Journal of Research in Ecology

ISSN No: Print: 2319 –1546; Online: 2319– 1554

An International Scientific Research Journal

Original Research

Contributory study to the assessment of bee's fauna in market gardening areas in northern Ivory Coast (case of Korhogo)

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ABSTRACT:

Bees are primordial in the conservation of plant diversity. They ensure food security through pollination services. Despite their great importance, very few studies are devoted to them in Ivory Coast, considered as country with an agricultural vocation. The databases on bees being rare or sometimes non-existent, the realization of many scientific studies including those relating to the pollination of certain crops becomes difficult. To overcome this scientific data deficit, this study focused on the assessment of bees' diversity and abundance in market gardening areas of Korhogo. Sampling was carried out in 2017 in nine market garden crops sites, covering the dry and rainy seasons of the year. A botanical survey allowed to identify plant species encountered in the study areas. Bees capturing was done using sweeps nets. Overall, 541 bee specimens belonging to 3 families (Apidae, Halictidae and Megachilidae) and 38 species were sampled. Also, the results revealed a high number of species in dry season (23 species) as opposed to rainy season (21 species). During the two seasons, Lorgokaha was the most species rich site (18 species). The prominent bee species were *Apis mellifera, Pachynomia atrinervis* and *Lipotriches* sp. Among the botanical family recorded in the study area, the flowers of Solanaceae, Poaceae and Malvaceae were the most visited by bees. The identification of bee species encountered in market garden crops is an important step in finding the most effective pollinators for these crops. This could improve the yield of these crops, which are prominent in the fight against hunger in rural areas.

Keywords:

Abundance, Bees, Diversity, Market garden crops, Pollination service.

Article Citation:
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Contributory study to the assessment of bee's fauna in market gardening areas in northern Ivory Coast (case of Korhogo)
Journal of Research in Ecology (2019) 7(2): 2534-2545

Dates:
Received: 01 July 2019 **Accepted:** 21 July 2019 **Published:** 05 Aug 2019

Web Address:
http://ecologyresearch.info/documents/EC0684.pdf

Journal of Research in Ecology
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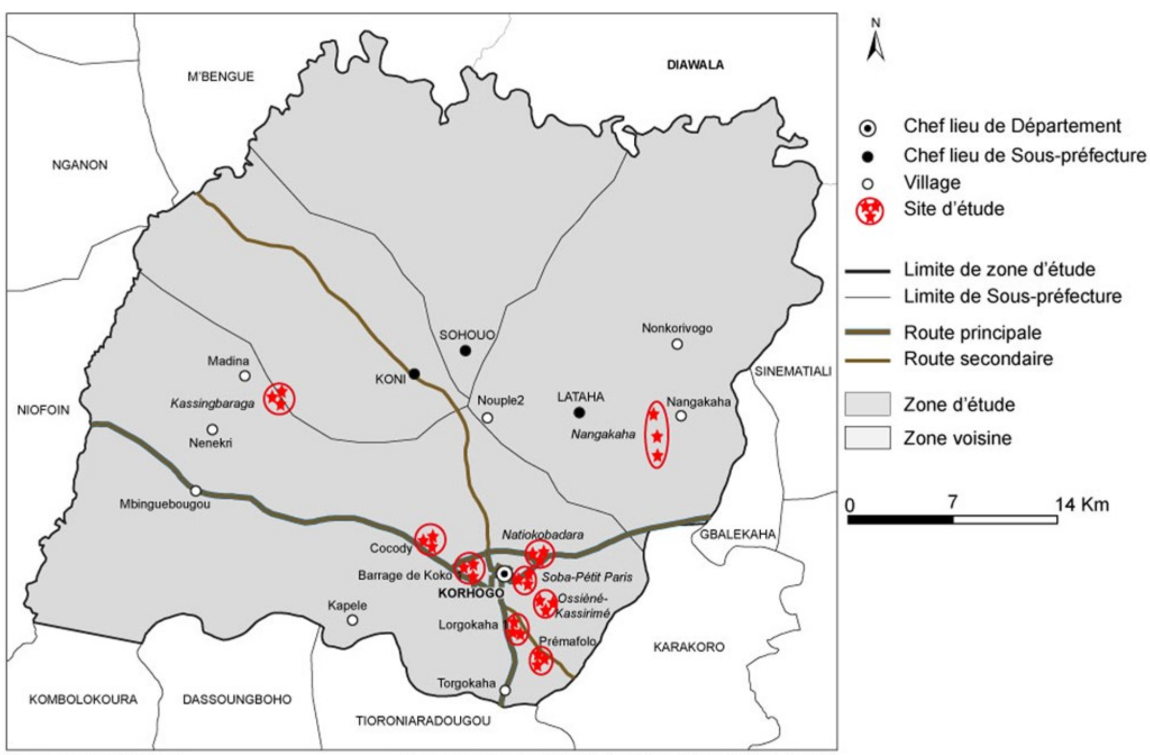
INTRODUCTION

Insects play an important role in pollination of many wild and cultivated plants. Seventy percent of plant species grown for human consumption in the world are highly dependent on insect pollination (McGregor, 1976; Klein *et al.,* 2007). Among the pollinating insects, bees are the major and effective pollinators worldwide. Over 80% of flowering plants are pollinated by bees and 65% are especially, agricultural type. Indeed, several studies reported that bees are the best pollinators of crops (McGregor, 1976; Michener, 2007). A decrease of this pollination service could potentially reduce yields by 40% (Klein *et al*., 2007). Thereby, bees present a great interest in natural ecosystems and agro-ecosystems. Their effectiveness in agricultural yield improvement is well-known through various results of scientific studies. For example, according to a study realized by Coulibaly (2017), pollination by honeybees and wild bees significantly increased yield quantity and quality on an average up to 62%, while exclusion of pollinators caused an average yield gap of 37% in cotton and 59% in sesame (Coulibaly, 2017).

The majority of phanerogams such as market garden plants, could not thus, complete their development cycle without bees' intervention (Michener, 2000). Market garden and fruit crops account for 35% of crops pollinated by bees (Michener, 2000). Indeed, bees intervene much in market garden crops because of the abundance of the flowers which are present there. Studies conducted by Benachour (2008) on diversity and pollinating activity of bees on nine market garden plants, showed that the presence of bees had significantly improved the yield of these plants. The same study revealed that market garden plants are visited by a significant diversity of apoidal fauna. The mutually beneficial relationship between bees and flowers has led to the coevolution and diversity of species that is known today. In terms of production, both quantitatively and qualitatively, pollination by bees is quite appreciable (Crepet, 1984). Bee's abundance and diversity, appear



Source : BNETD/CCT, 2012 *Conception et réalisation : YAO Kouadio F. et ALLA Kouadio A., 2018*

Figure 1. Location of the study sites (Kouadio and Kouadio, 2018)

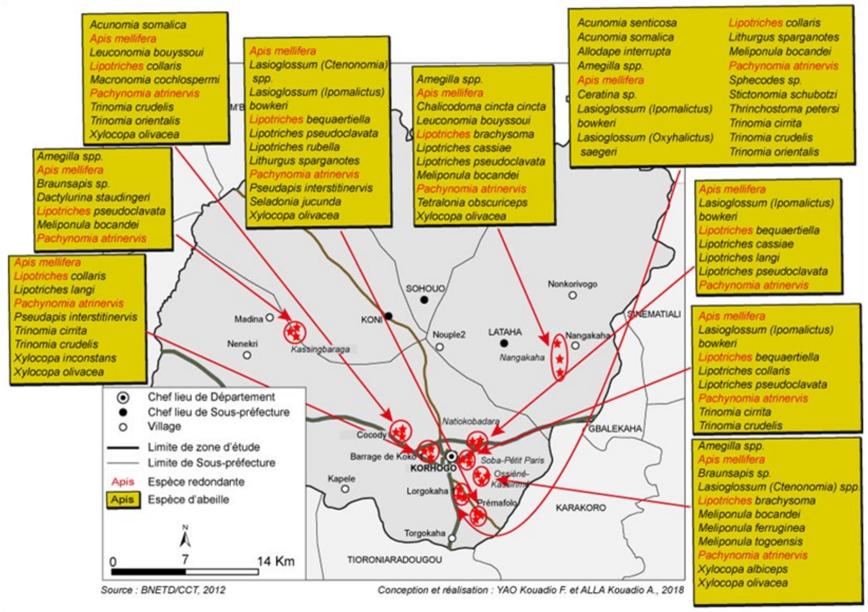


Figure 2. Distribution of harvested bee species in the study sites (Kouadio and Kouadio, 2018)

as production factors for entomophile crops, thus ensuring the maintenance of plant biodiversity (Klein *et al*., 2002; Roubik, 2002; Klein *et al*., 2007). However, bee activity remains fragile in terms of ecological service that depends in part on the agro-ecosystem (Kremen *et al.,* 2002; Ricketts *et al*., 2004).

Worldwide, bee populations have been declining rapidly for the past 50 years and this trend appears to be accelerating (Williams 1986; Rasmont and Mersch, 1988; Corbet *et al*., 1991; Day, 1991; Banaszak, 1995). However, while some regions of the world have a flow of information on bees, this is not the case in West Africa, particularly in Côte d'Ivoire, where very few studies have been conducted in this way. Therefore, there is no taxonomic list of bees pollinating market garden crops for this country that we are aware of. The aim of this study is to contribute at the knowledge of bees community pollinating market gardening crops in Korhogo areas. Specifically, this study consisted of (1) assessing bee's diversity and abundancein market gardening areas, (2) comparing this diversity and abundance according to the seasons, (3) identifying the families of plants visited by bees in market gardening crops.

MATERIALS AND METHODS

Study sites

The study was conducted in Korhogo department (Figure 1). Seven (07) sites of high market gardening production were selected in the commune and two others in the sub-prefecture of Korhogo. Lorgokaha, Premafolo, Ossiéné-Kassirimé, Soba-Petit Paris, Natio-Kobadara, Dams of Koko and Cocody, are the study sites inside the commune. As for the sub-prefecture, it is the shallows of Nangakaha and Kassingbaraga villages which have been chosen. The sampling of bees was made between 7 am and 11 am, covering dry and rainy seasons of the year, for a total of 5 weeks of capture per season.

Data collection

Data sampling was based essentially on bees capture and their identification. On each sampling plot, bees foraging the inflorescences of the different crops were captured using a sweep net, with back-and-forth movements for five min. Insects captured per plant species were kept in the same flask containing 70% alcohol and then labeled. On each label, the name of the study site, the type of plant visited, and the harvest date were mentioned. As for the unknown plants, their specimens

Table 1. Assessment of sampling method

Study sites		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**X̄**
Dry season	S.obs	10	5	8	3	3	6	4	10	6	
	S.est	13.5	5.67	26.67	5	3.33	9.33	4.22	16.22	8	
	S.R (%)	74.07	88.18	30	60	90.09	64.3	94.79	61.65	75	**70.9**
Rainy season	S.obs	10	7	4	6	5	4	7	4	2	
	S.est	14.67	10.8	4.75	8.5	6.5	4.75	7.3	4.75	2	
	S.R (%)	68.2	64.8	84.21	70.6	76.92	84.2	95.9	84.21	100	**81**

Study sites		A	B	C	D	E	F	G	H	I	**X̄**
Dry season	S.obs	10	5	8	3	3	6	4	10	6	
	S.est	13.5	5.67	26.67	5	3.33	9.33	4.22	16.22	8	
	S.R (%)	74.07	88.18	30	60	90.09	64.3	94.79	61.65	75	**70.9**
Rainy season	S.obs	10	7	4	6	5	4	7	4	2	
	S.est	14.67	10.8	4.75	8.5	6.5	4.75	7.3	4.75	2	
	S.R (%)	68.2	64.8	84.21	70.6	76.92	84.2	95.9	84.21	100	**81**

A : Lorgokaha; **B :** Premafolo; **C :** Ossiéné-Kassirimé; **D :** Soba-Petit Paris; **E :** Natio-Kobadara; **F** : Barrage Koko; **G :** Cocody **H :** Nangakaha**; I :** Kassingbaraga

were collected or sometimes photographed and thereafter handed over to botanists who helped to identify them. The morphological characteristics of insects were observed using Motic SMZ-140 series binocular magnifier at 10x20 and magnification to identify bees at family or genera level. The determination keys Pauly *et al.* (2010) and AH (2019), were used for identifications. The specimens difficult to identify using our tools, were sent to the Royal Belgian Institute of Natural Sciences for identification up to species level by the taxonomy expert, Alain Pauly.

Data analysis

To assess the effectiveness of bee sampling method, the coverage average rate was calculated by the ratio of observed specific richness (Sobs) on the estimated specific richness (S.est) multiplied by 100. Shannon diversity index H' (Shannon, 1948) and Pielou's evenness index E (Blondel, 1979) were calculated to evaluate bee alpha diversity. In fact, Shannon diversity index (H') makes accounts for the specific richness and the abundance of bees. It allowed to compare bee diversity between the sampled sites. This index was calculated using Estimate software (Version 9.1.0). As for Pielou's evenness Index (E), it allowed to measure species distribution within sites.

$$H' = -\sum\left(\left(\frac{Ni}{N}\right) * \log_2\left(\frac{Ni}{N}\right)\right)$$

where 'Ni' is the number of individuals of a given species, 'i' ranging from 1 to S (total number of species); 'N' is the total number of individuals. Pielou's evenness index (E) is given by the following formula: E = H'/ H'max (with H'max = $\log_2 S$, where 'S' represents the total species richness). Jaccard similarity index (Bello and Leps *et al*., 2007) was used to compare the species composition between sites, seasons and plant families. This index is a test of similarity between two habitats. J = $\frac{a}{(a+b+c)}$, where, a represents the number of common species between habitats; b represents the number of unique species for habitat 1 and c represents the number

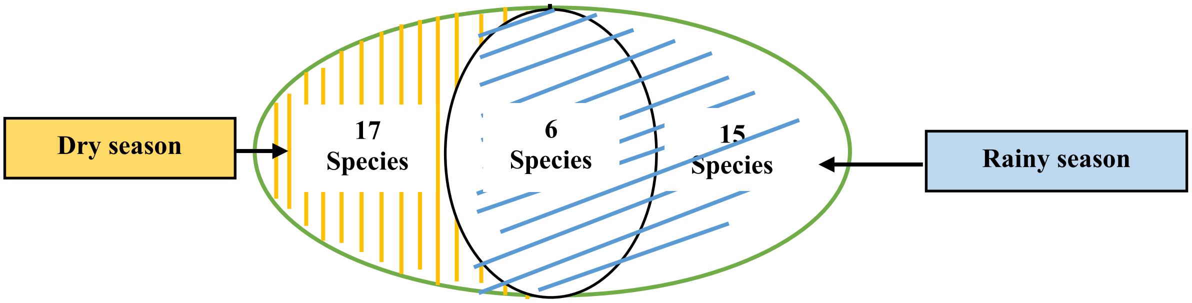


Figure 3. Distribution of bee species identified per season (Coulibaly, 2019)

of unique species for habitat 2. Abundance of collected bees was determined by direct counting of specimens. Abundance reflects the numerical importance of a species in a population.

RESULTS

Effectiveness of sampling and harvesting method

The sampling coverage is 70.9% in dry season and 81% in rainy season. These high values indicated a good efficiency of the sampling method (Table 1).

Specific richness of bees

In this study, 38 species of bees representing 25 genera and 3 families (Apidae, Halictidae and Megachilidae) were collected. Halictidae (23 species) was the most species rich family followed by Apidae (13 species) and Megachilidae (2 species).

Influence of seasons on diversity parameters

The highest specific richness was recorded during the dry season with 23 species compared to the rainy season with 21 species. For all seasons, the highest spices specific richness was recorded in Lorgokaha with 20 species followed by Nangakaha, Premafolo and Ossiéné -Kassirimé (11 species each one). Specifically in dry season, the specific richness of bees is higher in Lorgokaha (10 species) and Nangakaha (10 species) (Table 2). Shannon diversity index is also higher in Lorgokaha (H'= 2.25) (Table 2). On the other hand, Natio-Kobadara recorded the lowest value of Shannon diversity index (Table 2). Pielou's evenness indices are almost the same value close to 1 for all sites. The different bee species identified have approximately the same abundance on the sites during dry season. In rainy season, the specific richness of bees is also greater in Lorgokaha compared to the other sites (Table 2). The same is true for Shannon index (H'= 2.25). In addition, the lowest Shannon index (H'= 0.64) is obtained in Kassingbaraga. Equitability indices are substantially identical and close to 1 for all sites (Table 2).

Influence of plant families on diversity parameters

Solanaceae family had the highest Shannon diversity index (H'= 2.76) compared to other plant families (Table 3), indicating that Solanaceae family is the most diverse in term of bee species.

Influence of seasons on abundance of bees

Overall, 541 bee specimens were captured in the 9 study sites: In dry season, 318 bee specimens belonging to 3 families (Apidae, Halictidae and Megachilidae) were identified. *Pachynomia atrinervis* (151 specimens) and *Apis mellifera* (59 specimens) are the most abundant species captured during the dry season. In rainy season, 223 bee specimens belonging to the same 3 families as in dry season were captured. *Apis mellifera* (81 individuals) and *Lipotriches pseudoclavata* (51 individuals) are the most abundant.

Influence of plant families on abundance of bees

On the 541 bee specimens recorded in the study areas, 459 specimens, about 3/4 of the population, were captured from only 3 main plant families which are Solanaceae (246 specimens), Poaceae (162 specimens) and Malvaceae (51 specimens) (Table 4). Among bee species caught, *Pachynomia atrinervis* (161 individuals) and *Apis mellifera* (140 individuals) are the most abun-

Table 2. Bee diversity indices by site in dry and rainy seasons

Diversity indices	A	B	C	D	E	F	G	H	I
Dry season									
Shannon Diversity Index (H')	**2.25**	1.55	2.08	1.1	1.04	1.74	1.33	2.1	1.68
Shannon Equitability Index (E)	0.94	0.94	1	1	0.94	0.95	0.94	0.95	0.9
Rainy season									
Shannon Diversity Index (H')	**2.25**	1.91	1.33	1.74	1.56	1.33	1.9	1.33	0.64
Shannon Equitability Index (E)	0.95	0.96	0.94	0.95	0.95	0.95	0.95	0.95	0.94

Diversity indices	A	B	C	D	E	F	G	H	I
Dry season									
Shannon Diversity Index (H')	**2.25**	1.55	2.08	1.1	1.04	1.74	1.33	2.1	1.68
Shannon Equitability Index (E)	0.94	0.94	1	1	0.94	0.95	0.94	0.95	0.9
Rainy season									
Shannon Diversity Index (H')	**2.25**	1.91	1.33	1.74	1.56	1.33	1.9	1.33	0.64
Shannon Equitability Index (E)	0.95	0.96	0.94	0.95	0.95	0.95	0.95	0.95	0.94

A : Lorgokaha; **B :** Premafolo; **C :** Ossiéné-Kassirimé; **D :** Soba-Petit Paris; **E :** Natio-Kobadara; **F** : Barrage Koko; **G :** Cocody **H :** Nangakaha; **I :** Kassingbaraga

dant. They represent alone 55.63% of total number of bees. On Solanaceae family, *Pachynomia atrinervis* is the most abundant bee species with 132 specimens, but it is much more common on nightshade (*Solanum nigrum*). As for *Apis mellifera*, it is subservient to all plant families even if it has a preference for Cucurbitaceae.

Specific composition of bees according to the sites

Jaccard similarity indices obtained show a strong similarity (50%) between the sites of Soba-Petit Paris and Natio-Kobadara in terms of specific composition in bees (Table 5). On the other hand, the similarity indices between the other sites are less than 50%, indicating a weak similarity between these sites in terms of specific composition in bees (Table 5). *Apis mellifera*, *Pachynomia atrinervis* and *Lipotriches* sp are three species of bees identical to all study sites (Figure 2).

Specific composition according to the seasons

On all the bees caught, 17 species were identified in dry season while 15 were caught in rainy season. Six (6) species of bees are encountered in both seasons. The similarity index calculated between the seasons is

Table 3. Bee diversity indices by plant families

Diversity indices	A	B	C	D	E	F	G	H	I
Shannon Diversity Index (H ')	**2.76**	1.98	1.83	1.75	1.55	1.39	1.33	0.69	0.1
Shannon Equitability Index (E)	0.98	0.96	0.95	0.9	0.88	0.84	0.79	0.67	0.34

A : Solanaceae; **B :** Poaceae; **C :** Malvaceae; **D :** Asteraceae; **E :** Fabaceae; **F :** Convolvulaceae; **G :** Cucurbitaceae; **H :** Liliaceae; **I :** Tiliaceae.

0.16. This low index indicates a strong dissimilarity between the two seasons in terms of specific composition in bees. The analysis of this result showed that the specific composition of bees varies from one season to another (Figure 3).

Specific composition of bees according to the families of market garden plants

Jaccard similarity indices (Sj) calculated between families of market garden plants are low (less than 50%). These weak indices reflect a dissimilarity between the species of foraging bees of the different families of market garden plants. It appears thus that the specific composition of bee species is function of plant families (Table 6).

DISCUSSION

The identification of bees caught in the study area revealed 3 families (Apidae, Halictidae and Megachilidae). According to Michener (2000), there are 7 families of bees in the world (Apidae, Colletidae, Halictidae, Andrenidae, Melittidae, Stenotritidae and Megachilidae), including six in sub-Saharan Africa. The low number of bee families recorded in this study area would have been related to climate and vegetation. Indeed, bees are very abundant and diversified in regions with a temperate climate such as the Northeast United States, Europe, and the far South Brazil until Argentina (Michener 2000). Kremen *et al*. (2002), bee diversity is also important in Mediterranean climate regions such as North Africa and the West Coast of the United States (California). In Canada for instance, 409 species of wild bees are recorded and distributed in six families (Packer *et al*., 2007). The least rich regions are the extreme South Africa, the arid regions, the Far North Australia, East Africa and the equatorial and tropical savannas to which our study area belongs. The presence of Apidae, Halictidae and Megachilidae in the 9 study sites might be due to the ecological and geological characteristics of the study area but also to the characteristics of bee species belonging to these different families. Indeed, according to Benachour (2008), Apidae and Megachilidae are diversified in sub-Saharan, Eastern and Neotropical regions while Halictidae are cosmopolitan. Among the three families of bees, the specific richness of bees is most large in the Halictidae. This great diversity within Halictidae family has been reported by Bendifallah *et al*. (2010) in Algeria. In a similar study, Pauly *et al*. (2010), showed that Halictidae family was indeed the most diverse in Africa and particularly in sub-Saharan Africa. According to these researchers, about one-third of African bee species belong to this family. Lorgokaha site recorded the greatest specific richness of bees. The great diversity of bees caught in this market garden site could be explained by the great diversity of plant spe-

Table 4. Number and proportion of bees on plant families

Plant family	Solanaceae	Poaceae	Malvaceae	Others	Total
Number of bee specimens	246	162	51	82	541
Proportion (%)	45.47	29.94	9.4	15.19	100

Table 5. Jaccard similarity indices (Sj) between sites

Jaccard similarity indices (Sj)	A	B	C	D	E	F	G	H	I
A	1								
B	12	1							
C	12	24	1						
D	27	2	36	1					
E	14	31	38	**50**	1				
F	23	19	25	42	23	1			
G	29	27	18	31	14	38	1		
H	16	31	22	18	13	18	18	1	
I	14	33	21	27	30	15	15	31	1

A : Lorgokaha; **B :** Premafolo; **C :** Ossiéné-Kassirimé; **D :** Soba-Petit Paris; **E :** Natio-Kobadara; **F** : Barrage koko; **G :** Cocody **H :** Nangakaha; **I :** Kassingbaraga.

cies observed on this site. Lorgokaha site seems less disturbed by the existence of small gallery forests located along the river in addition to being dominated by agricultural land and human activities. Moreover, this site is close to the University protected area. This environment would therefore be conducive to ensure the conservation of wild bee species and promote the development of populations. These results are like those obtained by Green leaf and Kremen in 2006.

According to them, the proximity of heterogeneous natural habitats, foraging distance, cultural practices and climatic conditions affect the presence and diversity of wild bees in the crops. In a study of bee diversity and abundance in urban biotopes from Vancouver, British Columbia in Canada, Tamassi *et al*. (2004) reported that vegetable and botanical gardens had a high abundance of bees while the wild urban surroundings exhibited the most diverse populations of bees. *Apis mellifera* and *Pachynomia atrinervis* are more abundant in this study. The strong presence of *Pachynomia atrinervis* (buzzing bee) would be correlated with the number of Solanaceae plant species encountered. Indeed, during the study, this species remained very faithful to Solanaceae. Studies conducted by Shanika *et al*. (2017) on a Solanaceae species, have shown that it is generally more pollinated by buzzing bee species than non-buzzing species. According to the specialists Michener (1979); Buchmann (1983); Smith *et al*. (2002); Shanika *et al*. (2017), Solanaceae are mostly pollinated by buzzing bees. On the other hand, the flowers of Solanaceae do not offer any nectar and have very little perfume, only the pollen seems to interest the visitors (Symon 1979; D'Arcy *et al*. 1990 cited by Smith *et al*. 2002; Todd and Ethel, 2000). According to these same researchers, the anther secretion of Solanaceae is only available to specialized buzzing bees to vibrate the anthers of these flowers, so-called "buzz pollination" (Michez and Vereecken, 2010; Shanika *et al*., 2017). It is for this reason that in our observations, Halictidae (consisting essentially of solitary and buzzing bees) abounded in bee species on Solanaceae. On the other hand, the abundance of *Apis mellifera* could be explained by its social and polylectic character. In fact, this polylectic species is considered as the most important pollinator of many cultivated plants (McGregor 1976; Payette and Oliveira, 1989; Robinson *et al*., 1989; Free 1993 told that Benachour, 2008). These results are in accordance to those of Meurgey (2014). According to the author, honeybee (*Apis mellifera*) observed on 70 different plant species, had shown opportunistic behav-

Table 6. Jaccard similarity indices (Sj) between families of market garden plants

Jaccard similarity indices (Sj)	A	B	C	D	E	F	G	H	I
A	1								
B	15	1							
C	12	12	1						
D	17	7	8	1					
E	7	13	9	12	1				
F	4	18	38	11	9	1			
G	1	8	22	11	15	33	1		
H	5	0	0	14	5	0	2	1	
I	1	17	9	16	21	29	29	18	1

A : Solanaceae; **B :** Poaceae; **C :** Malvaceae; **D :** Asteraceae; **E :** Fabaceae; **F :** Convolvulaceae; **G :** Cucurbitaceae; **H :** Liliaceae; **I :** Tiliaceae.

ior, while other species of *Megachile* were strictly subservient to a single plant family (Fabaceae). The growing practice of beekeeping in the study area may justify the abundance of the honeybee (*Apis mellifera*).In our study, the highest specific richness (23 species) and greatest abundance (318 individuals) of bees were observed in dry season. This result could be related to the abundance and diversity of vegetable species in the department during dry season. In fact, in this zone, during dry season, the landowners who are rice producers for the majority, give up their portions of lowlands to the market gardeners during rainy season, who produce several speculations in order to get money in the local and Abidjan markets. Honeybee abundance observed in dry season is consistent with the results of Russell *et al*. (2005) and Gotlieb *et al*. (2011). According to these researchers, climatic and seasonal conditions influence Apiformes communities. According to Coiffait *et al*. (2016), the spring (from February to April) and early summer (May and June) periods are the most favorable for bees, whether in terms of abundance of individuals or specific diversity. According to Coulibaly (2017), the flowering of many plants, takes place during dry season and bees browse enough flowers during this period. Another hypothesis that explains the abundance of bees in dry season is the preference of these insects for areas with dry climate rather than areas with a humid climate (Michener, 1979). According to the author, some species prefer dry season, particularly because the nesting conditions are more favorable (less mold problems in the nests). In addition, most savanna tree species bloom during the dry season and are good floral resources for these bees (Coulibaly, 2017). From a qualitative and quantitative point of view, three families of plants (Solanaceae, Poaceae and Malvaceae*)* have been visited by bees. Nguemo *et al*. (2004) in a study realized in Cameroon, reported that Asteraceae, Solanaceae, Euphorbiaceae, Myrtaceae and Malvaceae were the most visited plant families by bees. In Algeria, according to Hamel and Boulemtafess (2017), among the 36 families of plants visited by bees, the most represented were Fabaceae (14 species), Asteraceae (13 species) and Lamiaceae (12 species). According to Nguemo *et al*. (2004), the melliferous flora of an area is influenced by several factors: the ecological environment, the extent of the area, the duration, and the time. All this would explain the differences found between our results and those of the literature. The preference for Solanaceae could be explained by the fact that in the different sites sampled, the plant species belonging to this family were the most representative. Indeed, according to Potts *et al*. (2006), Loyola and Martins (2008), Westphal *et al*. (2008), Kuhlmann (2009), Vandermeer *et al*. (2010) and Gotlieb *et al*. (2011), the diversity of environments and in particular the richness of plant communities (structure, composition, specific richness) is important for the diversity of Apiformes communities and constitutes a real challenge for their conservation.

CONCLUSION

This study is the first in terms of assessing the diversity of bee species in the market gardening areas of Korhogo Department in Ivory Coast. Overall, 541 bee specimens were captured on 13 plant species belonging to 9 families (Solanaceae, Malvaceae, Asteraceae, Cucurbitaceae, Poaceae, Convolvulaceae, Fabaceae, Liliaceae and Tiliaceae). Thirty-eight bee species grouped into 25 genera and 3 families (Apidae, Halictidae and Megachilidae) were identified. Halictidae (23 species) is the most diversified family, followed respectively by Apidae (13 species) and Megachilidae (2 species). *Apis mellifera*, *Pachynomia atrinervis*, *Xylocopa* sp and *Lipotriches* sp are the bee species that are common to all market garden sites, in contrary to the others that are sometimes rare. This study shows the great diversity and abundance of bees in market garden crops. It will contribute undoubtedly to the monitoring of bee biodiversity in these areas with strong agricultural pressures.

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