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Impact of *Apis mellifera* (Hymenoptera: Apidae) in increasing fruit and seed yields of *Waltheria indica* (Malvaceae) at Dang (Ngaoundéré, Cameroon)

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Abstract

To evaluate *Apis mellifera* impact on fruit and seed yields of *Waltheria indica*, its foraging and pollinating activities were studied at Dang, during the rainy in 2010 and 2011. Each year, treatments included flowers accessible to all visitors, bagged flowers to avoid insect visits and bagged flowers using gauze bag nets destined to be visited exclusively by *A. mellifera*. The honeybee daily rhythm of activity, its foraging behaviour and its pollination efficiency were evaluated. On flowers, worker bees intensely and exclusively collected nectar. The fruiting rate, the number of seeds per fruit and the percentage of normal seeds of unprotected flowers were significantly higher than those protected from insects. Through its pollination efficiency, *A. mellifera* provoked a significant increment of the fruiting rate by 34.20% and 34.95%, the number of seeds per fruit by 55.32% and 49.92% and the percentage of normal seeds by 39.95% and 41.81% in 2010 and 2011 respectively. The conservation of *A. mellifera* colonies close to *W. indica* fields is recommended to improve fruit and seed productions in the region.

Key words: *Apis mellifera*, *Waltheria indica*, flowers, yield, pollination.

Introduction

During the past decade, traditional systems of medicine have become a topic of global importance. In many developing countries people relies heavily on medicinal plants to meet primary health care needs (WHO, 1999). *Waltheria indica* is one of the medecinal plants largely sought after by traditional healers.

The plant begins flowering at about 6 months old and blooms more or less continuously until its death. Glomerulus contains yellow to orange flowers and reproduction is ensured by seeds (Saunders, 2011). *W. indica* flowers are a source of nectar and pollen for insects (Pauly, 2019; Ruto, 2019), this plant is heavily visited by insects

Indeed, previous researches have shown that Nomiinae, Sphecidae and Vespidae forage *W. indica* flowers in Bobo-Dioulasso and Boromo respectively in Bukina Faso (Pauly, 2019). In Sagalla, Kenya, Ruto (2019) observed honeybees collecting pollen on *W. indica* flowers. The Pollinator partnership and NAPPC (2018) reported bees and butterflies as the main pollinators of *W. indica* in Hawaiian Island Province. In northeastern Brazil, Lima *et al.* (2019) observed Thrips species, *Haplothrips trellesi* (Moulton) on *W. indica* flowers.

Waltheria indica is among the plant species for which information on insect pollination is still lacking in Cameroon. Therefore, it is of greatest necessity to study insect pollination of this woody plant to provide new useful data in this country. In Cameroon, before these studies, no previous research has reported the relationships between *W. indica* and its flowering insects, although the activity and diversity of flowering insects of a plant species vary with regions (Roubik, 2000).

The main objective of this work was to contribute to the understanding of the relationships between *W. indica* and *A. mellifera*, to develop management plans that will increase the overall quality and quantity of *W. indica* yields and hive products and to stabilize bee colonies in Cameroon. Specific objectives were to: (a) determine the place of *A. mellifera* in the *W. indica* floral entomofauna; (b) study the activity of this honey bee on its flowers; (c) evaluate the impact of the flowering insects including *A. mellifera* on pollination and fruit and seed yields of this plant; (d) estimate the pollination efficiency of *A. mellifera* on this plant species.

Materials and methods

Study site, experimental plot and biological material

The experiment was carried out twice, from 07th to 31th August in 2010 and 2011 at Dang in Ngaoundere, Adamaoua region of Cameroon. This region belongs to the high-altitude Guinean savannah agro-ecological zone. The climate is characterized by a rainy (April to October) and a dry season (November to March), with an annual rainfall of about 1500 mm. The mean annual temperature is 22°C, while the mean annual relative humidity is 70% (Amougou et al., 2015). Plants chosen for observations were located at three km away in diameter, centered on a Kenyan top-bar hive inhabited by an *Apis mellifera* (Hymenoptera: Apidae). This hive is located at 7°24.949'N, 13°32.870'E and 1093 m above sea level. The animal material included many insect species naturally present in the environment. The number of honeybee colonies located in this area varied from 51 in August 2010 to 64 in August 2011. The vegetation was represented by crops, ornamental, hedge and native plants of the savannah and gallery forests.

Determination of the reproduction mode of Waltheria indica

On August 07th, 2010, 240 inflorescences from untreated subplots at the budding stage were labeled among which 120 inflorescence were left unprotected (treatment 1), while 120 others were bagged using gauze bags (treatment 2) to prevent visiting insects (Tchuenguem et al., 2001). In similar subplots, on August 24th, 2016, 240 inflorescences at the budding stage were labeled of which 120 flowers were unprotected (treatment 3), while 120 were bagged (treatment 4). For each cropping year, two weeks after shedding of the last labeled flower, the number of fruits was assessed in each treatment. The fruiting index was then calculated as described by Tchuenguem et al. (2001) : $Pi = Fb/Fa$, where Fb is the number of fruits formed and Fa the number of viable flowers initially set. The allogamy rate (TC) from which derives the autogamy rate (TA) was expressed as the difference in fruiting indexes between treatment X (unprotected flowers) and treatment Y (bagged flowers) [10]. $TC = [(PiX - PiY) / PiX] * 100$, where PiX and PiY are respectively the mean fruiting indexes of treatment X and treatment Y; $TA = 100 - TC$.

Fig. 1: Partial view of Waltheria *indica quadrat*

A B

Fig. 2: Unprotected (A) and protected (B) inflorescence of *Waltheria indica* with gauze bag

Study of the foraging activity of Apis mellifera on Waltheria indica flowers

Observations were conducted on inflorescence of treatments 1 and 3, from the opening of the first flower bud (07th August 2010 and 08th August 2011) to the fading of the last flower (31th August 2015 and 31th August 2016), according to six daily time frames: 6 - 7 h, 8 - 9 h, 10 - 11 h, 12 - 13 h, 14 - 15 h and 16 - 17 h. Flowering insects that visited W*. indica* flowers were recorded at each daily time frame during the blooming period. All insects encountered on flowers were recorded and the cumulated results expressed in number of visits have been used to determine the relative frequency of *A. mellifera* (*Fx*) among flowering insects of *W. indica*.

For each year of study, $Fx = [(Vx / Vi) * 100]$, where *Vx* is the number of visits of *A. mellifera* on flowers of free treatment and *Vi*, the total number of insect visits on flowers of the same treatment (Tchuenguem et al., 2001).

During our investigations, before starting with the record of visit of pollinators, the number of open flowers was counted. The same days as for the registration of frequency of visits, the floral products (nectar and/or pollen) collected by a worker bee were recorded for the same date and daily time frame as that of insects' counts. Thestudy of this parameter indicates whether *A. mellifera* is strictly polliniferous and / or nectariferous on *W. indica* flowers (Adamou and Tchuenguem, 2014). This can give an idea of its involvement *in* the pollination of this plant. The duration of the individual flower visits was recorded (using a stop watch) according to six daily time frames: 7 - 8 h, 9 - 10 h, 11 - 12 h, 13 - 14 h, 15 - 16 h and 17 - 18 h (Tchuenguem, 2005). The foraging speed expressed as the number of flowers visited by a worker bee per minute according to Jacob - Remacle (1989) was calculated using the following formula : $Vb = (Fi/di) * 60$ where *di* is the time (s) given by a stopwatch and *Fi* is the number of flowers visited during *di*.

The abundance of foragers (highest number of individuals foraging simultaneously) per flower or per 1000 flowers (*A1000*) were recorded on the same dates and time slots as the registration of the duration of visits. Abundance per flower was recorded as a result of direct counting. For determining the abundance per 1000 flowers, some foragers were counted on a known number of opened flowers and *A1000* was calculated using the following formula: $A1000 = [(Ax / Fx) * 1000]$, where *Fx* and *Ax* are respectively the number of flowers and the number of foragers effectively counted on these flowers at time *x* (Tchuenguem et al., 2004). The disruption of the activity of foragers by competitors and / or predators and the attractiveness exerted by other plant species on this insect was assessed by direct observations. For the second parameter, the number of times the worker bee went from *W. indica* flowers to another plant species and vice versa was noted throughout the periods of investigations. During each day, temperature and relative humidity of the station were registered after every 30 minutes using a mobile thermo-hygrometer (HT-9227) installed in the shade.

Evaluation of the effect of Apis mellifera and other insects on Waltheria indica yields

This evaluation was based on the impact of visiting insects on pollination, the impact of pollination on fructing of *W. indica*, and the comparison of yields (fruiting rate, mean number of seed per fruit and percentage of normal or well developed seeds) of treatments 1 (unprotected flowers) and 2 (bagged flowers). The fruiting rate due to the influence of foraging insects (*Fri*) was calculated using the formula: $Fri = \{[(FrX - FrY) / FrX] * 100\}$ where FrX and FrY are the fruiting rate in treatments X and Y. The podding rate (Fr) is: $Fr = [(Fb/Fa) * 100]$ where Fb is the number of fruits formed and Fa the number of opened flowers initially set. At maturity, fruits were harvested and counted from each treatment. The mean number of seeds per fruit and the percentage of normal seeds were then calculated for each treatment.

Evaluation of the pollination efficiency of Apis mellifera on Waltheria indica

Parallel to the set up of treatments 1 and 2, treatments 5 and 6 were set up made of 200 flowers each. These flowers were protected as those of treatment 2. As soon as the flowers were opened, the gauze bag was delicately removed from each flower and the flowers were observed for up to 10 minutes; to record a single visit of honeybee. The visited flowers by *A. mellifera* were marked and then protected thereafter.

The contribution of A*. mellifera* in the fruiting rate, number of seeds per fruit and percentage of normal seeds were calculated for each treatment per studied year.

The contribution of A*. mellifera* in fruiting rate (FrX) was calculated using the formula: $FrX = \{[(Fra-Frb)/Fra]*100\}$, where Fra and Frb are fruiting rates in treatment *a* (flowers visited exclusively by *A. mellifera*) and treatments *b* (flowers bagged then opened and closed without insect or other organism visits). At the maturity, fruits were harvested and counted from each treatments. The fruiting rate, the percentage of fruits with seeds and the percentage of normal seeds were then calculated for each treatment.

Statistical analysis

Data were analysed using descriptive statistics, student's *t*-test for the comparison of means of the two samples, Pearson correlation coefficient (r) for the study of the association between two variables, and chi-square ($\chi 2$) for the comparison of percentages, Microsoft Excel 2013 software was also used.

Results

Reproduction mode of Waltheria indica

The fruiting indexes of W*. indica were* 1 for all treatments (1, 2, 3 and 4) (Table 1).

T**able 1:** Fruiting indexes of *Waltheria indica* in 2010 and 2011

Years	**Treatments**	**Number of flowers**	**Number of fruits**	**Fruiting indexes**	**Autogamy rate**	**Allogamy rate**
2010	1 (unprotected flowers)	120	120	1	100	0
	2 (protected flowers)	120	120	1		
2011	3 (unprotected flowers)	120	120	1	100	0
	4 (protected flowers)	120	120	1		
2010/2011	Total	480	480	1	100	0

For the two cumulative years, the autogamy rate was 100% whereas the allogamy rate was 0%. It appears that W*. indica is* exclusively an autogamous plant.

Activity of Apis mellifera on Waltheria indica flowers

Frequency of visits

Amongst the 7324 and 6499 visits of 28 and 20 insects species recorded on its flowers in 2010 and 2011 repectively, *A. mellifera* was the most frequent insects with 4760 visits (64.99%) and 4766 visits (73.33%) in 2010 and 2011 respectively (Table 2). The difference between these two percentages is highly significant ($\chi 2 = 111.87$; $df = 1$; $P < 0.001$).

Table 2: Diversity of insects collecting nectar on *Waltheria indica* flowers in 2010 and 2011 at Dang, number and percentage of visits of different insects

Order	Family	Genus and especies		2010		2011		Total	
				n_1	P_1(%)	n_2	P_2(%)	n_T	P_T (%)
Coleptera	Coccinellidae	(2 sp.)		132	0.91	-	-	132	0.46
Diptera	Sarcophagidae	(1 sp. 1)		33	0.45	33	0.51	66	0.48
	Syrphidae	(1 sp.)		37	0.51	-	-	37	0.26
Hymenoptera	Apidae	*Apis mellifera*		4760	64.99	4766	73.33	9526	69.16
		Ceratina sp.		72	0.98	69	1.06	141	1.02
		Lasioglossum sp.		171	2.33	161	2.49	332	2.41
		(1 sp.)		69	0.94	62	0.95	131	0.95
	Formicidae	*Polyrachis* sp.		141	1.93	136	2.1	277	2.02
	Vespoidae	*Belonogaster griseus*		69	0.94	-	-	69	0.47
		Belonogaster juncea		71	0.97	61	0.94	132	0.96
		Bembex sp.		73	1	58	0.89	131	0.95
		Coelioxys sp.		70	0.95	62	0.95	132	0.95
		Dolichovespula adulterine		186	2.54	159	2.45	345	2.5
		Phylanthus triangulum		106	1.45	91	1.4	197	1.43
		Synagris cornuta		69	0.94	-	-	69	0.47
		Vespa sp.		37	0.5	28	0.43	65	0.47
		Vespa velutina		73	1	-	-	73	0.5
		(6 sp.)		551	7.5	356	5.48	907	6.49
Lepidoptera	Pieridae	*Eurema* sp.		232	3.17	214	3.3	446	3.24
		(4 sp.)		372	5.1	243	3.74	615	4.42
Total		Total	Visits	7324	100 %	6499	100 %	13823	100 %
			Species	29		20		28	

n_1 and n_2: number of visits on 120 flowers in 25 days; percentage of visits p_1= (n_1 /7324) *100; p_2 (n_1 /6499) *100 Comparison of percentages of *Apis mellifera* visits (2010/2011): $\chi 2$ = 111.87 ; df = *1* ; *P* < 0.001; ne: collection of nectar; sp.: unidentified species.

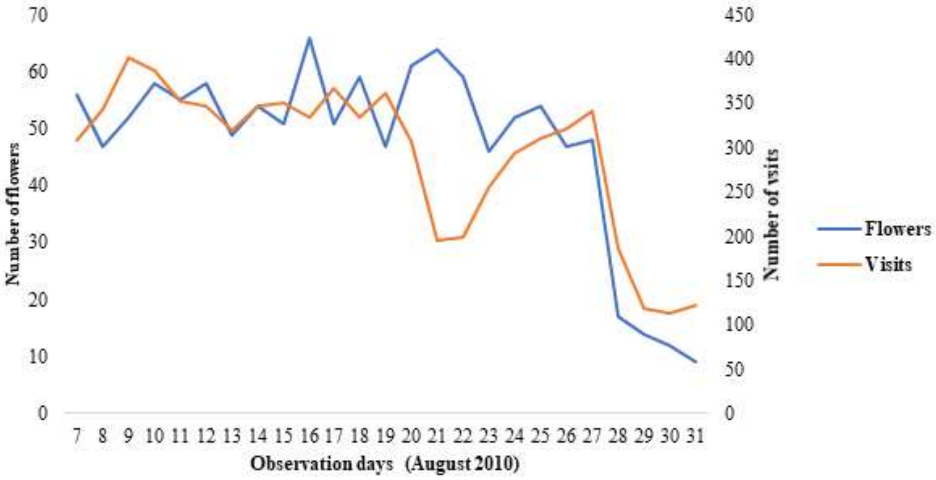
Floral products harvested

From our observations and during the two flowering periods, *A. mellifera* were found to intensively and regularly harvesting nectar on flowers from *W. indica* (Figure 3).

Fig. 3: *Apis mellifera* harvesting nectar on *Waltheria indica* flower

Relationship between visits and flowering stages

The visits of *A. mellifera* were more numerous on treatment 1 and 3 when the number of opened flowers was high (Figures 4A and 4B). The correlation was higly significant between the number of *W. indica* opened flowers and the number of *A. mellifera* visits in 2010 ($r = 0.73$; $df = 23$; $p < 0.01$) as well as in 2011 ($r = 0.72$; $df = 23$; $p < 0.01$).



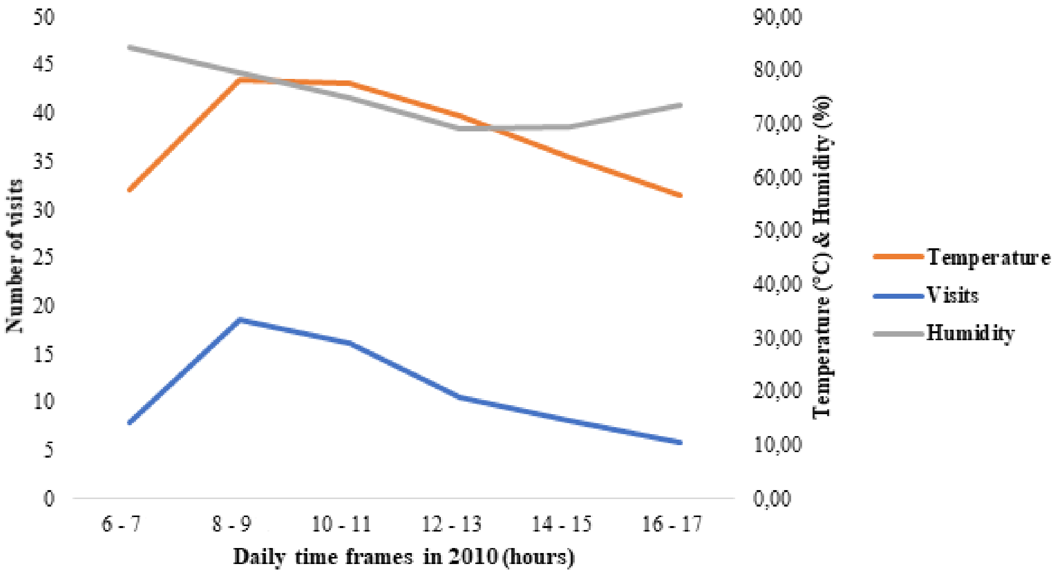
A

B

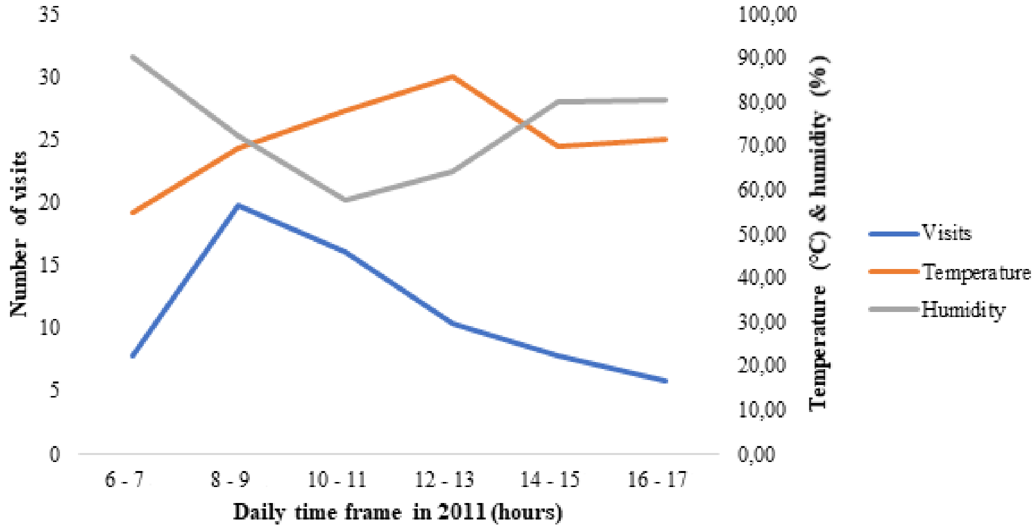
Fig. 4: Seasonal variation of the number of *Waltheria indica* opened flowers and the number of *Apis mellifera* visits in 2010 (A) and 2011 (B) at Dang.

Daily visits

The worker bee was active on *W. indica* flowers throughout the day. The correlation was not significant between the number of *A. mellifera* visits and relative humidity in 2010 (r = 0.20; df = 4; P > 0.05) (Figure 5A) as well as in 2011 (r = -0.60; df = 4; P > 0.05) (Figures 3A and B) (Figure 5B). The correlation was not significant between the number of *A. mellifera* visits and the temperature in 2010 (r= -0.03; df = 4; P > 0.05) and 2011 (r = 0.22; df = 4; P > 0.05).



A



B

Fig. 5: Daily distribution of *Apis mellifera* visits on *Waltheria indica* flowers over 25 days in 2010 (a) and 2011 (b) as influenced by mean temperature and mean humidity at Dang

Duration of a visit per flower

In 2010, the mean duration of a flower visit was 2.01 sec (n = 6733; s = 1.06; maxi = 15 sec), while in 2011, its was 2.02 sec (n = 6648; s = 1.06; maxi = 13 sec), giving not significant difference (t = 0.55; P > 0.05) between the two sampling years. For the two cumulated years, the mean duration of a flower visit was 2.02 sec.

Abundance of Apis mellifera

In 2010, the highest mean number of *A. mellifera* simultaneously active was one per flower (n = 2151, s = 0) and 23.03 per 1000 flowers (n = 439; s = 129.6; maxi = 810). In 2011, the corresponding figures were 1 per flower (n = 2164; s = 0) and 24.64 per 1000 flowers (n = 549; s = 145.96, maxi = 850). The difference between the mean number of *A. mellifera* per 1000 flowers in 2010 and that in 2011 was not significant (t = 0.18; P > 0.05).

Foraging speed of Apis mellifera on Waltheria indica flowers

During obervations, *A. mellifera* visited between 4 and 57 flowers/min in 2010 and between 1 and 57 flowers/min in 2011. The mean foraging speed was 25.46 flowers/min (*n* = 549, *s* = 9.61) in 2010 and 26 flowers/min (*n* = 574, *s* = 9.76) in 2011. The difference between these means is not significant ($t = 0.93$; $df = 1121$; $P > 0.05$). For the two cumulated years, the mean foraging speed was 25.73 flowers/min.

Influence of neighboring floral

During each observation periods, flowers of many other plant species growing in the study area were visited by *A. mellifera*, for nectar. Among these plants were: *Bidens pilosa*, *Bixa orellana*, *Cajanus cajan*, *Callistemon rigidus*, *Cosmos sulfereus*, *Gossypium hirsutum*, *Mangifera indica*, *Phaseolus coccineus*, *Psidium guajava*,*Tithonia diversifolia* and *Vigna unguiculata.* During the whole observation periods worker bee foraging on *W. indica* were not seen flying form *W. indica* flowers to the neighboring plant flowers and vice versa.

Influence of wildlife

The foragers of *A. mellifera* were disturbed in their foraging activity by other arthropods that were either by competitors for nectar or by other biotic and abiotic factors. These disturbances resulted in the interruption of some visits. In 2010, for 6733 visits of *A. mellifera*, 1092 (16.22%) were interrupted by wind, 763 (11.33%) by *A. mellifera*, 983 (14.60%) by *Phylanthus triangulum*, 1583 (23.52%) by *Belonogaster juncea*, 2091 (31.06%) by *Dolichovespula adulterine* and 2342 (34.78%) by *Eurema* sp. While in 2011 for 6648, 1080 (16.25%) were interrupted by wind, 531 (7.99%) by *A. mellifera*, 1172 (17.63%) by *Phylanthus triangulum*, 2058 (30.96%) by *Belonogaster juncea*, 2058 (30.96%) by *Dolichovespula adulterine* and 2304 (34.66%) by *Eurema* sp. For their load of nectar, some individuals of *A. mellifera* who suffered such disturbances were forced to visit more flowers and/or plants during the corresponding foraging trip.

Impact of anthophilous insects including Apis mellifera on the pollination, fruit and seed yields of Waltheria *indica*

During nectar harvest, some foraging insects always shake flowers and contact anthers and stigma, increasing the cross pollination possibilities of this Malvaceae. The comparison of the fruiting rate (Table 3) showed that the differences observed were highly significant between treatments 1 and 2 ($\chi 2 = 922.21$; $df = 1$; $P < 0.001$) and treatments 3 and 4 ($\chi 2 = 865.60$; $df = 1$; $P < 0.001$). Consequently, in 2010 and 2011, the fruiting rate of unprotected flowers (treatments 1 and 3 respectively) was higher than that of protected flowers during their flowering period (treatments 2 and 4 respectively).

Apicultural value of Waltheria indica

During the two cumulated years, a well elaborated activity of *A. mellifera workers* was registered on *W. indica flowers*. In particular, there were good daily and seasonal frequency of visits, high density of workers per plant, good nectar harvest and fidelity of the workers to flowers. These observations highlight the good attractiveness of W*. indica nectar* to *A*. *mellifera*. Therefore W*. indica is* a highly nectariferous bee plant.

Table 3: Fruiting rate, number of seeds per fruit and percentage of normal seeds according to different treatments of *Waltheria indica* in 2010 and 2011 at Dang

Years	Treatments	NF	NFF	FrR (%)	Seeds/fruit		TNS	NS	%NS
					m	*sd*			
2010	1 (Unprotected flowers)	2353	2332	99,11	10.6	6.37	1269	904	71,24
	2 (Protected flowers)	2246	1461	65,05	4.96	4.19	595	276	43,02
	5 (Flowers visited exclusively by *A. mellifera)*	2471	2443	98,86	11.1	6.13	1446	1036	71.64
2011	3 (Unprotected flowers)	2304	2268	98,44	11.02	6.16	1322	964	72,92
	4 (Protected flowers)	2276	1471	64,63	5.9	4.54	708	292	41,24
	6 (Flowers visited exclusively *by A. mellifera*)	3778	3742	99,05	11.78	6.26	2355	1669	70,87

NF: Number of flowers; NFP: Number of formed fruit; PrR: fruiting rate; TNS: Total number of seeds; NS: Normal seeds; % NS: Percentage of normal seeds; *m*: mean; *sd*: standard deviation.

The comparison of the mean number of seeds per fruit (Table 3) showed that the difference observed were highly significant between treatments 1 and 2 ($t = 32.88$; $P < 0.001$) and treatments 3 and 4 ($t = 29.19$; $P < 0.001$). As a matter of fact, in 2010 and 2011, the mean number of seeds per fruit in opened flowers was higher than that of bagged flowers.

The comparison of the percentage of normal seeds (Table 3) showed that the difference observed were highly significant between treatments 1 and 2 ($\chi 2 = 107.69$; $df = 1$; $P < 0.001$) and treatments 3 and 4 ($\chi 2 = 363.55$; $df = 1$; $P < 0.001$).

Hence, in 2010 as well as 2011, the percentage of normal seeds of exposed flowers was higher than that of flowers bagged during their flowering period.

In 2010, the contributions of anthophilous insects on fruiting rate, the mean number of seeds per fruit and the percentage of normal seeds were 37.35%, 53.21% and 69.47% respectively. In 2011, the corresponding figures were 34.15%, 46.46% and 69.71% respectively. For the two cumulate years, the numeric contributions of flowering insects were 35.75%, 49.84% and 69.59% on the fruiting rate, the number of seeds per fruit and the normal seeds, respectively.

Pollination efficiency of Apis mellifera **on Waltheria** ***indica***

During the nectar harvest, the worker bee were always in contact with the stigma and anthers (Tables 4 and 5). Thus, this honey bee highly increased the pollination of *W. Indica flowers.* The comparison of the fruiting rate (Table 3) shows that the differences observed were highly significant between treatments 2 and 5 ($\chi 2$ = 922.21; P < 0.001) and between treatments 4 and 6 ($\chi 2$ = 1076.85; P < 0.001). Hence in 2010 and 2011 the fruiting rate of flowers exclusively visited by *A. mellifera* (treatments 5 and 6 respectively) was significantly higher than that of bagged flowers their flowering period (treatment 2 and 4) respectively.

Table 4: Number and frequency of contacts with insect parts, anthers and stigma during floral visits to *Waltheria indica* in 2010 and 2011

Years	Number of studied visits	Visits with thorax contact		Number of studied visits	Visits with stigma contact	
		Number	%		Number	%
2010	6733	6733	100	6733	6733	100
2011	6648	6648	100	6648	6648	100

Table 5: Number and frequency of contacts with insect parts and stigma during floral visits of a flower to another of Waltheria *indica* in 2010 and 2011

Years	Number of studied visits	Visits with thorax contact		Number of studied visits	Movement of a flower to another flower	
		Number	%		Number	%
2010	6733	6733	100	6733	3275	48,64
2011	6648	6648	100	6648	3233	100

The comparison of the mean number of seeds per fruit (Table 3) showed that the difference observed was highly significant between treatments 2 and 5 (t = 37.08; P < 0.001) and treatments 4 and 6 (t = 37.57; P < 0.001). For the two years, the difference was highly significant between the mean number of seeds per fruit of bagged flowers and visited exclusively by *A. mellifera* (treatment 5 and 6 respectively) and those of bagged flowers during their opening period (treatment 2 and 4 respectively).

The comparison of the percentage of normal seeds (Table 5) showed that the differences observed were highly significant between treatments 2 and 5 ($\chi 2$ = 117.14; df = 1; P < 0.001) and treatments 4 and 6 ($\chi 2$ = 207.45; df = 1; P < 0.001). Hence, in 2010 as well as in 2011, the percentage of normal seeds of flowers exclusively visited by *A. mellifera* (treatment 5 and 6 respectively) was significantly higher than that of bagged flowers during their opening period (treatment 2 and 4).

In 2010, the contributions of *A. mellifera* in the fruiting rate, the number of seeds per fruit and the normal seeds via its single visit were 34.20%, 55.32% and 39.95% respectively, wheras in 2011, the corresponding figures were 34.95%, 49.92% and 41.81% respectively. For the two cumulate years, the corresponding figures were 34.58%, 52.62%, and 40.88% respectively.

Discussion

Apis mellifera was the main floral visitor of *W. indica* during the observation period. This honey bee is known as the floral visitor of *W. Americana* in Guarico State in Venezuela (Rodriguez-Parilli and Graderol, 2011), in Sagalla in Kenya (Ruto, 2019) and in Bobo-Dioulasso and Boromo in Burkina Faso (Paly, 2019). The significant difference between the percentage of visits of *A. mellifera* within during the studied years could be explained by increased of honeybee colonies at the vicinity of the experimental plot.

During each of the two flowering periods, *A. mellifera* were found to intensively and regularly harvesting nectar on flowers from *W. indica* (Figure 3). This could be attributed to the needs of worker bees colonies during the flowering period of this Malvaceae. In Sagalla (Kenya), Ruto (2019) observed A. *mellifera* *collecting* pollen on *W. indica flowers*. The disruptions of visits by other insects reduced the duration of some *A. mellifera* visits. Similar observations were done for the same honey bee foraging on other Malvaceae flowers, *G. hirsitum* in Maroua (Dounia and Tchuenguem, 2013) and in Ngaoundéré (Mazi et al., 2013).

The peak of *A. mellifera* activity on *W. indica* flowers was between 08 am and 09 a.m, which correlate with the period of highest availability of nectar on this Malvaceae. The abundance of A*. mellifera* workers per 1000 flowers and the positive and highly significant correlation between the number of *W. indica* flowers in bloom as well as the number of *A. mellifera* visit indicates the high attractiveness of nectar with respect to this honeybee.

During the collection of nectar, workers regularly contact the stigma and anthers. They collected nectar with their mouth accessories from one plant to another. Individuals of this worker bee could thus allow selfpollination and cross-pollination (Adamou and Tchuenguem, 2014; Mazi et al., 2013). Similar observations were done with *A. mellifera* foraging on flowers of *W. americana* in Venezuela (Rodriguez-Parilli and Graderol, 2011).

Apis mellifera played a positive role in self-pollination: when collecting nectar, *A. mellifera* shakes flowers; this movement could facilitate the liberation of pollen by anthers, for optimal occupation of the stigma (Adamou and Tchuenguem, 2014). Results of the present study confirm those of the studies carried out by Dounia and Tchuenguem (2013) and Mazi et al. (2013) on G*. hirsitum* in Maroua and Ngaoundere respectively.

The higher productivity of fruits in unlimited visits when compared with bagged flowers showed that insect visits were effective in increasing cross and/or self-pollination. Higher productivity of flowers exposed to A*. mellifera* visits compared with those under unlimited visits by all kinds of visitors shows that this honey bee is an important pollinator of *W. indica* and thus can be targeted for the managed pollination of this plant. Our results confirmed those of Dounia and Tchuenguem (2013) and Mazi et al., 2013) in Maroua and Ngaoundéré respectively who revealed that G*. hisitum* flowers set few fruits in the absence of insect pollinators. The positive and significant contribution of *A. mellifera* to the yields through its pollination efficiency is in agreement with similar findings in Maroua and Ngaoundéré on *G. hirsitum* (Dounia and Tchuenguem, 2013; Mazi *et al.,* 2013).

Conclusion

This study reveals that at Dang, *W. indica* is a highly nectariferous bee plant that obtained benefits from the pollination by insects among which *A. mellifera* is the must important. The comparison of fruit and seed sets of unprotected flowers with those of flowers exclusively visited by *A. mellifera* underscores the value of this honey bee in increasing fruiting rate, number of seeds/fruit and percentage of normal seeds of *W. indica*. The installation of *A. mellifera* hives at the proximity of *W. indica* should be recommended to increase the fruit and seed yields of this natural plant.

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