals and one for behavioral observations and visitor visit counts) from 05:00 to 16:00 h, at 30 min intervals during every hour of observation during the study months, at one area of 15 m x 13 m (195 m²). In study area the number of flowers observed varied during each month (82 flowers in November to 337 in June). The behaviors of the floral visitors were determined using direct observations, videos, and photographs. Only the numbers of floral visits by the most abundant and constant insects were taken into consideration in the analyses of daily activities. Daily activities were analyzed during the dry (Austral spring: September, October, and November) and rainy (Austral autumn/winter: May, June, and July) trimesters. For visitor species of difficult identification, the numbers of visits were considered at the family level (as for example, Halictidae).

The Spearman correlation test was used for the analyses of the numbers of open flowers, numbers of sampled visits, numbers of visitors collected, and climatic factors, using

SPSS 8.0 software for Windows, with a Bonferroni correction ($p<0.01$). The normality of the data was verified using the Kolmogorov-Smirnov test ($p<0.05$), also run on SPSS 8.0 software for Windows.

The sizes of floral visitors were determined by measuring the total lengths (from the median ocellus to the end of the abdomen) and widths (intertegular distance) of ten individuals of each visiting species. Flower visitors size classification was based on the parameters proposed by Viana and Kleinert (2005). Visitor constancy was calculated using the formula: C = (number of samples with the species/ number of samples) x 100. The species were classified as C = constant (C > 50%), A = accessory (C = > 25% < 50%), or Ac = accidental (C < 25%) (Thomazini & Thomazini, 2002).

Glycerol gelatin semi-permanent slides were made with pollen from the bodies of the most frequent and constant floral visitors for analysis. Seven individuals of each visiting species were analyzed, and five slides were made from each individual. The criteria used for evaluating the pollinators were: frequency, constancy, behavior, daily activity, body dimensions compatible with floral dimensions, contact with the reproductive structures of the plant, and pollen load analysis.

The floral visitors collected were deposited in the Prof. Johann Becker Entomological Collection at the Zoology Museum of the Universidade Estadual de Feira de Santana (MZFS). The botanical voucher specimens were deposited in the UEFS (HUEFS 159.600) and Maria Eneyda P. Kauffmann Fidalgo herbaria (SP 420.331).

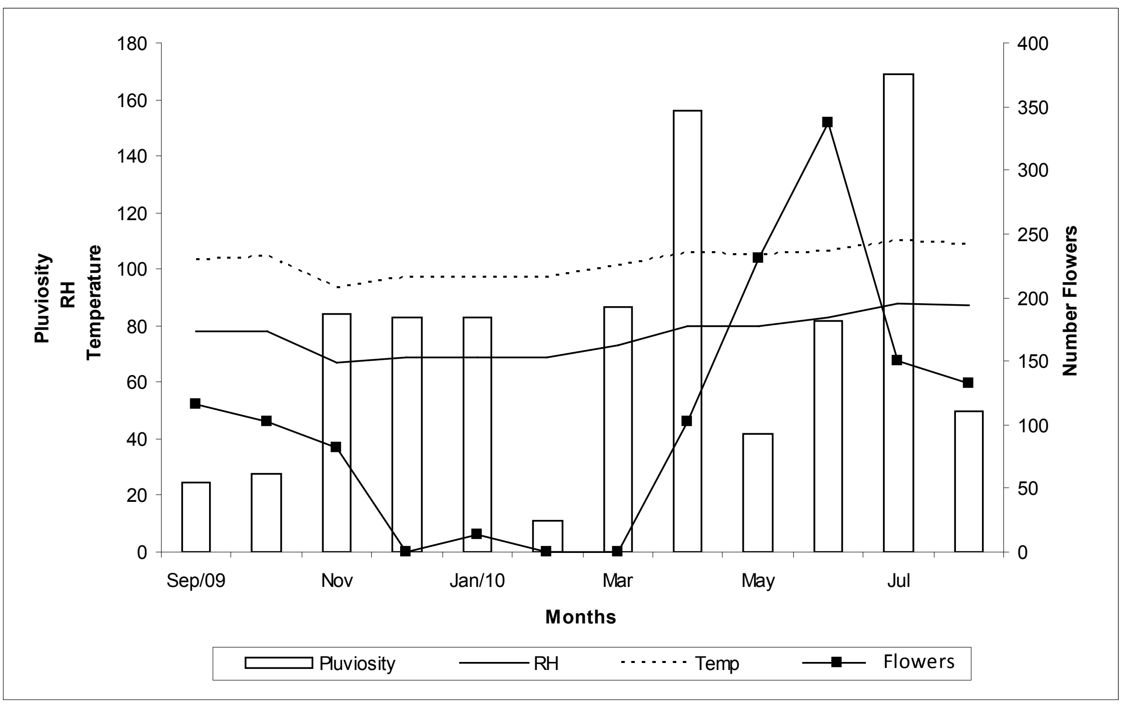


Fig 1. Number of flowers in *Jacquemontia evolvuloides* (Convolvulaceae), and rainfall (mm), relative humidity (%), and temperature (°C) in anthropized semiarid (area observed: 195 m^2), of Bahia State, Northeastern Brazil, between September/2009 and January 2010, and between April and August/2010. Source: UEFS Climatology Station.

Results

Jacquemontia evolvuloides flowering was continuous during the months of observation, but with variations in the number of flowers. The greatest number of flowers were observed in May and June/2010 (231 and 337 open flowers respectively); the lowest number of flowers (n = 14) was observed in January/2010 (Fig 1). Correlation tests performed showed no significant correlation between the number of flowers and the climatic variables of temperature ($r = -0.711$, $p>0.0125$) or rainfall ($r = -0.38$, $p>0.0125$), but showed a statistically significant correlation with relative humidity ($r = 0.152$, $p<0.0125$).

The flowers of *J. evolvuloides* are held in simple axillary cyme inflorescences, presenting one to three open flowers daily, with approximately 18 flower buds in different stages of development. The shallow, funnel-shaped flowers are odorless to humans and do not show osmophores; ultraviolet-reflecting pigments were detected in the corolla and anthers. The corolla is 20.7 ± 1.3 mm wide (average ± SD) and 17.5 ± 1.9 mm deep, being large, conspicuous, with blue flowers with a lilac inner-central region (Fig 2).

The androecium is white and surrounds the pistil. The two largest stamens are 8.5 ± 0.2 mm long, while the three smaller stamens measure 7.1 ± 0.2 mm. The anthers are white, 1.5 ± 0.1 mm long, with outward rimose dehiscence in relation to the corolla tube. The gynoecium is white, the stigma 8.2 ± 0.7 mm long, with a discoid nectary surrounding the ovary.

Fig 2. (A) Flower of *Jacquemontia evolvuloides* (Convolvulaceae). Detail of the reproductive structures. (B) Detail of a floral visitor bee (*Augochlora* sp., Halictidae).

The anthesis of *J. evolvuloides* flowers occurs in the morning. Pollen is available to flower visitors from the moment of opening, and the stigma is receptive immediately and remains so until senescence; the flowers last approximately five to six hours. The first flowers of *J. evolvuloides* open near 05:30 h, with full opening generally occurring between 06:40 and 07:00 h, with a longer delay during the winter months due to lower temperatures and later sunrises. The flowers close between 11:47 and 14:09 h (Table 1). The flowers opened and closed later in June and July when temperatures were lower and the photoperiod shorter (later sunrises).

Fruit set in both manual and spontaneous self-pollination experiments suggest that *J. evolvuloides* is self-compatible (Table 2), although there were significant statistical differences between the treatments ($c^2 = 26.558$, $p<0.01$). Fruit set was observed in both the manual and spontaneous self-pollination experiments, but the highest fruit set rates were observed in cross-pollination experiments and in the control group, and with no occurrence of apomictic fruits (Table 2). The fruits of *J. evolvuloides* are dry capsules, usually containing four light-black, pubescent seeds, which are formed within 7 to 10 days.

Table 1. Average values (± standard deviation, SD) of the opening and closing times of flowers of *Jacquemontia evolvuloides* (Convolvulaceae), and average temperatures (T) in an anthropized semiarid area of Bahia State, Northeastern Brazil, during the months between September/2009 and January/2010, and between April and August/2010. Flower Opening = FO, Flower Closing = FC, Flower duration = FD.

Months	FO	± SD	T (ºC)	FC	± SD	T (ºC)	FD
Sep-2009	06:40	00:09	22.6	12:20	00:19	33.5	05:39
Oct-2009	06:54	00:17	25.3	12:56	00:46	28.5	06:02
Nov-2009	07:00	00:17	26.8	12:21	00:30	34.4	05:19
Jan-2010	06:57	00:18	26.7	11:52	00:09	31.7	04:55
Apr-2010	07:00	00:09	26.2	11:47	00:24	30.6	04:45
May-2010	07:18	00:30	22.4	12:13	00:17	27.3	04:55
Jun-2010	08:05	00:22	20.6	13:42	01:08	26.6	05:37
Jul-2010	08:51	00:39	22.0	14:09	01:12	24.6	05:18
Aug-2010	06:54	00:12	21.8	12:31	00:23	28.4	05:37

The flowers of *J. evolvuloides* were visited by small (48.3%) and medium small-sized (16.1%) insects. A total of 159 insect individuals were sampled, and 543 visits to the flowers were recorded, distributed among 31 insect species. Most of the floral visitors were classified as accidental (84.5%), 12.5% were considered accessory, and 3% were constant. Among them, the most frequent were: *Toxomerus watsoni* (Syrphidae, Diptera) with 50 individuals collected and 157 floral visits and Halictidae (Fig 2) (especially the genus Augochlora), with 25 individuals collected and 175 floral visits. *T. watsoni* and *Augochlora* spp. were responsible for

Table 2. Results of the reproduction experiments carried out with *Jacquemontia evolvuloides* (Convolvulaceae) flowers, in an anthropized semiarid area of Bahia State, Northeastern Brazil, during the months between September/2009 and January 2010, and April and August/2010.

Treatment	Flowers (n)	Fruits (n)	%
Apomixis	15	0	0
Spontaneous self-pollination	15	2	13.3
Hand self-pollination	15	5	33.3
Hand cross-pollination	15	11	70.3
Natural pollination (control)	15	10	66.7

61% of the total floral visits, and both were also considered constant on the flowers (Table 3).

Although there was no correlation between the number of floral visitors and climatic factors (p>0.01), some trends were detected. When comparing the two study trimesters in relation to insect visits, we observed that the rainiest trimester (May, June and July, Austral autumn/winter) had the largest number of flowers (719), but the bees visited fewer flowers (41 visits) than dipterans (125 visits); butterflies visited 44 times and wasps did not appear. The driest trimester (September, October, November, Austral spring) had the lowest number of flowers (302), and bees were observed in higher numbers than dipterans (112 and 12 visits respectively); Lepidoptera species visited 8 flowers, and wasps 79 (Fig 3).

Individuals of the orders Lepidoptera, Hymenoptera, and Diptera visited flowers to collect resources from the beginning of anthesis to flower senescence, sometimes arriving even before the flowers were fully open. Their visits were more abundant in the interval between 07:00 and 11:00 h, decreasing along the day during both the spring and autumn/winter seasons.

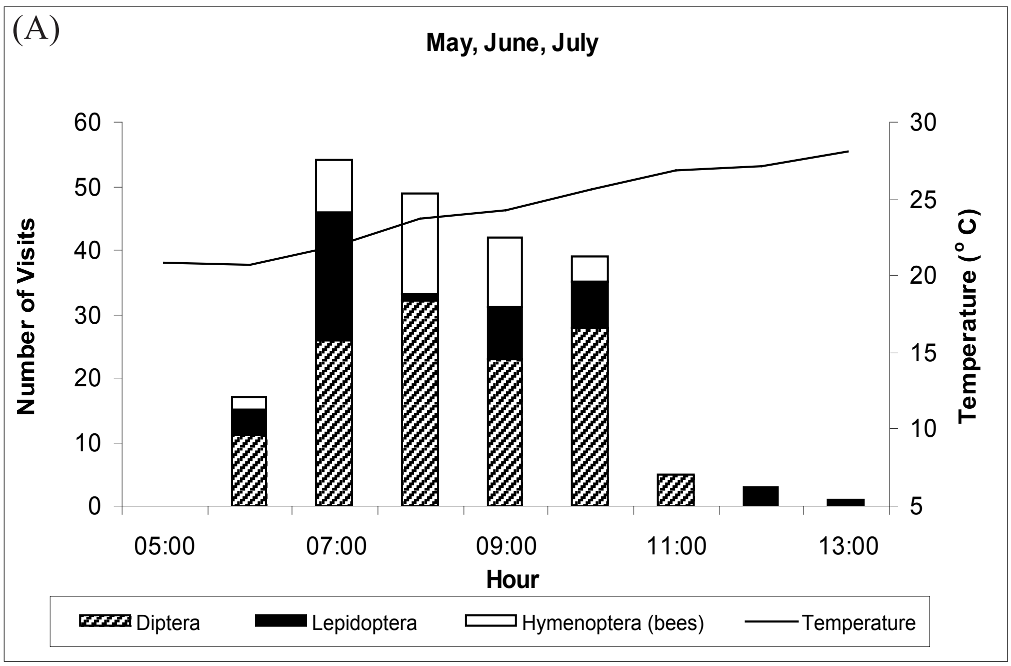
Floral resource collection behavior varied among the different groups of insects visiting *J. evolvuloides*. Lepidopterans collected nectar by landing on the corolla and inserting their proboscis into the nectary, quite close to the

Table 3. Numbers of insect visits (NV), numbers of insect individuals (NI), and the resources collected (RC) from *Jacquemontia evolvuloides* (Convolvulaceae) in an anthropized semiarid area of Bahia State, Northeastern Brazil, during the months between September/2009 and January/2010, and between April and August/2010. (Size: MR = Medium robust, MI = Medium intermediate, MS = Medium small, S = Small; Resource Collected (RC): Ne = Nectar, Po = Pollen. Constancy (Co): C = constant, A = accessory, Ac = accidental). Presence of pollen on the insect body (PPB: Yes = Y, No = N, O = occasionally).

Insect visitors	NI	NV	Size	RC	PPB	Co
COLEOPTERA						
Bruchidae sp. 1	3	3	S	Ne	N	Ac
DIPTERA						
Bombyliidae sp. 1	2	2	S	Ne	N	Ac
Syrphidae						
Pseudodorus clavatus (Fabricius, 1794)	5	3	MS	Ne	N	A
Toxomerus productus (Curran, 1930)	2	6	S	Ne	O (Head)	Ac
Toxomerus watsoni (Curran, 1930)	50	157	S	Ne	O (Head)	C
HYMENOPTERA						
Apidae						
Apis mellifera Linnaeus 1758	8	16	MI	Ne	N	A
Trigona spinipes (Fabricius, 1793)	3	1	S	Ne	N	Ac
Halictidae		175				C
Augochlora sp. 1	3	--	MS	Po/Ne	Y (Head, Thorax)	
Augochlora sp. 2	13	--	S	Po/Ne	Y (Head, Thorax)	
Augochlora sp. 3	2	--	S	Po/Ne	Y (Head, Thorax)	
Augochlora sp. 4	7	--	S	Po/Ne	Y (Head, Thorax)	
Pseudaugochlora pandora (Smith, 1853)	2	--	MS	Po/Ne	Y (Thorax)	
Vespidae						
Polybia occidentalis (Olivier, 1791)	3	92	MS	Ne	N	Ac
LEPIDOPTERA						
Hesperiidae						
Hesperiidae sp. 1	1	6	MR	Ne	N	Ac
Hesperiidae sp. 2	1	2	MR	Ne	N	Ac
Hesperiinae sp. 1	8	26	MI	Ne	N	Ac
Pyrgus orcus (Stoll, 1780)	8	26	S	Ne	N	Ac
Pyrgus veturius Plötz, 1884	24	15	S	Ne	N	Ac
Pieridae						
Phoebis sennae (Linnaeus, 1758)	1	2	MR	Ne	N	Ac

corolla wall and relatively distant from the anthers. No contact was observed between those insects and the floral reproductive structures during nectar collection (which lasted about 35 seconds on the average), independent of their sizes. Syrphidae dipterans hovered in front of the flowers before landing on the corolla. These insects were generally small and reached the nectary by simply moving through the center of the corolla; their visits lasted about 23 seconds. Some individuals of *Toxomerus* spp. were observed to have pollen grains adhering to their heads after their visits, indicating contact occasional with the reproductive structures of the flowers.

Halictidae bees (medium/small, but mostly small) landed on the corolla and then moved towards the nectary area, where they inserted their tongue during visits that lasted only between 2 and 4 seconds. During most of these nectar collections, contact was observed between the ventral region of the bee's thorax and the reproductive structures of the flowers (Fig 2). Halictidae bees also collected pollen as soon as the flowers opened by manipulating the anthers with their legs, "embracing" them with circular movements (up to 180º) during visits that lasted between 10 and 45 seconds. During that time, the bees often came into contact with the



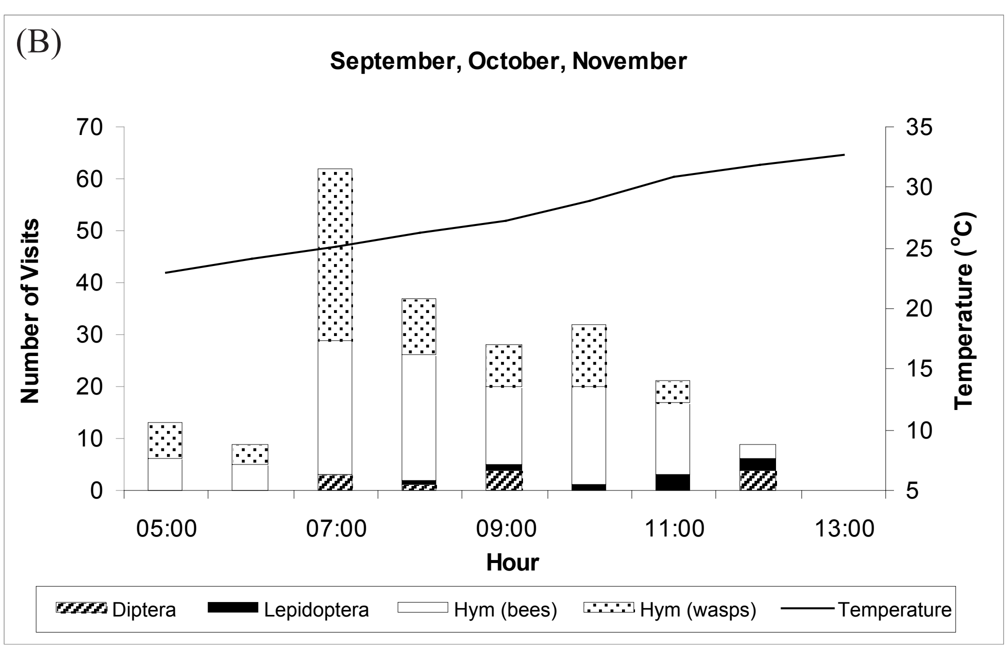


Fig 3. Number of flower-visiting insects (Diptera, Lepidoptera and Hymenoptera) in *Jacquemontia evolvuloides* (Convolvulaceae) per hour throughout the day, in anthropized semiarid (area observed: 195 m^2), of Bahia State, Northeastern Brazil. (A) Between September and November/2009 (dry months). (B) Between May and July/2010 (wet months).

reproductive structures of the flowers and many pollen grains remained adhered to the ventral portion of their bodies. The analysis of pollen loads of the ventral portion, showed the presence of four different pollen morphotypes, with *J. evolvuloides* pollen being predominant (approximately 75% of the pollen grains). Only Halictidae bees were observed collecting nectar and pollen from flowers.

Other bees observed on *J. evolvuloides* flowers, including *Apis mellifera* and *Trigona spinipes*, as well as wasps, collected nectar by landing on the flowers and inserting their tongues into the nectary – but without contacting the reproductive structures. Due to the fragility of the petals, especially larger visitors would have difficulty landing on the flowers to collect floral resources.

Discussion

Flowering of *J. evolvuloides* occurred in almost every month of the study period, with the peak in May and June (autumn/winter), correlated with relative humidity. In other areas of the Caatinga of Northeast Brazil (PE), *Jacquemontia* species may show flowering peak during during of the rainy season [*Jacquemontia nodiflora* (Desr.) G. Don (Kiill & Simão-Bianchini, 2011)] and at the end of the rainy season [*Jacquemontia multiflora* (Choisy) Hallier f. (Piedade-Kiill & Ranga, 2000)].

Jacquemontia evolvuloides flowers are ephemeral and remain open for less than 10 hours, which somewhat limits the resources offered to floral visitors. Those ephemeral flowers showed regularity in terms of their opening and closing times throughout the observation period, although they opened and closed later during winter, probably due to lower temperatures and later sunrises at that time of the year. The ephemeral nature of *Jacquemontia* flowers is one of the main features of that genus, with flowers opening early in the morning (especially in environments with high temperatures, such as the Caatinga) (Piedade-Kiill & Ranga, 2000; Kiill & Simão-Bianchini, 2011).

Flowers usually large, showy, and colorful of *J. evolvuloides* stand out from the surrounding vegetation and attract floral visitors as was noted by authors studying different genera of the Convolvulaceae (Kiill & Ranga, 2003; Kiill & Simão-Bianchini, 2011; Paz et al., 2013). The presence of UV-reflecting pigments in the corolla and anthers may also facilitate their location, especially among insects sensitive to those wavelengths, such as bees (Roubik, 1989).

Reproductive tests indicated that *J. evolvuloides* population studied was self-compatible, although the greatest fruit production was obtained through cross-pollination, as observed with other species of the genus *Jacquemontia* (Piedade-Kiill & Ranga, 2000; Pinto-Torres & Koptur, 2009). While animal-mediated pollination is very successful, its self-pollination capability favors the invasion and establishment in disturbed and/or anthropized environments such as cultivated areas, vegetable gardens, and orchards in northeastern Brazil.

Jacquemontia evolvuloides shows morphological features that classify it as melittophilous according to Faegri and Van der Pijl (1979) but, in addition to bees, wasps, dipterans, lepidopterans, and coleopterans also visited their flowers and collected nectar. A rigid concept of floral syndromes could not be considered in the present study with *J. evolvuloides*, especially because the frequencies of different types of floral visitors change during the year. Hymenoptera species predominate in the spring (especially bees of the genus *Augochlora,* and the wasp *Polybia occidentalis*) while autumn/winter shows the largest numbers of flowers and a predominance of visits by Diptera (especially *T. watsoni*) and Lepidoptera. Only *Augochlora* spp. and *T. watsoni* were constant visitors to *J. evolvuloides* flowers. A combination of floral features of *J. evolvuloides* (especially the shallow funnel shape of its flowers - which can also function as a landing platform) facilitate access by floral visitors of different insect orders, but only limited types of visitors were observed coming into contact with its reproductive structures, with consequent variations among them in terms of their pollination abilities.

Augochlora spp. showed morphologies and behavioral characteristics that resulted in its contact with floral reproductive structures, which was also attested by the presence of the pollen of *J. evolvuloides* on that bee's body. These bees also synchronized their arrivals with floral opening, and are therefore considered relevant pollinators of *J. evolvuloides*, especially in the spring.

Interactions of bees with *Jacquemontia* flowers have been documented in various studies. Piedade-Kiill and Ranga (2000) observed *Augochlora* sp. visiting flowers of *J. multiflora* in the Caatinga. But even though these bees were observed making contact with the reproductive structures of the flowers, they were not considered the principal pollinator as they did not make frequent visits. Then, in these flowers the bees *A. mellifera* and *T. spinipes* were considered effective pollinators due to their visitation frequencies and their behaviors within the flowers. Silva et al. (2010) observed the pollination of *Jacquemontia montana* (Moric.) Meisn. by Halictidae bees, with a predominance of the genus *Dialictus* Robertson, 1902, in a rupestrian field. Pinto-Torres and Koptur (2009) observed the pollination of *Jacquemontia reclinata* House ex Small by Apidae, Megachilidae, and especially Halictidae bees in southeastern Florida (USA).

Toxomerus spp. showed the highest frequency of visits to *J. evolvuloides* flowers in the autumn/winter (with the presence of large numbers of flowers), occasionally touching their reproductive structures. Its role in pollination may therefore be relevant due to its high frequency of visits and by the synchronization of these visits with the opening times of the flowers, making it a potential pollinator. The constant presence of syrphids in *J. evolvuloides* may be associated with its floral morphology, which promotes easy access to the nectary, as those insects have high energy demands (Marinoni et al., 2007).

The presence of syrphids on the flowers of *J. evolvuloides* may indicate their role as potential pollinators, especially during times when bee visitors are infrequent. Freitas and Sazima (2003) observed that syrphids frequently visited the flowers of *Sisyrinchium vaginatum* Spreng (Iridaceae) in Serra da Bocaina (SP), which has a flowering peak in the winter. According to those authors, only small numbers of bees are present at high altitudes in the winter, and pollination by syrphids appears to be of great importance at that time. The syrphids presented synchronization of visitation with the opening hours of the flowers (Freitas & Sazima, 2003).

The flowers of *J. evolvuloides* were visited by numerous other insects, but they did not appear to play any role in pollination. The wasp *P. occidentalis*, as well as Hesperiidae lepidopterans were frequent, but not constant, visitors to *J. evolvuloides* and collected nectar without touching the reproductive structures of the flowers and did not pollinate them. Piedade-Kiill and Ranga (2000) noted that *J. montana* flowers were visited by butterflies considered nectar robbers. Butterflies have likewise been mentioned as floral visitors to other species of the genus, such as *J. multiflora* (Piedade-Kiill & Ranga, 2000), *J. reclinata* (Piedade-Kiill & Ranga, 2000), and *Jacquemontia velutina* (Choisy) (Rodriguez et al., 2010), but they were considered only occasional pollinators or not effective pollinators of those plants.

Because of the easy access of insect visitors to the floral offerings of *J. evolvuloides* due to its floral morphology, pollination in this plant could be considered generalist. Pinto-Torres and Koptur (2009) studied the pollination of *J. reclinata* and observed that all of the visitors that collected nectar could act as potential pollinators (except ants), and that its pollination system could be regarded as generalist.

While *J. evolvuloides* flowers are visited by several insects, only small bees (*Augochlora* spp.) and small syrphids (*T. watsoni*) appear to play a role in pollination of flowers. Although bees have been considered efficient pollinators of this plant, the significant presence of syrphids (frequent and constant visitors), may indicate their role as potential pollinators, especially when bees are not abundant in the fall/winter. As such, even in pollination systems that are considered generalist (with flowers allowing easy access to various visitor groups), visitor size may be an important factor for efficient pollination, especially when associated with high visitation frequencies.

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