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Foraging and pollination activity of *Macronomia vulpina* (Gerstaecker, 1857) (Hymenoptera: Halictidae) on *Gossypium hirsutum* L. (Malvaceae) flowers at Maroua, Cameroon

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Abstract

To evaluate the impact of *Macronomia vulpina* (Hymenoptera: Halictidae) on bolls and seeds of *Gossypium hirsutum,* its foraging and pollinating activities were studied in Maroua, during two seasons of flowering (August-October 2010 and 2011). Treatments included unlimited flowers access by all visitors, bagged flowers to avoid all visits and limited visits of *Macronomia vulpina*. Observations were made on 30 to 100 flowers per treatment. In addition, all flower visitors were recorded. The bee's seasonal rhythm of activity, its foraging behavior on flowers, its pollination efficiency, the fruiting rate, the number of seeds per fruit and the percentage of normal seeds were recorded. Among individuals from 40 species of insects recorded on flowers of *Gossypium hirsutum* after two seasons of observations, *Macronomia vulpina* was second with 7.5% and 6.52% of visits in 2010 and 2011 respectively. This bee intensely and exclusively foraged for pollen, almost throughout the day, with a peak between 8 and 9am. The foraging speed was 14.92 ± 8.24 flowers per minute. *Macronomia vulpina* foraging resulted in a significant increase in the fruiting rate by 7.50% in 2010 and 6.52% in 2011, as well as the number of seeds per boll by 41.19% in 2010 and 33.85% in 2011, and the percentage of normal seeds (well developed) by 21.83% in 2010 and 16.82% in 2011. The conservation of *Macronomia vulpina* nest in cotton plantations is recommended to increase fruit and seed yields of this species.

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Introduction

Reproduction of many plant species depends on pollination, which is done by several agents including insects (Faegri and Pijl, 1979, McGregor, 1976, Pesson and Louveaux, 1984, Philippe, 1991, Tchuenguem Fohouo et al., 2007, 2008b and 2009a). Pollination by theses arthropodes can increase fruit yield and quality of seeds (Morison et al., 2000a, Philippe, 1991, Vaissière and Izard, 1995). In fact the lack of pollinating insects during flowering time can lead to kidney yields fruits and/or seeds for some crops (Delbrassine and Rasmont, 1988, McGregor, 1976, Tchuenguem Fohouo et al., 2009b). Cotton was domesticated by pre-Columbian people of Yacatan peninsula (Brubaker and Wendel, 1993). Its development cycle is seven months (Ahmed et al., David 1971, Lagière, 1966, 1989, Philippe, 1991, Sassenrath-Cole, 1995, Wise et al., 2000). The cotton grown in Cameroon belongs to species *Gossypium hirsutum* (David, 1971, Lagière, 1966,). It is a woody shrub with an average height of less than 1.5 m (David, 1971, Ooterhuis and Jerntedt, 1999). This Malvaceae consists of vegetative branches and fruiting branches called sympodes (David, 1971, Lagière, 1966, Ooterhuis and Jerntedt, 1999, Ritchie et al., 2007). The flowers of *G. hirsutum* are hermaphrodite and attract insects (Green and Jones, 1953, McGregor, 1976). The fruit is a boll shaped ovoid or spherical (David, 1971, Lagière, 1966, Philippe, 1991, Ritchie et al., 2007), containing 29 to 40 grains (Eastick, 2002, Yasuor et al., 2007). Fibers are a very important raw material for the textile industry. Seeds are rich in oil (Cherry and Lefflter, 1984, David, 1971, Lagière, 1966, Philippe, 1991). World production in total is more than 24.5 million tons of which 40% is produced by the USA (Cotton Australia, 2005). Cameroon is the 3rd in the African (MINADER, 2010). Cotton producer with nearly 240 000 tons of cotton seeds in this country, needs for cotton seed is over 250 000 tons (MINADER, 2010). The floral entomofauna of *G. hirsutum* is not well studied in Cameroun. Cotton yields can be increase in this country if its flowering insects are well known and exploited. Before 2013 the few studies on the relationship concern Cotton and floral insect from the literature concern notably, Sudan (Ahmed et al., 1989), Russia (McGregor, 1976), Australia (Mungomery and Glassop, 1969, Richards et al., 2005, Thomson, 1966,) and USA (Llewellyn et al., 2007, McGregor, 1976, Umbeck et al., 1987, Van Deynze et al., 2005,). In 2013, two articles were published on the pollination of *G. hirsutum* by *A. m. adansonii* in Cameroon (Dounia and Tchuenguem, 2013, Mazi et al., 2013). However, the flowering and pollination activities on a plant can vary from one insect species to another. A preliminary study on the relationship insect-flowers in Maroua before 2010 (unpublished data) showed that *Macronomia vulpina* intensely visit the flowers of *G. hirsutum*. This paper was studies the activity of *Macronomia vulpina* on the flowers of *G. hirsutum* and assesses the effectiveness of the pollination by this Halictidae bee on yields of this Malvaceae in Maroua.

Material and methods

Site and biological materials

The studies were conducted from August to October, in 2010 and 2011 at Mayel-Ibbé (Latitude 10° 62 'N, Longitude 14° 33' E and altitude 400 m), Far North Region of Cameroon. This Region belongs to the ecological zone with three phytogeographical areas (Sahel-Sudanian, Sahelian and Sudanian altitude) periodically flooded, with unimodal rainfall (Letouzey, 1985). It has a Sahel-Sudanian climate type, characterized by two annual seasons: a long dry season (November to May) and a short rainy season (June to October). Annual rainfall varies from 400 to 1100 mm (Kuete et al., 1993). The annual average temperature varies between 29 and 38° C and a daily temperature range between 6 and 7° C (Kuete et al., 1993). The experimental plot is an area of 440 m². The animal material was represented by *Macronomia vulpina* (Gerstaecker, 1857) (Hymenoptera: Halictidae) and other insects. Vegetation was represented by wild species and cultivated plants. The plant material was represented by the seeds of *G. hirsutum* provided by SODECOTON.

Planting and maintenance of culture

On May 31st, 2010 and 2011, the experimental plots (that have been previously plowed) was divided into

six sub - plots of 6.5 x 5 m² each, with a row of two meters between subplots. This field received seedlings of 6 lines per sub - plot. The seeds were sown in holes at the rate of 10 grains per hole. The spacing was 25 cm between rows and 80 cm on rows; a hole was 4 cm depth (Cotton Australia, 2002, David, 1971, Lagière, 1966, MINADER, 2010). Two weeks after germination (occurred July 17, 2010 and July 24, 2011), the plants were thinned leaving the stronger. From the thinning to the opening of the first flower, which occurred August 6, 2010 and August 16, 2011, weeding was done with a hoe every three weeks. Manual weeding was performed regularly at the beginning of flowering until harvest, which ended November 28, 2010 for the first growing season and December 05, 2011 for the second growing season.

Study of the activity of *Macronomia vulpina* on the flowers of *Gossypium hirsutum*

On September 02, 2010, 200 flowers of *G. hirsutum* at bud stage were labeled; among which, 100 were left unattended (Treatment 1) and 100 were bagged (treatment 2) to prevent visitors (Dounia and Tchuenguem, 2013). On September 07, 2011, 200 flowers of *G. hirsutum* at bud stage were labeled; among which, 100 were left unattended (Treatment 3) and 100 were bagged (treatment 4) to prevent visitors (Dounia and Tchuenguem, 2013). Observations were done every two days, on treatments 1 and 3 flowers, according to six time frames: 7-8 h, 9-10 h, 11-12 h, 13-14 h, 15-16 h and 17-18 h. From September 3 to September 23, 2010 and from September 7 to September 27, 2011, the blooming periods of labeled flower buds. Insects found on flowers were counted at each daily time frame. Data obtained were used to determine *M. vulpina* visits frequency (F_m) of on flowers of *G. hirsutum*. For each year, $F_m = [(V_m / V_i) \; x \; 100]$, where V_m is the number of *M. vulpina* visits on flowers of free treatment and V_i the total number of insect visits on flowers of the same treatment (Dounia and Tchuenguem, 2013).

The floral products (nectar and / or pollen) collected by the bee were recorded for the same dates and time frame as those of insect counts. The study of this parameter indicates whether *M. vulpina* is strictly pollinivorous, or nectarivore, or pollinivorous and nectarivore. This can give an idea on its involvement in the pollination of this plant. The duration of visits and foraging speed (number of flowers visited per minute) (Tchuenguem *et al.*, 2004) were timed at the same dates and in six time frames. Abundances (larger numbers of individuals simultaneously active) per flower and per 1000 flowers 1000 (A_{1000}) were recorded on the same dates and time slots as the registration of the duration of visits. The first parameter was recorded as a result of direct counts. For A_{1000}, *M. vulpina* individuals were counted on a known number of open flowers; A_{1000} was then calculated by the formula: $A_{1000} = [(A_m / F_x) \; x \; 1000]$, where F_x and A_m are respectively the number of flowers and the number of *M. vulpina* effectively counted on these flowers at time *x* (Tchuenguem *et al.*, 2004). The influence of the surrounding flora was assessed by direct observation: the number of times the bee went from *G. hirsutum* flowers to another plant species and vice versa was noted throughout the period of investigation.

Measuring the temperature and humidity of the experimental site

During the days of investigation, the temperature and humidity of the study site were recorded every 30 min, from 7am to 6pm, using a thermo hygrometer installed in the shade.

Measuring the effectiveness of pollination by *Macronomia vulpina* on *Gossypium hirsutum*

Along with the development of treatments 1 and 2, 100 flowers were isolated (treatment 5) as those of treatment 2. Along with the development of treatments 3 and 4, 100 flowers were isolated (treatment 6) as those of treatment 4. Between 7 and 9am, the gauze bag net was gently removed from each newly bloomed flower of treatment 5 and 6 observed for up to 20 min. Flowers visited by *M. vulpina* were marked. After this manipulation, the flowers were protected once more. At boll maturity, harvesting was done in treatments 5 and 6. For each year of study, the digital input (*Pfx*) of *M. vulpina* on fruiting is $Pfx = \{[(fz\text{-}fy) \; / \; fz] \times 100\}$, where *fz* and *fy* are the fruiting rate in treatment *z* (protected flowers and

visited exclusively by *M. vulpina*) and *y* (protected flowers) (Tchuenguem et al., 2004). The digital input (*Pgx*) of *M. vulpina* in the number of seeds is *Pgx* = {[(*gz-gy*) / *gz*]} *x 100* where *gz* and *gy* are the average number of seeds per boll in treatments *z* and *y*. The digital input (*Pgnx*) of *M. vulpina* on normal seeds formation is *Pgnx* = {[(*gnz-gny*) / *gnz*]} *x 100* where *gnz* and *gny* are the percentages of normal seeds in treatments *z* and *y*.

Data analysis

SPSS and Microsoft Excel software were used for three tests: Student's (*t*) for comparison of means, Pearson correlation coefficient (*r*) for the study of linear relationship between two variables, Chi-square ($\chi 2$) for the comparison of percentages.

Results

Activity of *Macronomia vulpina* on the flowers of *Gossypium hirsutum*

Seasonal frequency of visits

For 21 and 23 days of the flowering periods in 2010 and 2011, 587 and 644 visits of 38 and 36 species of insects were counted on 100 and 100 flowers of *G. hirsutum* respectively in 2010 and 2011(Dounia and Tchuenguem, 2013). *Mocronomia vulpina* comes with 44 and 42 visits spread all over the periods flowering, that is 7.50% and 6.52% of all visits recorded in 2010 and 2011 respectively; this bee species ranked second in both year of investigation after *A. m. adansonii* (Dounia and Tchuenguem, 2013). The difference between these two percentages is not significant ($\chi 2$ = 0.45 [*df* = 1, *P* > 0.5]). This *M. vulpina* has been active on the flowers of *G. hirsutum* from 6 am to 5 pm, with a peak of visits between 8 am and 9 am in 2010 as well as in 2011 (Figure 1).

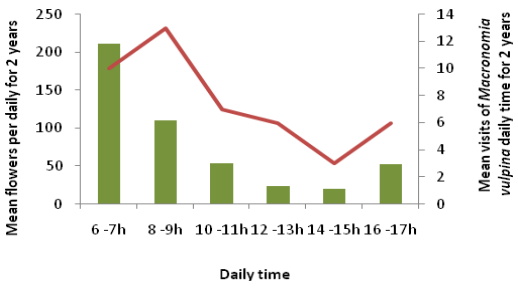

Figure 1. Variation of number of flowers and visits of *Macronomia vulpina* on the flowers of *Gossypium hirsutum* according to daily time slot in 2010, 2011.

Abundance of individuals

In 2010, the highest mean number of *M. vulpina* simultaneously active was one bee per flower (*n* = 50, *s* = 0) and 124.25 per 1000 flowers (*n* = 43, *s* = 137.49, *max* = 500). In 2011, the corresponding figures were 1 per flower (*n* = 50, *s* = 0) and 155.77 per 1000 flowers (*n* = 42, *s* = 168.53, *max* = 500). The difference between the mean number of bees per 1000 flowers in 2010 and 2011 is highly significant (*t* = - 4.71 [*df* = 83, *P* < 0.001]).

Floral substances taken

During each period of flowering of *G. hirsutum, M. vulpina* harvest exclusively and regularly pollen (Figure 2).

Figure 2. *Macronomia vulpina* collecting pollen in a flower of *Gossypium hirsutum*

Rythm of visits according to the flowering stages

Overall, visits of *M. vulpina* were more numerous on treatments 1 and 3 when the number of open flowers was highest (Figure 3). The correlation between the number of visits of *M. vulpina* and the number of opened flowers was positive and highly significant in 2010 (*r* = 0.81 [*df* = 8, *P* < 0.05]) as well as in 2011 (*r* = 0.83 [*df* = 8, *P* < 0.05]).

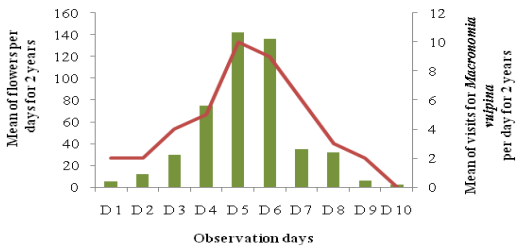

Figure 3. Variation of number of flowers and number of visits of *Macronomia vulpina,* on the flowers of *Gossypium hirsutum* in 2010 and 2011.

Duration of visits per flower

The average duration of a visit of *M. vulpina* per *G. hirsutum* flower varied significantly per year. In 2010, the average duration of a visit was 5.09 sec (n = 43, s = 2.47, *max* = 11). In 2011, the corresponding results were 3.16 sec (n = 42, s = 1.66) and 3.37 sec (n = 67, s = 2.03, *max* = 9). The difference between the duration of visit in 2010 and 2011 is highly significant (t = 17.37 [df = 83, P < 0.001]).

Foraging speed of *Macronomia vulpina* on the flowers of *Gossypium hirsutum*

On the plot of *G. hirsutum, M. vulpina* visited 4 to 29 flowers / min in 2010 and 7 to 19 flowers / min in 2011. The average speed is 17.08 flowers / min (n = 30, s = 10.32) in 2010 and 12.77 flowers / min (n = 30, s = 6.16) in 2011. The difference between these two means is highly significant (t = 7.56 [df = 58, P < 0.001]).

Influence of wildlife

Individuals of *M. vulpina* were disturbed in their foraging by other individuals of the same species, other arthropods which are either predators or competitors for the search of pollen (Dounia and Tchuenguem, 2013). These disturbances resulted in the interruption of certain visits. In 2010, for 44 visits of *M. vulpina,* 2 (4.54%) were interrupted by individual of the same specie and in 2011, for 42 visits of *M vulpina,* 1 (2.38%) was interrupted by an individual of the same bee specie same. During the study period, other plant species located near the experimental field of cotton were also visited by *M. vulpina* for nectar (ne) and/or pollen (po). Among these plants, there were: *Arachis hypogaea* (Fabaceae, po), *Mitracarpus villosus* (Rubiaceae, ne and po), *Jathropha gossipiifolia* (Euphorbiaceae, ne), *Striga hermonthica* (Scrophulariaceae, ne), *Hibiscus asper* (Malvaceae, ne and po), *Sesamum indicum* (Pedaliaceae, ne), *Sorghum bicolor* (Poaceae, po). During *M. vulpina* foraging trips of 2010, on 44 visits, only 1 (2.27%) was made by an individual from *Sorghum bicolor*. In 2011, of the 42 visits, 4 were made by individual from *Hibiscus asper* and *Sorghum bicolor* plants species (9.52%).

Daily rythm of visits

Macronomia vulpina has been active on the flowers of *G. hirsutum* from 6 am to 6 pm, with a peak of visits between 8 and 9 am in 2010 and 2011. Climatic factors have influenced the activity of *M. vulpina* on the flowers of *G. hirsutum* in field conditions (Table 1). The correlation was negative and significant between the number of visits of *M. vulpina* on the flowers of *G. hirsutum* and temperature in 2010 (r = - 0.66 [df = 4, P <0.05]) and in 2011 (r = - 0.75 [df = 4, P < 0.05]). The correlation between the number of visits and the relative humidity of the air was positive and significant in 2010 (r = 0.71 [df = 4, P < 0.05]) and 2011 (r = 0.90 [df = 4, P < 0.05]) (figure 4).

Table 1. Daily distribution of *Macronomia vulpina* visits on 100 *Gossypium hirsutum* flowers over 10 days of observation in 2010 and 2011 respectively, mean temperature and mean humidity of the study site.

Year	Parameter registered	Daily period (hours)					
		6 - 7	8 - 9	10 - 11	12 -13	14 - 15	16 -17
2010	Number of visits	9	13	7	6	2	7
	Temperature (°C)	29.12	31.95	34.5	37.54	36.14	34.52
	Hygrometry (%)	72.4	63.8	59.2	52.4	46.9	48.8
2011	Number of visits	10	12	8	5	3	4
	Temperature (°C)	27.2	31.4	34.06	37.21	35.9	34.34
	Hygrometry (%)	71.8	63.8	59.79	52.9	47.2	49.11

2010: for temperature and hygrometry, each figure represents the mean of 50 observations.

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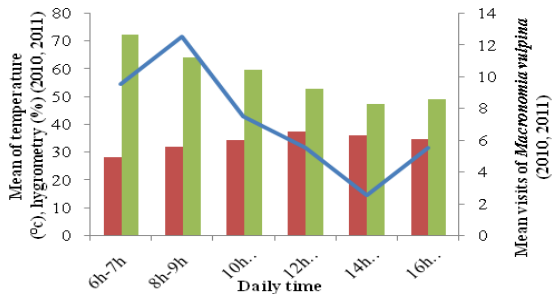

Figure 4. Mean daily temperature and humidity and mean number of visits of *Macronomia vulpina* on the flowers of *Gossypium hirsutum* in 2010 and 2011.

Pollination efficiency of *Macronomia vulpina* on *Gossypium hirsutum*

During the pollen harvest from, foragers were always in contact with the stigma and the anthers. The total number of visits expressed as percentage during which foragers bees came into contact with anthers and stigma was 100% during pollen harvest. Thus, this bee highly increased the pollination of *G. hirsutum* flowers. The comparison of figure from the table 2 shows that:

a) The difference observed between the fruiting rate of treatments 2 and that of treatments 5 was highly significant in 2010 ($\chi 2$ = 17.08 [df = 1, P < 0.01]) as well as 2011($\chi 2$ = 16.11 [df = 1, P < 0.01]). The fruiting rate of flowers exclusively visited by *M. vulpina* (treatments 5) was significantly higher than that of protected flowers bagged during their flowering period (treatments 2). In 2010 and in 2011, the fruiting rate due to the efficiency of pollinating *M. vulpina* were 7.50% and 6.52% respectively. For the two years of experiments, the percentage is 7.01%;

b) There was a highly significant difference between treatments 2 and 5 the first year (t = - 22.07 [(df = 92, P < 0.001]) and the second year (t = - 17.18 [(df = 95, P < 0.001]). Consequently a high mean number of seeds per boll of flowers visited exclusively by *M. vulpina* (treatments 5) were noticed compared to bagged flowers (treatments 2).The percentages of the number of seeds per boll due to the pollination efficiency of *M. vulpina* were 41.19% and 33.85% in 2010 and 2011 respectively. For the two seasons of study, this percentage is 37.52%;

c) There was a highly significant difference between the percentage of normal seeds of treatments 2 and that of treatments 5 in the first year ($\chi 2$ = 135.95 [df = 1, P < 0.001]) as for as the second year ($\chi 2$ = 82.90 [df = 1, P < 0.001]). Thus the percentage of normal seeds of flowers exclusively visited by *M. vulpina* (treatments 5 and 6) was higher than that protected flowers (treatments 2 and 4). The percentages of normal seeds due to pollination efficiency of *M. vulpina* were 21.83% and 16.82% in 2010 and 2011 respectively. For the two years of experimentation, this percentage was 19.32%.

Table 2. *Gossypium hirsutum* yields under pollination treatments.

Treatment	Year	Flowers	Boll	Fruiting rate	Seeds / boll		Total seeds	Normal seeds	% normal seeds
					Mean	sd			
Unlimited visits	2010	100	91	91.00	31.16	10.43	3116	2878	92.36
Bagged flowers	2010	100	62	62.00	17.67	14.39	1767	1229	69.55
Unlimited visits	2011	100	94	94.00	32.68	9.68	3268	2959	90.54
Bagged flowers	2011	100	67	67.00	20.14	15.09	2014	1450	71.99
Mocronomia vulpina	2010	32	32	100	30.05	4.32	1016	904	88.98
Mocronomia vulpina	2011	30	30	100	30.45	4.09	1056	914	86.55

Discussion

The peak of *M. vulpina* activity on the flowers of *G. hirsutum* was in the morning, which corresponds to the period of the high availability of pollen on flowers of *G. hisutum*. Furthermore, this pollen is produced in large quantities, up to 20,000 pollen grains per flower (Ter Avanesian, 1978) and is easily accessible to insects (Green and Jones, 1953; McGregor, 1976; Oosterhuis and Jonestedt, 1999): the opened flower has a large diameter (5-9 cm) (Maffett, 1983, Ter Avanesian, 1978). The decreased of the activity between 12 am and 15 pm could be related to the increase of the temperature in the experimental field. Some high temperature negatively affects insect activity on foraged flowers. Similarly, rainfall has been documented as an environmental factor that can disrupt the floral insect activity (Kasper et al., 2008, McGregor, 1976). The abundance of *M. vulpina* foragers on 1000 flowers and the positive and highly significant correlation between the number of *G. hirsutum* flowers in bloom and the number of *M. vulpina* visits indicates the attractiveness of *G. hirsutum* pollen with respect to this bee. In fact the significant difference between the duration of visits in 2010 and 2011 could be attributed to the availability of floral products or the variation of diversity of flowering insects from one year to another. During each of two flowering periods of *G. hirsutum, M. vulpina* intensely and regularly harvested pollen. This could be attributed to the needs of individual nutrition during the flowering period. The disruptions of visits by other insects reduced the duration of certain *M. vulpina* visits. This obliged some bees to visit more flowers during a foraging trip in order to maximize their pollen loads. Similar observations were made for: a) *A. m. adansonii* (Hymenoptera: Apidae) workers foraging on flowers of *Entada africana* (Fabaceae), *Psidium guajava* (Myrtaceae) (Tchuenguem et al., 2007), *Croton macrostachyus* (Euphorbiaceae), *Syzygium guineense* var. *guineense* (Myrtaceae) (Tchuenguem et al., 2008a), *Persea americana* (Lauraceae), *Vitellaria paradoxa* (Sapotaceae) (Tchuenguem et al., 2008b), *Vigna unguiculata* (L.) (Fabaceae) (Tchuenguem et al., 2009b), *Combretum nigricans* (Combretaceae), *Erythrina sigmoidea* (Fabaceae), *Lannea kerstingii* (Anacardiaceae), *Vernonia amygdalina* (Asteraceae) (Tchuenguem et al., 2010), *G. hirsutum* (Malvaceae) (Dounia and Tchuenguem, 2013; Mazi et al., 2013), *Phaseolus vulgaris* (Fabacaea) (Douka and Tchuenguem, 2013); b) *Chalicodoma cincta cincta* (Hymenoptera: Megachilidae) foraging on flowers of *Cajanus cajan* (Fabaceae) (Pando et al., 2011b); c) *Xylocopa olivacea* (Hymenoptera: Apidae) foraging on flowers of *P. vulgaris* (Fabaceae) flowers (Kingha et al., 2012), *P. coccineus* (Fabaceae) and *Vigna unguiculata* (Fabaceae) (Pando et al., 2011a, 2013). *Macronomia vulpina* foragers had a high affinity with respect to *G. hirsutum* when compared to the neighboring plant species, indicating their faithfulness to this Malvaceae, a phenomenon known as "floral constancy" (Backhaus, 1993, Basualdo et al., 2000, Louveaux, 1984;). Flower constancy is an important aspect in the management of pollination. For this research, it indicates that *M. vulpina* can provide benefits to pollination management of *G. hirsutum*. During the collection of pollen on each flower, *M. vulpina* foragers regularly come into contact with the stigma. They were also able to carry pollen with their hairs, legs and mouth accessories from a flower of one plant to stigma of another flower of the same plant (geitonogamy), to the same flower (autogamy) or to that of another plant (xenogamy) (Pesson and Louveaux, 1984, Philippe, 1991). The workers can thus influence self-pollination and cross-pollination (Moffett et al., 1975; Rao et al., 1969). The significant contribution of *M. vulpina* in boll and seed yields of *G. hirsutum* is in agreement with similar findings for *A. m. adansonii* in Australia (Llewellyn et al., 2007) in United State of America (Vam Deynze et al., 2005) and in Cameroun (Dounia and Tchuenguem, 2013; Mazi et al., 2013).

Conclusion

This study reveals that *G. hirsutum* outlets studied is a highly polliniferous bee plant that obtained benefits from the pollination by insects among which *M. vulpina* is of great importance. The comparison of boll and seeds set of unprotected flowers with that of flowers visited exclusively by *M. vulpina* underscores the value of this bee in increasing boll and seed yields

as well as seed quality. The preservation of *M. vulpina* nest at the proximity of *G. hirsutum* fields should be recommended for the increase of boll and seed yields of this valuable crop.

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