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Pollination and yield components of *Physalis minima* (Solanaceae) as affected by the foraging activity of *Apis mellifera* (Hymenoptera: Apidae) and compost at Dang (Ngaoundéré, Cameroon)

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Abstract

This research was conducted to assess the interactions between compost and honeybee on *P. minima* yields in the field from April to August 2015 and 2016 at Dang. A total of 600 and 540 flowers were labeled in 2015 and 2016 respectively, then divided into twelve treatments each year, differentiated according to whether subplots were applied with compost, chemical fertilizer or not, flowers were protected from insect activities or not, flowers were protected then opened only to *A. mellifera* or closed without insect visits. The foraging behavior of *A. mellifera* on flowers, the mature fruits rate, the number of seeds per fruit, and the percentage of normal seeds were evaluated. Results indicate that *A. mellifera* foraged on *P. minima* flowers from 06.00 am to 6.00 pm and throughout the blooming period. This bee intensively harvested nectar and pollen. In compost treatment, the mature fruits rate and the number of seeds per fruit of unprotected flowers were significantly higher than those of flowers protected from insects. Through its pollination efficiency, *A. mellifera* increased the mature fruits rate by 21.43% and the number of seeds per fruit by 8.06%. The synergistic activity of *A. mellifera* and compost contributed to enhance mature fruits rate by 26.10% and the number of seeds per fruit by 14.80%. Hence, applying *P. minima* with compost and conserving *A. mellifera* colonies close to *P. minima* fields could be recommended to improve its fruit production and maintain honeybee colonies during the rainy season.

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Introduction

Physalis minima (L.) is a small herbaceous annual herb, native to warm temperate and subtropical regions throughout the world (Norhanizan, 2014). Leaves are simple, heart-shaped and alternated, 5 to 15 cm long and 4 to 10 cm wide (Olorode *et al.*, 2013). Flowers are unique, pedunculate and hermaphrodite, derived from the axillary bud, with five yellow petals; calyx is green, formed by five sepals of nearly 5 cm long, covering completely the fruit during all its development (Muniz *et al.*, 2014). The fruit is berry-shaped, from green to yellowish, with a diameter of 12.5-25.0 mm and a weight of 4-10 g, containing 100-300 seeds (Soares, 2009). The demand for this fruit has increased due to its antimicrobial (Shariff *et al.*, 2006), and antioxydant (Singh and Prakash, 2014) activities, but the production remains very low.

The decline in land productivity in most African countries is the result of fast growing human population pressure compared to other regions (FAO, 2000). In addition, poor land management practices result in soil nutrient depletion (Henao and Baanante, 2006). Yet the amount of nutrients present in the soil during the crop cycle determines the quality of plant mineral nutrition and largely the quantitative yields of crops (Bacye, 1993). Mineral fertilizers coupled with its low accessibility to growers are limiting factors for plant growth. Hence, using organic amendments could be cheaper and beneficial for maximizing crop yield in a context of high cost of mineral fertilizers (Kitabala *et al.*, 2016).

The role of pollinators for many plant species is well known throughout the world and their activities are essential to ecosystem functioning and agriculture (Muo *et al.*, 2009; Klein *et al.*, 2012). Honey bees are well adapted to pollination because their sense of smell, eyes, mouthparts, and numerous branched body hairs are ideally suited for searching food sources, sipping nectar, collecting and distributing pollen (Abrol, 2012). This enables the reproduction, productivity and diversification of plants. The floral entomofauna of *P. minima* is not well known. The only published data on this plant for Cameroon is that of Otiobo *et al.* (2015) done in the North West region. According to this work: (a) *A. mellifera* was the most frequent flower visitor among 13 insect species and intensively harvested pollen and nectar; (b) this honey bee increased the percentage of fruiting rate by 2.66% and the percentage of the number of seeds per pod by 3.03%. However, the mature fruits rate was not evaluated by Otiobo *et al.* (2015). Moreover, floral entomofauna of a plant species has been reported to vary from one region to another (Roubik, 2000; Gallai *et al.*, 2009). Up to date, no previous research has been reported on the relationships between compost, *A. mellifera* and *P. minima*.

This work was conducted to study the activity of *A. mellifera* on *P. minima* flowers, evaluate the apicultural value of this plant, assess the pollination efficiency of the honey bee on this Solanaceae and determine the cumulative action of compost and honey bee on the crop yield in the Adamawa region.

Material and methods

Study site, experimental plot and biological material

The experiment was carried out from April to August 2015, and from April to August 2016 at Dang, within the experimental field of the Unit for Apply Apidology (latitude: 7°42.264 N; longitude: 13°53.945 E; altitude: 1106 m a.s.l.) of the Faculty of Science, University of Ngaoundéré, Cameroon. The site belongs to the high altitude Guinean savannah agro-ecological zone. The climate is characterized by a rainy season (April to October) and dry season (November to March), with an annual rainfall of approximately 1500 mm. The mean annual temperature is 22°C, while the mean annual relative humidity is 70% (Amougou *et al.*, 2015). The animal material was included many insect species naturally present in the environment. The number of honeybee colonies located in this area varied from 48 in April 2015 to 78 in October 2016.The existing vegetation was represented by ornamental, hedge and native savannah plant species, as well as gallery forest trees. During the survey, flowers of the surrounding plant species were observed to attract *A. mellifera*. Among these were: *Tithonia diversifolia*, *Cosmos sulphureus* and *Helianthus annuus* (Asteraceae); *Stylosanthes guianensis* and *Cajanus cajan* (Fabaceae); *Croton macrostachyus* (Euphorbiaceae) and *Callistemon rigidus* (Myrtaceae). Compost was produced in the Composting Unit established and monitored at the Faculty of Science of the University of Ngaoundere. The sowing plant material was represented by Small Yellow seed of *P. minima* sampled from the surrounding of the Unit for Apply Apidology.

Sowing and weeding

Nursery plantlets of *P. minima* established on May 12, 2015 were transplanted in the field on June 18, 2015. Those established on April 12, 2016 were transplanted on May 18, 2016. The experimental plot was prepared and divided into nine subplots, each measuring 36 m^2. Three subplots were applied with compost (treatment a), three with chemical fertilizer NPK (20-10-10) (treatment b) and three others left unapplied neither with compost, nor with chemical fertilizer (treatment c). Plants were transplanted in 6 lines per subplot, each of which had 5 holes. Holes were separated 1 m each other, while lines were 1 m apart. Weeding was performed manually as necessary to maintain plots weed-free.

Determination of the reproduction mode of P. minima

On August 22nd 2015, 90 flowers from untreated subplots at the budding stage were labeled among which 45 flowers were left unprotected (treatment 1) while 45 other were bagged using gauze bags net (treatment 2) to prevent visiting insects. In similar subplots, on June 11th 2016, 90 flowers at the budding stage were labeled of which 45 flowers from were unprotected (treatment 3), while 45 were bagged (treatment 4). For each cropping year, ten days after shedding of the last labeled flowers, the number of fruits was assessed in each treatment. The fruiting index was then calculated as described by Tchuenguem *et al.* (2001): $P_i = F_2/F_1$, where F_2 is the number of fruits formed and F_1 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) (Demarly, 1977). $TC = [(P_{iX}-P_{iY})/P_{iX}]*100$, where P_{iX} and P_{iY} are respectively the mean fruiting indexes of treatment *X* and treatment respectively.*Y*. $TA = 100-TC$.

Assessment of the foraging activity of Apis mellifera on Physalis minima flowers

Observations were conducted on 270 individual open pollinated flowers from untreated, compost and chemical fertilizer applied subplots each day, from August 22nd to August 29th 2015 and from June 11th to June 19th 2016 at 06.00-07.00, 08.00-09.00, 10.00-11.00, 12.00-13.00, 14.00-15.00 and 16.00-17.00 h. The identity of all insects visiting *P. minima* flowers was recorded after observations. Specimens (2 to 5) of each insect taxa encountered were caught with an insect net on unlabeled flowers and preserved in 70% ethanol, excluding butterflies that were preserved dry (Borror and White, 1991) for subsequent taxonomic identification. All insects encountered on flowers were recorded and the cumulated results expressed in number of visits to determine the relative frequency of *A. mellifera* in the anthophilous entomofauna of *P. minima*.

In addition to the determination of the floral insect's frequency, direct observations of the foraging activity on flowers were made on insect pollinator fauna in the experimental field. The floral rewards (nectar or pollen) harvested by *A. mellifera* during each floral visit were registered based on their foraging behavior. Nectar foragers were expected to extend their proboscis to the base of the corolla and stigma, while pollen gatherers were expected to scratch the anthers with their mandibles and legs (Jean-Prost, 1987). On each sampling day, the number of opened flowers was counted. The same days as for the frequency of visits, the duration of individual flower visits was recorded (using a stopwatch) at least three times during each of the following daily time frames: 07.00-08.00, 09.00-10.00, 11.00-12.00, 13.00-14.00, 15.00-16.00 and 17.00-18.00h. Moreover, the number of pollinating visits (the bee came into contact with the stigma: Jacob-Remacle, 1989; Freitas, 1997; Fameni *et al.*, 2012), the abundance of foragers (highest number of individuals foraging simultaneously on a flower or on 1000 flowers: Tchuenguem *et al.*, 2004) and the foraging speed (number of flowers visited by a bee per minute: Jacob-Remacle, 1989) were measured. Abundance per flower was recorded following the direct counting, on the same dates and daily periods as for the registration of the duration of visits. For the abundance per 1000 flowers (A_{1000}), some foragers were counted on a known number of flowers. A_{1000} was then calculated by the formula: $A_{1000} = ((A_x/F_x)*1000)$, where F_x and A_x are the number of opened 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 or predators and the attractiveness exerted by other plant species on *A. mellifera* was assessed by direct observations. The ambient temperature and relative humidity of the station were registered every 30 min using a handheld thermohygrometer (techno WS-7018, Germany) during all sampling periods.

Assessment of the concentration in total sugars of Physalis minima nectar

The concentration in total sugars is an important parameter for the attractiveness of the honey bee vis-à-vis of many flowers (Philippe, 1991). The concentration in total sugars of *P. minima* nectar was determined using a handheld refractometer (0-90% Brix), from August 22nd to August 29th 2015 and from June 11th to June 19th 2016 at least three times during each of the following daily time frames: 07.00-08.00, 09.00-10.00, 11.00-12.00, 13.00-14.00, 15.00-16.00 and 17.00-18.00 h. Since the nectar of *P. minima* is not directly accessible to the investigator, the *A. mellifera* workers in full activity of harvest nectar were captured on the flowers of this Solanaceae. Thus harvested individuals were anesthetized by their introduction in a small bottle containing cotton moistened of chloroform. Then, by small pressures on the bee abdomen placed between the thumb and the forefinger of the experimenter, the nectar of the crop was expelled and its concentration in total sugars (g/100g in dry matter) measured. The registered values were corrected according to the ambient temperature, using a table provided by the device leaflet (Tchuenguem *et al.*, 2007).

Evaluation of the apicultural value of Physalis minima

The apicultural value of *P. minima* plants was assessed as in other plant species (Guerriat, 1996; Tchuenguem *et al.*, 2004, 2008), using data on the plant flowering intensity and the attractiveness of *A. mellifera* workers with respect to nectar and pollen.

Determination of mature fruits rate of Physalis minima

The percentage of mature fruits in each treatment (*Mf*) was calculated using the formula:

$Mf = \{[(F_y-F_x)/F_y]*100\}$, where F_y and F_x are the percentage of fruiting index and the percentage of fruits fall before maturity respectively (Djonwangwé *et al.*, 2011).

Evaluation of the impact of compost on yield of Physalis minima

To evaluate the impact of compost on *P. minima* yield, 90 flowers were labeled and protected to form treatments 5 (2015) and 6 (2016) (like those of treatments 2 and 4) on the compost subplots. Comparison of fruiting rate, mature fruits rate, number of seeds per fruit, and percentage of normal seeds of treatments 2 and 5 for the first year, 4 and 6 for the second year were assessed as influenced by compost on *P. minima*.

Assessment of the pollination efficiency of Apis mellifera on Physalis minima

To assess the pollination efficiency of *A. mellifera*, 150 flowers were bagged in 2015 (treatment 7) and in 2016 (treatment 8) on control subplots, relative to the constitution of treatments 2 and 4. As soon as the first flower was opened, each flower of treatments 7 or 8 was inspected once between 9 am and 4 pm. Hence the gauze bag was delicately removed from each flower carrying new opened flowers and observed for up to 20 min for the eventual visitation by *A.*

mellifera before reprotection. Unvisited flowers by this bee were included in treatments 9 or 10. Along with the constitution of treatments 7 and 8, 70 flowers labeled and bagged in 2015 (treatment 9) and in 2016 (treatment 10) were set up on untreated subplots, relative to the constitution of treatments 2 and 4 related to opening and closing without the visit of insects or any other organism.

The contribution of *A. mellifera* in fruiting (Fr_a) rate was calculated using the formula: $Fr_a = \{[(Fr_Z - Fr_Y)/Fr_Z]*100\}$, where Fr_Z and Fr_Y are fruiting rate in treatment 7 or 8 (flowers visited exclusively by *A. mellifera*) and treatments 9 and 10 (bagged flowers destined to opening and closing without visits). At maturity, fruits were harvested from treatments 9 and 10 and, the number of seeds per fruit was counted. The mean number of seeds per fruit and the percentage of normal seeds were then calculated for each treatment. The impact of *A. mellifera* on seed yields was evaluated using the above method as mentioned for fruiting rate.

Assessment of the cumulative action of Apis mellifera and compost on Physalis minima yields

This evaluation was based on the impact of both compost and *A. mellifera* on *P. minima* yield. A total of 150 flowers were bagged in 2015 (treatment 11) and in 2016 (treatment 12) on compost subplots relative to the constitution of treatments 9 and 10. The comparison of yields (fruiting rate, mature fruit rate, mean number of seeds per fruit and percentage of normal seeds) of treatment 2 or 4 with those of treatment 11 or 12 was assessed. The contribution of cumulative effect of *A. mellifera* and compost on *P. minima* in fruiting rate, mean number of seeds per fruit and the percentage of normal seeds was calculated using data of treatment 11 or 12 (flowers visited exclusively by *A. mellifera* in compost subplots) and those of treatment 2 or 4 (bagged flowers in untreated subplots).

Data analysis

Data were subjected to descriptive statistics, student's *t*-test for the comparison of means of the two samples, ANOVA for the comparison of means of more than two samples, Pearson correlation coefficient (r) for the study of the association between two variables, and chi-square (χ^2) for the comparison of percentages, using Microsoft Excel 2010 software.

Results

Reproduction mode of Physalis minima

The fruiting index of *P. minima* was 0.98, 0.93, 0.96 and 0.89, respectively for treatments 1, 2, 3 and 4 (Table 1).

Table 1. Reproduction mode of *Physalis minima*.

Study year	Treatments	Number of flowers	Number fruits	of fruiting index	allogamy rate	Autogamy rate
2015	1 (unprotected flowers)	45	42	0.98	4.54	95.45
	2 (bagged flowers)	45	39	0.93		
2016	3 (unprotected flowers)	45	43	0.96	6.98	93.02
	4 (bagged flowers)	45	40	0.89		

Thus, in 2015 allogamy rate was 4.54%, whereas autogamy rate was 95.45%. In 2016, the corresponding figures were 6.98% and 93.02%. For the two cumulative years, the allogamy rate was 5.76% and the autogamy rate was 94.24%. It appears that *P. minima* has a mixed reproduction mode with the predominance of autogamy over allogamy.

Frequency of floral entomofauna of Physalis minima

Among the 395 and 294 visits of 12 and 13 insect species recorded on 135 and 120 flowers in 2015 and 2016 respectively, *A. mellifera* was the most represented insect species with 83 visits for the control treatment (76.22%), 96 visits (70.59%) for compost treatment and 102 visits (25.95%) for chemical fertilizer treatment in 2015. the corresponding figures were 57 visits (73.06%), 68 visits (67.33%) and 77 visits (66.96%) in 2016 for control, compost and chemical fertilizer respectively (Table 2).

Table 2. Diversity of insects visiting *Physalis minima* flowers as influenced by compost and chemical fertilizer at Dang in 2015 and 2016, number and percentage of insect visits.

Insects			2015						2016						Total	
			Treatments													
			Untreated		Compost		Chemical fertilizer		Untreated		Compost		Chemical ferilizer		2015/2016	
Order	Family	Genus and species	n1	P1 (%)	n2	P2 (%)	n3	P3 (%)	n4	P4 (%)	n5	P5 (%)	n6	P6 (%)	nT	PT (%)
Diptera	*Calliphoridae*	(1 sp.) (ne)	-	-	-	-	-	-	1	1.28	1	0.99	2	1.74	4	0.58
Hemiptera	Pentamidae	(1 sp.) (ne)	2	1.85	3	2.21	5	3.36	3	3.85	2	1.98	3	2.61	18	2.62
Hymenoptera	Apidae	*Apis mellifera* (ne, po)	83	76.85	96	70.59	102	68.46	57	73.08	68	67.33	77	66.96	483	70.31
		Amegilla sp.1 (ne)	-	-	-	-	-	-	-	-	2	1.98	1	0.87	3	0.44
		Amegilla sp. 2 (ne)	-	-	1	0.74	-	-	-	-	-	-	-	-	1	0.15
		Ceratina sp.1 (ne, po)	2	1.85	4	2.94	5	3.36	2	2.56	2	1.98	1	0.87	16	2.33
		Dactylurina staudingeri (po)	2	1.85	3	2.21	4	2.68	-	-	-	-	-	-	9	1.31
		Lipotriches collaris (po)	-	-	-	-	-	-	6	7.69	8	7.92	9	7.83	23	3.35
		Lipotriches sp.1 (po)	-	-	-	-	-	-	3	3.85	6	5.94	8	6.96	17	2.47
		Lasioglossum sp.1 (ne, po)	5	4.63	7	5.15	5	3.36	1	1.28	2	1.98	2	1.74	22	3.20
		Meliponula ferruginea (po)	8	7.41	11	8.09	11	7.38	-	-	-	-	-	-	30	4.37
	Formicidae	*Camponotus flavomarginatus* (ne)	2	1.85	4	2.94	5	3.36	4	5.13	5	4.95	7	6.09	27	3.93
	Halictidae	*Halictus* sp.1 (ne)	-	-	3	2.21	3	2.01	-	-	-	-	-	-	6	0.87
		Halictus sp. 2 (po)	1	0.93	-	-	2	1.34	1	1.28	2	1.98	2	1.74	8	1.16
	Vespidae	*Belonogaster juncea* (ne)	2	1.85	3	2.21	4	2.68	-	-	-	-	2	1.74	11	1.60
		(1 sp.) (ne)	1	0.93	1	0.74	3	2.01	-	-	1	0.99	-	-	6	0.87
Total		16 species	110	100.00	136	100.0	149	100.0	78	100.0	101	100	115	100	689	100.00

n_1, n_2, n_3 and n_4: number of visits on 270 flowers in 17 days; sp.: undetermined species; P_1, P_2, P_3, P_4, P_5, P_6: percentages of visits: $P_1 = (n_1/110)*100$; $P_2 = (n_2/136)*100$; $P_3 = (n_3/149)*100$; $P_4 = (n_4/78)*100$; $P_5 = (n_5/101)*100$; $P_6 = (n_6/115)*100$. Comparison of percentages of *Apis mellifera* visits (2015/2016): $\chi^2 = 0.04$; $df = 687$; $P > 0.05$; ne: collection of nectar; po: collection of pollen.

Table 3. Frequence visits of *Apis mellifera* on *Physalis minima* flowers according to daily observation periods at Dang in 2015 and 2016.

Studied	Daily periods (houre)												Total number of
Years	6 - 7		8 - 9		10 - 11		12 - 13		14 - 15		16 - 17		visits (A)
	n	*P* (%)	*n*	*P* (%)	*n*	*P* (%)	*n*	*P* (%)	*N*	*P* (%)	*n*	*P* (%)	
2015	9	3.20	51	18.14	76	27.04	78	27.75*	49	17.43	18	6.40	281
2016	15	7.42	32	15.84	50	24.75	55	27.22*	40	19.80	10	4.95	202
Total	24	4.96	83	17.18	126	26.06	133	27.53*	89	18.42	28	5.79	483

No significant difference was obtained between flowers from the control and those from the compost plants ($\chi^2 = 0.18$, $df = 1$ and $P > 0.05$ in 2015; $\chi^2 = 0.12$, $df = 1$ and $P > 0.05$ in 2016) and between the control and chemical fertilizer (2015: $\chi^2 = 0.35$, $df = 1$, $P > 0.05$; 2016: $\chi^2 = 0.15$, $df = 1$, $P > 0.05$).

Activity of Apis mellifera on Physalis minima flowers

Floral products harvested

From field observations and during each of the two flowering periods, workers of *A. mellifera* were regularly and intensely harvesting nectar and pollen on compost, control and chemical fertilizer subplots flowers of *P. minima*. Harvesting of nectar was more frequent than that of pollen.

In 2015, the number of visits related to nectar harvest (Fig. 1a) was 270 (71.24%), whereas that for pollen collection (Fig. 1b) it was 109 (28.76%). In 2016, the number of visits accounting for nectar harvest of was 393 (68.22%) whereas that for collection of pollen it was 183 (31.77%). For the total of 955 visits recorded during the two seasons, the number of visits allocated to nectar harvest was 663 (69.42%) and that for pollen collection was 392 (30.57%).

Table 4. Abundance of *Apis mellifera* on *Physalis minima* flowers at Dang in 2015 and 2016.

Years	Mean abundance per 1000 flowers								
	Untreated			Compost			Chemical fertilizer		
	n	*m*	*s*	*n*	*m*	*s*	*n*	*m*	*s*
2015	93	216	124.39	89	220	121.27	103	256	139,64
2016	129	145	59.65	125	251	84.37	130	309	93.73
$T_{2015/2016}$	222	180.50	92.02	214	235.50	102.82	233	282.50	116.68

Table 5. Duration visits of *Apis mellifera* on *Physalis minima* flowers at Dang in 2015 and 2016.

Years	Harvested Products	Duration visits per flower (sec)								
		Untreated			Compost			Chemical fertilizer		
		n	*m*	*s*	*n*	*m*	*s*	*n*	*m*	*s*
2015	Nectar	120	8.02	2.89	111	7.45	2.50	128	8.00	2.57
2016		127	8.93	2.68	130	8.65	3.43	136	8.90	2.80
Total		247	8.47	2.78	241	8.05	2.96	264	8.45	2.68
2015	Pollen	26	9.07	3.93	44	8.04	3.28	39	8.76	5.31
2016		53	9.54	2.19	64	10.00	2.84	66	10.87	2.84
Total		79	9.30	3.06	108	9.02	3.06	105	9.81	4.07

Relationship between Apis mellifera and flowering stages of Physalis minima

Visits of *A. mellifera* workers were most numerous when the number of opened flowers was highest on untreated, compost and chemical subplots (Fig. 2). A positive and significant correlation was found between: (a) the number of *P. minima* opened flowers from untreated subplots and the number of *A. mellifera* visits (r = 0.83; df = 14; P < 0.001); (b) the number of opened flowers of *P. minima* applied compost subplots and the number of *A. mellifera* visits (r = 0.91; df = 14; P < 0.001); (c) the number of opened flowers of *P. minima* applied chemical fertilizer subplots and the number of *A. mellifera* visits (r = 0.92; df = 14; P < 0.001).

Table 6. Concentration in total sugars of *Physalis minima* nectar at Dang in 2015 and 2016.

Years	Subplots	Concentration in total sugars (%)				
		n	*m*	*s*	*min*	*max*
2015	Untreated	40	39.31	4.64	26.3	48.65
	Compost	38	38.39	4.58	22.8	47.81
	Chemical fertilizer	47	38.10	6.00	20.79	47.65
	Total	125	38.60	5.07	20.79	48.65
2016	Untreated	31	38.75	5.38	26.30	48.65
	Compost	34	37.06	4.99	2280	47.23
	Chemical fertilizer	32	36.75	6.03	20.79	4765
	Total	97	37.52	5.46	20.79	47.23
	$T_{2015/2016}$	222	38.06	5.26	20.79	48.65

Diurnal flower visits

The workers of *A. mellifera* daily foraged on *P. minima* flowers throughout the flowering period, with a peak activity between 10.00 and 11.00 am (Table 3). This activity seems not to be always influenced by ambient temperature or hygrometry.

The correlation between the number of *A. mellifera* visits and temperature was not significant on untreated subplots (r = - 0.43; df = 7; P > 0.05), applied compost subplots (r = 0.49; df = 7; P > 0.05), and applied chemical fertilizer subplots (r = 0.64; df = 7; P > 0.05). The correlation between the number of

A. mellifera visits and relative humidity was not significant on untreated subplots ($r = 0.63$; $df = 7$; $P > 0.05$) and applied chemical fertilizer subplots ($r = 0.64$; $df = 7$; $P > 0.05$). The correlation between the number of *A. mellifera* visits and the relative humidity was significant on compost subplots ($r = 0.67$; $df = 7$; $P < 0.05$).

Table 7. Foraging speed of *Apis mellifera* on *Physalis minima* flowers at Dang in 2015 and 2016.

Years	Foraging speed (flowers/min)								
	Untreated			Compost			Chemical fertilizer		
	n	*m*	*s*	*n*	*m*	*s*	*n*	*m*	*s*
2015	104	5.16	1.45	115	5.28	1.34	118	5.13	1.75
2016	107	3.94	1.17	104	4.13	1.14	110	4.79	1.55
$T_{2015/2016}$	211	4.55	1.31	219	4.70	1.24	228	4.96	1.65

Abundance of Apis mellifera workers

In 2015, the highest mean number of *A. mellifera* simultaneously in activity per 1000 flowers was 216 ($n = 93$, $s = 124.39$), 220 ($n = 89$, $s = 121.27$), and 256 ($n = 103$, $s = 139.64$) respectively on untreated, compost, and chemical fertilizer subplots. In 2016, the corresponding values were 145 ($n = 129$; $s = 59.65$), 251 ($n = 125$, $s = 84.37$) and 309 ($n = 130$, $s = 93.73$) (Table 4). For the two cumulated years the mean number of foragers per 1000 flowers is 180, 235, and 282 on untreated, compost, and chemical fertilizer subplots respectively.

The difference between these three abundances is highly significant ($F = 379035.40$; $df_1 = 5$; $df_2 = 663$; $P < 0.001$).

Table 8. Interrupted frequence visits of *Apis mellifera* on *Physalis minima* flowers in 2015 and 2016.

Years	NVE	n	P (%)	Percentages of flowering insects responsible of the interrupted visit (%)					
2015	468	21	4.48	*Am* = 1.49	Ha_1 = 0.64	*Lc* = 1.06	*Mf* = 0.85	Ce_1 = 0.42	-
2016	576	40	6.94	*Am* = 2.08	Ha_1 = 0.21	*Lc* = 1.38	-	Ce_1 = 0.86	Li_1 = 1.04
Total	1044	61	5.71	*Am* = 1.78	Ha_1 = 1.56	*Lc* = 1.22	*Mf* = 0.85	Ce_1 = 0.64	Li_1 = 1.04

NVE : Number of studied visits ; n : Number of interrupted visits ; P = (n/NVE)*100 : Percentage ; Am : Apis mellifera ; Ha_1 : Halictus sp.1 ; Lc : Lipotriches collaris ; Mf : Meliponula ferruginea ; Li_1 : Lipotriches sp1 ; Ce_1 : Ceratina sp.1.

Duration of Apis mellifera visits per flower

In 2015, the mean duration of a visit for nectar collection by *A. mellifera* was 8.02 sec ($n = 120$; $s = 2.89$), 7.45 sec ($n = 111$; $s = 2.50$) and 8.00 sec ($n = 128$; $s = 2.57$) on untreated, compost, chemical fertilizer subplots respectively.

In 2016, the corresponding figures were 8.93 sec ($n = 127$; $s = 2.68$), 8.65 sec ($n = 130$; $s = 3.43$) and 8.90 sec ($n = 136$; $s = 2.80$) (Table 5). For the two cumulated years, the mean duration of a flower visit for nectar collection was 8.47 sec, 8.05 sec and 8.45 on untreated, compost, chemical fertilizer subplots respectively. Difference between these three latest means is highly significant ($F = 42.99$; $df_1 = 5$; $df_2 = 746$; $P < 0.001$).

The mean duration of a visit for pollen collection by *A. mellifera* was 9.07 sec ($n = 26$; $s = 3.94$), 8.04 sec ($n = 44$; $s = 3.28$) and 8.76 sec ($n = 39$; $s = 5.31$) on untreated, compost, chemical fertilizer subplots in 2015. In 2016, the corresponding figures were 9.54 sec ($n = 53$; $s = 2.19$), 10.00 sec ($n = 64$; $s = 2.84$) and 10.87 sec ($n = 66$; $s = 2.84$). For the two cumulated years, the mean duration of a flower visit for pollen collection was 9.30 sec, 9.02 sec, and 9.81 on untreated, compost, chemical fertilizer subplots. Difference between these three treatments is highly significant ($F = 51.70$; $df_1 = 5$; $df_2 = 286$; $P < 0.001$).

The difference between the mean duration of a visit for pollen collection and that for nectar harvest in 2015 is highly significant on untreated ($t = 7.18$; $df = 144$; $P < 0.001$), compost ($t = 7.11$; $df = 153$; $P < 0.001$) and chemical fertilizer ($t = 6.62$; $df = 165$; $P < 0.001$) subplots respectively. For 2016 the difference between the mean duration of a visit for pollen harvest and that for nectar collection is highly significant on untreated ($t = 8.91$; $df = 178$; $P < 0.001$), compost ($t = 17.66$; $df = 192$; $P < 0.001$) and chemical fertilizer ($t = 30.66$; $df = 192$; $P < 0.001$) subplots respectively.

Table 9. Floral products harvested by *Apis mellifera* on plant species flowers surrounding the experimental site.

Plants	Floral products harvested	
	Nectar	Pollen
Aspilia africana	+++	++
Bidens pilosa	+++	+++
Callistemon rigidus	+++	++
Cosmos sulphureus	+++	+++
Croton macrostachyus	+++	+++
Helianthus annuus	+++	+++
Manihot esculenta	+++	+++
Mimosa pudica	-	+++
Stylosanthes guanensis	+++	+++
Tithonia diversifolia	+++	++

+++ = high harvest; ++ = low harvest.

Concentration in total sugars of Physalis minima nectar

The mean concentration in total sugars of the *P. minima* was 39.31%, 38.39% and 38.10%, for flowers of untreated, compost and chemical fertilizer subplots in 2015. In 2016, the corresponding figures were 38.75%, 36.75% and 37.07% (Table 6). For the two years, the mean concentration in total sugars of *P. minima* nectar was 39.03%, 37.73% and 37.42% for flowers of untreated, compost and chemical fertilizer subplots respectively difference between these three treatments is highly significant ($F = 34.17$; $df_1 = 5$; $df_2 = 216$; $P < 0.001$).

In total, the mean concentration in total sugars of *P. minima* was 38.10 ($n = 222$; $s = 5.26$).

Table 10. Apicultural value of *Physalis minima* and the most indicated period (month) for honey and pollen collections.

Apicultural value	Harvest intensity	Period of collection
Nectar	****	
Pollen	***	
honey		September
pollen		August

2nd column: **** = very high nectariferous value; *** = high polliniferous value.

Foraging speed of Apis mellifera on Physalis minima flowers

In *P. minima* field, *A. mellifera* visited averagely 5.16 flowers/min ($n = 104$; $s = 1.45$), 5.28 flowers/min ($n = 118$; $s = 1.75$) and 5.13 flowers/min ($n = 115$; $s = 1.34$) on untreated, compost and on chemical fertilizer subplots in 2015.

In 2016, the corresponding figures were 3.94 flowers/min ($n = 107$; $s = 1.17$), 4.13 flowers/min ($n = 104$; $s = 1.14$) and 4.79 flowers/min ($n = 110$; $s = 1.55$) (Table 7). For the two cumulated years, the mean foraging speed was significantly lower on untreated subplots (4.54 flowers/min) and compost subplots (4.74 flowers/min) than that for the chemical fertilizer subplots (4.96 flowers/min) ($F = 35.36$; $df_1 = 5$; $df_2 = 652$; $P < 0.001$).

Influence of fauna

Workers of *A. mellifera* were disturbed in their foraging by other workers, or other arthropods which were either predators or competitors for the search of pollen or nectar. These disturbances have resulted in the interruption of some visits. In 2015, for 468 visits of *A. mellifera*, 21 (4.48%) were interrupted, whereas in 2016, for 576 visits, 40 (6.94%) was interrupted (Table 8). In order to obtain their nectar or pollen load, foragers who suffered such disturbances were forced to visit more flowers and/or plants during the corresponding foraging trip. In pollen foragers, these disturbances resulted in partial loss of carried pollen.

Table 11. Yield parameters of *Physalis minima* as influenced by *Apis mellifera* in 2015 and 2016 in untreated subplots.

Years	Treatments	Number of flowers	Number of fruits	Fruiting rate (%)	Number of mature fruits	% mature fruits	Number of Seeds/Fruit		Total number of seeds	Number of normal seeds	% Normal seeds
							m	*s*			
2015	1 (unprotected flowers)	45	42	93.33	39	92.85	149.43	14.21	5828	5785	98.88
	2 (bagged flowers)	45	39	86.66	28	71.79	145.25	13.78	4067	4006	98.50
2016	3 (unprotected flowers)	45	43	95.55	34	79.06	132.52	19.82	4506	4361	97.78
	4 (bagged flowers)	45	40	88.88	23	57.50	104.65	24.04	2407	2287	95.01
2015	7 (flowers bagged and visited exclusively by *A. mellifera*)	75	71	94.66	56	78.87	148.35	14.55	8308	8209	98.80
	9 (flowers bagged, opened and closed without visit)	35	30	85.71	22	73.33	146.18	15.98	3216	3158	98.19
2016	8 (flowers bagged and visited exclusively by *A. mellifera*)	55	52	94.54	43	80.76	122.18	19.36	5254	5150	98.02
	10 (flowers bagged, opened and closed without visit)	35	29	82.85	15	51.72	104.26	27.81	1564	1494	95.52

Influence of neighboring flora

During the observation periods, flowers of many other plant species growing near *P. minima* field were visited by *A. mellifera*, for nectar (ne) and/or pollen (po) (Table 9). During the two years of study, three worker bees foraging on *P. minima* were observed moving from flowers of this Solanaceae to those of *Tithonia diversifolia*.

Apicultural value of Physalis minima

During the two cropping years, a well elaborated activity of *A. mellifera* workers was registered on *P. minima* flowers. In particular, there were good daily and seasonal frequency of visits, high density of workers per plant, good nectar harvest, good pollen (Table 10) collection and fidelity of the workers to flowers and high total sugars concentration of nectar. Furthermore, each *P. minima* plant could produce 100 to more than 250 flowers. In addition, according to our investigations, during two to three days ($m = 2$; $s = 0.45$; $n = 66$), each flower of *P. minima* produces nectar that is rich in sugars (up to 38.10%) and easy for honeybees to harvest. These data highlight the good attractiveness of *P. minima* nectar and pollen to *A. mellifera*. Therefore, *P. minima* is a highly nectariferous and polliniferous bee plant.

Impact of anthophilous insects on pollination and on the fruit and seed yields of Physalis minima

The comparison of the fruiting rate (Table 11) showed that the differences observed were not significant between treatments 1 and 2 ($\chi^2 = 1.11$; $df = 1$; $P > 0.05$) and treatments 3 and 4 ($\chi^2 = 1.39$; $df = 1$; $P > 0.05$). Consequently, in 2015 and 2016, the fruiting rate of exposed flowers (treatments 1 and 3, respectively) was not different from that of flowers bagged during their flowering period (treatments 2 and 4, respectively).

Table 12. Yield parameters of *Physalis minima* as influenced by compost in 2015 and 2016 at Dang.

Years	Treatments	Number of flowers	Number of fruits	Fruiting rate (%)	Number of mature fruits	% mature fruits	Number of Seeds/Fruit		Total number of seeds	Number of normal seeds	%Normal seeds
							m	*s*			
2015	2 (bagged flowers on untreated subplots)	45	39	86.66	28	71.79	146.18	15.42	4798	4729	98.56
	5 (bagged flowers on compost subplots)	45	40	88.88	26	65.00	153.23	21.13	4597	4527	98.47
2016	4 (bagged flowers on untreated subplots)	45	40	88.88	23	57.50	104.65	24.04	2407	2287	95.01
	6 (bagged flowers on compost subplots)	45	42	93.33	25	59.52	125.24	17.60	3131	3069	98.01

The comparison of the mature fruits rate (Table 11) shows that the differences observed were significant between treatments 1 and 2 (χ^2 = 6.27; *df* = 1; *P* < 0.05), and treatments 3 and 4 (χ^2 = 4.48; *df* = 1; *P* < 0.05). As a matter of fact, in 2015 and 2016, the mature fruits rate of exposed flowers I (treatments 5 and 6, respectively) was higher than that of flowers bagged during their flowering period (treatments 3 and 4, respectively).

The comparison of the mean number of seeds per fruit (Table 11) shows that the differences observed were highly significant between treatments 1 and 2 (*t* = 383.06; *df* = 10624; *P* < 0.001), and treatments 3 and 4 (*t* = 2044.48; *df* = 6911; *P* < 0.001). Thus, in 2015 and 2016, the number of seeds per fruit of exposed flowers (treatments 1 and 3, respectively) was higher than that of protected inflorescences (treatments 2 and 4, respectively).

Table 13. Yield parameters of *Physalis minima* as influenced by *Apis mellifera* and compost in 2015 and 2016 at Dang.

Years	Treatments	Number of flowers	Number of fruits	Fruiting rate (%)	Number of mature fruits	% mature fruits	Number of Seeds/fruit		Total number of seeds	Number normal seeds	% Normal seeds
							m	s			
2015	2 (bagged flowers on untreated subplots)	45	39	86.66	28	71.79	146.18	15.42	4798	4729	98.56
	11 (bagged flowers visited by *A. mellifera* on compost subplots)	75	70	93.33	64	91.42	158.18	16.26	10188	10061	98.75
2016	4 (bagged flowers on untreated subplots)	45	40	88.88	23	57.50	104.65	24.04	2407	2287	95.01
	12 (bagged flowers visited by *A. mellifera* on compost subplots)	55	53	96.36	44	83.01	134,22	13,36	5906	5845	98.96

m : Mean ; *s* : Standard error.

Impact of Apis mellifera activity on pollination and on the fruit and seed yields of Physalis minima

During nectar and pollen collection from *P. minima*, workers of *A. mellifera* always shook flowers and regularly made contact with the anthers and stigma, increasing the possibility of *P. minima* pollination.

The comparison of the fruiting rate (Table 11) showed that differences observed were not significant between treatments 9 and 10 (χ^2 = 0.11; *df* = 1; *P* > 0.05), and treatments 7 and 8 (χ^2 = 0.18; *df* = 1; *P* > 0.05).

The comparison of the mature fruits rate (Table 11) showed that differences observed were significant between treatments 7 and 9 (χ^2 = 7.08; *df* = 1; *P* < 0.05) and treatments 8 and 10 (χ^2 = 7.53; *df* = 1; *P* < 0.05). For the two years, difference was highly significant between the yields of flowers protected and visited exclusively by *A. mellifera* visits (treatment 7 and 8) and those of flowers protected, opened and closed without visit (treatments 9 and 10) (χ^2 = 13.41; *df* = 3; *P* < 0.01).

The comparison of the mean number of seeds per fruit (Table 11) showed that the differences observed were highly significant between treatments 9 and 7 (*t* = 336.21; *df* = 11522; *P* < 0.001) and treatments 8 and 10 (*t* = 976.47; *df* = 6690; *P* < 0.001).

Hence, in 2015 and 2016, the number of seed per fruit of flowers bagged and visited exclusively by *A. mellifera* (treatments 7 and 8) was higher than that of flowers bagged, opened and closed without visit (and treatments 9 and 10).

The comparison of the percentages of normal seeds (Table 11) showed that the differences are significant between treatments 7 and 9 (χ^2 = 6.46; *df* = 1; *P* < 0.05) and highly significant (χ^2 = 30.20; *df* = 1; *P* < 0.001) between treatments 8 and 10. Consequently, in 2015 and 2016, the percentage of normal seeds of flowers bagged and visited exclusively by *A. mellifera* (treatments 7 and 8) was higher than that of flowers bagged, opened and closed without visit.

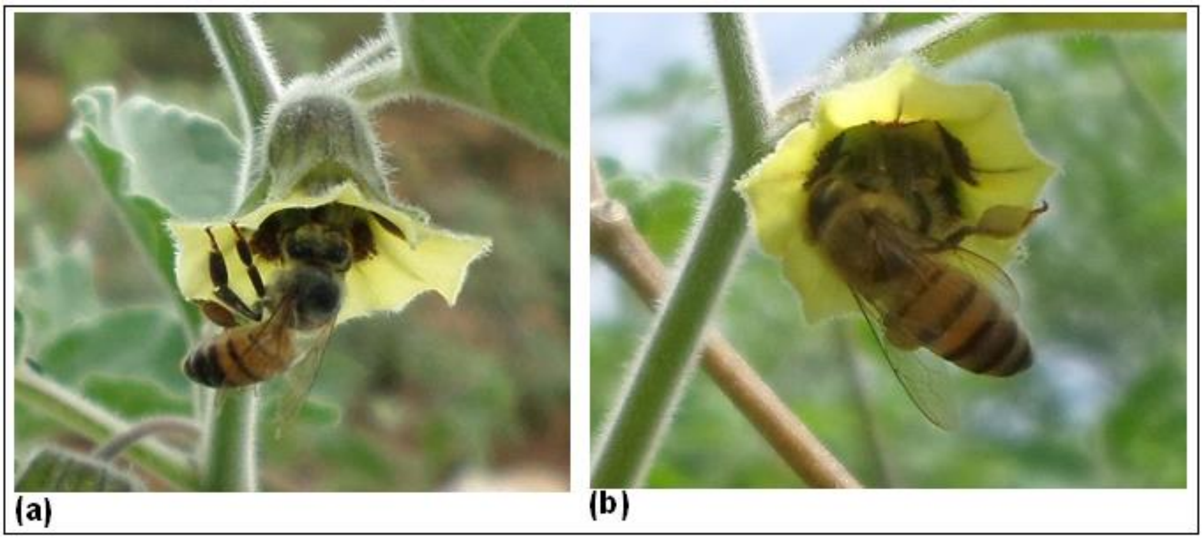

Fig. 1. Products collected by *Apis mellifera* on *Physalis minima* flowers at Dang in 2016. (a): collection of nectar; (b): collection of pollen.

The mature fruits rate due to *A. mellifera* activity was 6.91 % in 2015 and 35.96% in 2016. For the two years of study, the mature fruits rate attributed to the influence of *A. mellifera* was 21.43%.The number of seeds per fruit due to *A. mellifera* was 1.46% in 2015, 14.66% in 2016, and 8.06% for the two cumulated years.

Impact of compost on fruit and seed yields of Physalis minima

The comparison of the fruiting rate (Table 12) showed that the differences observed were not significant between treatments 2 and 5 (χ^2 = 0.10; *df* = 1; *P* > 0.05) and treatments 4 and 6 (χ^2 = 0.55; *df* = 1; *P* > 0.05).

The comparison of the mature fruits rate (Table 12) showed that differences observed were not significant between treatments 2 and 5 (χ^2 = 0.10; *df* = 1; *P* > 0.05) and treatments 4 and 6 (χ^2 = 0.55; *df* = 1; *P* > 0.05). The comparison of the mean number of seeds per fruit (Table 12) showed that differences observed were highly significant between treatments 2 and 5 (*t* = 897.65; *df* = 9393 *P* < 0.001) and between treatments 4 and 6 (*t* = 1356.81; *df* = 5536 *P* < 0.001). Hence, in 2015 and 2016, the mean number of seeds per fruit from flowers protected on compost subplots (treatments 5 and 6) was higher than that of protected flowers and untreated subplots (treatments 2 and 4). The number of seeds per fruit due to compost was 4.60% in 2015, 16.44% in 2016 and 10.52% for the two cumulated years.

Cumulative impact of Compost and Apis mellifera on pollination, fruit and seed yields of Physalis minima

The comparison of the fruiting rate (Table 13) shows that differences observed were not significant between treatments 2 and 11 (χ^2 = 1.50; *df* = 1; *P* > 0.05) and treatments 4 and 12 (χ^2 = 0.04; *df* = 1; *P* > 0.05).

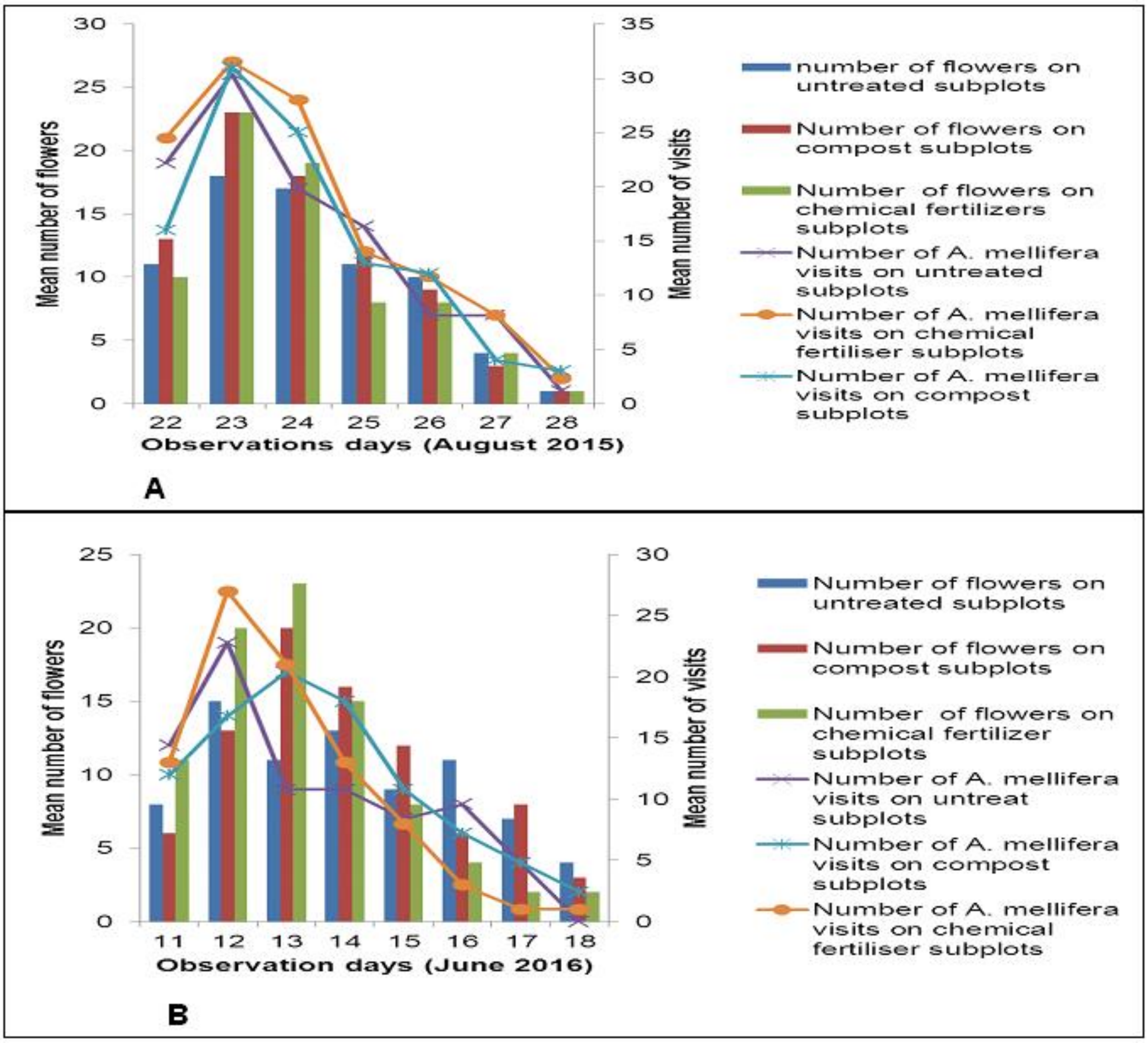

Fig. 2. Variations of the number of *Physalis minima* opened flowers and the number of *Apis mellifera* according to the observation dates in 2015 (A) and 2016 (B) at Dang.

The comparison of the mature fruits rate (Table 13) showed that differences observed were significant between treatments 2 and 11 (χ^2 = 7.13; *df* = 1; *P* < 0.001) and between treatments 4 and 12 (χ^2 = 7.37; *df* = 1; *P* < 0.001). Hence, for the two years, the mature fruits rate of flowers from subplots applied with compost and visited by *A. mellifera* (treatments 11 and 12) was higher than that of protected flowers on untreated subplots (treatments 2 and 4).

The comparison of the mean number of seeds per fruit (Table 13) showed that differences observed were highly significant between treatments 2 and 11 (*t* = 2446.85; *df* = 14984; *P* < 0.001) and between treatments 4 and 12 (*t* = 2948.02; *df* = 8311; *P* < 0.001). Hence, for 2015 and 2016, the mean number of seeds per fruit from flowers visited by *A. mellifera* on applied compost subplots (treatments 11 and 12) was higher than that of protected flowers on untreated subplots (treatments 2 and 4).

The mature fruits rate due to *A. mellifera* activity and compost was 21.47% in 2015, 30.73% in 2016 and 26.10% for the two years of study. The number of seeds per fruit was 7.58% in 2015, 22.03% in 2016 and 14.80% for the two years.

Discusssion

Activity of Apis mellifera on Physalis minima flowers

Apis mellifera was the most frequent insect visitor on *P. minima* flowers during the observation periods. This result confirms those reported by Otiobo *et al.*

(2015) at Bambui (Nord West, Cameroon). The significant difference between the percentages of *A. mellifera* visits for the two studied years could be explained by increased of honeybee colonies at the vicinity of the experimental plot. The peak activity of *A. mellifera* was observed on *P. minima* flowers in the morning. This peak could be linked to the period of the highest availability of nectar and pollen in the flower of this Solanaceae.

The high abundance of *A. mellifera* per 1000 flowers and the positive and significant correlation between the number of *P. minima* opened flowers and the number of honey bee visits underscore the attractiveness of *P. minima* nectar and pollen to *A. mellifera*. This nectar attraction could be explained by its concentration in total sugars (mean 38.10%) that is high, considering the range of 15 to 75% for several plant species (Proctor *et al.*, 1996; Thomson *et al.*, 2012). The high density of workers per 1000 flowers is due to the natural faculty of honeybees to recruit a high number of workers to exploit an interesting food source (Louveaux, 1984). Honeybees can smell or detect pollen or nectar odors (Free, 1970) using sensory receptors located on the flagellum of their antennae. Worker honeybees dance inside the nest after a successful foraging trip in other to communicate to their nestmates informations about the food odor, the distance and the direction from the hive to the food source (Frisch, 1967). The round dance is performed when the resource is within 50 meters from the hive, while the wagging dance takes place for the resource 100 meters away from the hive (Frisch, 1967). The abundance per 1000 flowers was higher (232 workers) than that recorded in Bambui (78 workers) by Otiobo *et al.* (2015). This difference could be explained by the high availability of honeybee colonies (up 78 colonies) on the study site in Dang compare to that in Bambui (only two colonies).

Significant differences observed between the duration of pollen harvest visit and that of nectar harvest could be explained by the accessibility of each of these floral products.

As a highly nectariferous and polliniferous bee plant with the flowering period located in the rainy season, *P. minima* could be cultivated and protected to strengthen *A. mellifera* colonies. The significant difference observed between the duration of visits in 2015 and 2016 could be explained by visit disruptions. Interruptions of bee visits took place when there was a heavy win, collisions between visitors, visitor capture attempts by a predator or approach of flower already occupied by a first visitor. Another species of *Physalis* (*P. angulata*) was identified as honey bees foraging plant in Nigeria (Abdullahi *et al.*, 2011).

The present study revealed that during one foraging trip, an individual bee foraging on a given plant species scarcely visited another plant species. This result indicates that *A. mellifera showed* flower constancy (Basualdo *et al.*, 2000) on *P. minima*.

During the collection of nectar and/or pollen on each flower, *A. mellifera* workers regularly come into contact with the stigma and anthers. They could thus enhance auto-pollination, which has been demonstrated in the past (Anderson and Symon, 1988; Lewis and Considine, 1999; Otiobo *et al.*, 2015). *Apis mellifera* could provoke cross-pollination through carrying of pollen with their furs, legs and mouth accessories, which is consequently deposited on another flower belonging to different plant of the same species (Abrol, 2012).

Impact of Apis mellifera activity on the pollination and yields of P. minima

The positive and significant contribution of *A. mellifera* in fruit and seed yields of *P. minima* could be justified by the action of this bee on pollination. The flowers that were exposed to pollinators provided more seeds than protected flowers, in agreement with previous results reported on the same plant in Bambui (Otiobo *et al.*, 2015). Chautá-Mellizo *et al.* (2012) reported that *A. mellifera* increased the number of seeds per fruit of *Physalis peruviana* by 7% in Colombia. The significant contribution of *A. mellifera* and other insects in the number of seeds per pod of *P. minima* is similar to the findings of Amoako and Yeboah-Gyan (1991) in Ghana, and those of Lewis & Considine (1999) in New Zealand which showed that solanaceous crops produce less seeds per pod in the absence of efficient pollinators.

Impact of compost and Apis mellifera on the pollination and yields of Physalis minima

The positive and significant contribution of compost in fruit and seed yields of *P. minima* could be justified by its richness in nutrients such as phosphorus, nitrogen and potassium. In fact, Nitrogen is considered the most important macro-element, responsible for longitudinal growing of branches and fruit production of *P. minima* (Muniz *et al.*, 2014). Similarly it could also be attributed to reduction of certain plant disease symptoms that have been reported in soybean (Ngakou *et al.*, 2014).

In our experiment, both pollinating insects and compost have highly improved the seed and pod yields of *P. minima*. Insects have facilitated the liberation of pollen from anthers for optimal occupation of the stigma, thus increasing pollination possibilities (Abrol, 2012). Compost has induced microbial activity, which contributed to the increase in soil nutrients through microbiological processes (Mulaji, 2011).

Conclusion

From our observations, *P. minima* is a highly nectariferous and polliniferous bee plant that benefits from pollination by the insect, among which *Apis mellifera* is the most important.

The comparison of fruit and seed sets of unprotected flowers with that of flowers visited exclusively by *A. mellifera* underscores the value of this bee in increasing mature fruits rate and the number of seeds per fruit. Furthermore, the comparison of fruit and seed yields of untreated and bagged flowers with those of flowers applied with compost and visited by *A. mellifera* have indicated the increased fruit and seed production due to the cumulated action of honey bee and compost.

These results suggest that transplanting *P. minima* with compost and the management of *A. mellifera* in terms of colonies provision at the vicinity of *P. minima* field are important tools for plant growers and for beekeepers.

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