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THE POLLINATING FAUNA OF THE BEAN *VICIA FABA L* AND THE QUANTITATIVE AND QUALITATIVE PERFORMANCE ROLE OF THE PLANT IN THE REGION OF MILA (EAST OF ALGERIA)

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Abstract

The bean is a protein plant cultivated in Algeria, with an economic and nutritional importance.
The study was conducted in the Mila region in March-April 2019 and 2020. The results indicate the presence of ten forager bean species with the dominance of two species, Honeybee *Apis mellifera* and Wild bee *Eucera numida*. All *Eucera numida* visits are positive because *Eucera numida* is automatically more adapted due to the long (long-tongued bee) length. However, most Honey bee *Apis mellifera* visits are negative (non-pollinating) due to his short tongue, leading to stealing the nectar from the holes drilled by bumblebees.
Depending on foraging speed, *Eucera numida* is the faster species. It visits ten flowers per minute on average. Concerning the number of pollen seeds filled by abandoned foragers on the bean flowers, *Eucera numida* filled 93 on average, and *Apis mellifera* filled 69 seeds. Other parameters were studied during the research period.
The quantitative and qualitative performance was determined after the seed recuperation. The results show that the obtained performance by the free access flowers of insects is clearly improved compared to the bagged flowers. Thus, the insects perform a paramount role in the *Vicia faba* pollinating.
Keywords: Pollination, *Apis mellifera*, *Eucera numida*, Pollinating efficiency, Performance, *Vicia faba*

LA FAUNE POLLINISANTE DU HARICOT *VICIA FABA* L ET LE RÔLE DE PERFORMANCE QUANTITATIVE ET QUALITATIVE DE LA PLANTE DANS LA RÉGION DE MILA (EST DE L'ALGÉRIE)

Résumé

La fève est une plante protéagineuse cultivée en Algérie sur de grande surface, elle a une importance économique et nutritionnelle.
L'étude a été menée dans la région de Mila durant la période printanière (mars-Avril) des années 2019, 2020. L'étude a révélé la présence de dix espèces visiteuses de la fève avec la dominance de deux espèces l'abeille domestique *Apis mellifera* et l'abeille sauvage *Eucera numida*. Les visites d'*Eucera numida* sont toutes positives car *Eucera numida* est plus adaptée anatomiquement et cela en raison de la longueur de sa longue, tandis que la plupart des visites de l'abeille domestique *Apis mellifera* sont négatives (non pollinisantes) à cause de sa courte langue, ce qui conduit à voler le nectar à partir des trous percé par les bourdons.
Selon la vitesse de butinage *Eucera numida*, est l'espèce la plus rapide. Elle visite en moyenne dix fleurs par minute. Concernant le nombre de graines de pollen déposé par les butineurs abondants sur les fleurs de la fève, *Eucera numida* a déposé en moyenne 93 graines de pollen contre 69 graines déposées par *Apis mellifera* ; d'autres paramètres ont été étudié durant la période de recherche.
Des calculs de rendement quantitatif et qualitatif sont déterminés juste après la récupération des graines. Les résultats montrent que le rendement obtenu par les fleurs à accès libre d'insectes est nettement amélioré par rapport à celui des fleurs ensachées ; ce qui conduit à conclure que les insectes jouent un rôle primordial dans la pollinisation de *Vicia faba*
Mots clé : pollinisation, *Apis mellifera*, *Eucera numida*, efficacité pollinisatrices, rendement, *Vicia faba*

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INTRODUCTION

The bean (*Vicia faba L*) is a proteinaceous legume cultivated in the whole world not only for its edible seeds but also since it improves the ground fertility due to Nitrogen fixation that increases the availability of phosphorus and the phytosanitary effect onto the ground bringing about high subsequent culture productivity [1]. It provides nectar and pollen for many pollinators [2]. According to the data, Algeria cultivates the bean in the coastal plains and the sublittoral zones occupying an area of approximately 65000 ha and a production between 20000 and 38000 tons per year (Zaghouane O.1991). The bean can be autogamous or allogamous in accordance with the lines [4] [5] [6].

Insect pollination is a vital service for the fruit set of many cultivated species [7] 75% of the cultures' sources of human feeding need insect pollination [8]. Even the self-fertile culture as the bean may benefit from cross-pollination. Several studies have shown that *Vicia faba* productivity increased in the presence of insects ;[9] [10] [11] [12] and particularly the Hymenoptera, which are the most efficient pollinators to facilitate the feeding production by improving fruits and seeds productivity [13]. Moreover, pollination leads to a more synchronous set of pods, seeds maturation and a better qualitative and quantitative harvest [13]; [14]. Flowering plants and insects have developed different adaptations to facilitate pollination and food harvest [15]. The plants attract insects through the nectar and the pollen secreted from the flower. Those recompenses are generally announced by different chemical or visual signals (perfume, form, color) [16]. Every plant has pollinating insects that are better suited to the morphology of its flowers.

In Europe, bees and bumblebees are the bean major pollinators [5], [11]. In the north of Algeria, the species *Eucera pulveracea* was the major pollinator in the abundance term [17]; in the south of Spain and the east of Algeria, *Eucera numida* is considered a bean major pollinator [18] [12], given *Vicia faba* visitors diversity, it is interesting to study plant-insects relations, we realized many settings to define the better-adapted visitors of the plant foraging, to make this, we analyzed and compared several phonological and morphological characteristics of the two main *Vicia faba* visitors in Algeria exactly in the region of Mila *Eucera numida* (oligolectic) *Apis mellifera* (polylectic), we also studied the foraging behavior of major visitors of the plant; many settings of the grain efficiency were realized during the two blooms 2019 and 2020.

Considering the bean's economic importance in Algeria, it seemed necessary to realize this study to elucidate the factors that directly help improve plant efficiency. This study aims to examine which bee species is better effective in pollinating the bean flowers, and for this matter, we started with the following questions: *(i)* Do the bee's species have a specific behavior toward Vicia faba? *(ii)* Which species is better adapted and affective to pollinate our plant? *(iii)* What is the pollinator's impact on the quantitative and the qualitative productivity?

MATÉRIEL ET MÉTHODES

1. Geographical settings and the study sites choice

Firstly, we carried out a data collection of bean farming from the direction of the agricultural sector of the wilaya of Mila to choose the study sites. The study took place in the station of Boumalek, located in the southeast of the wilaya of Mila, and we chose two different study sites. Blooming of 2019: our observations took place on a private farm. The first site has the following geographic coordinates (36°16'21'' N 6°14'03''E) with a surface of 3 hectares. In 2020, our study was realized in the second site (36°15'51''N 6°14'33''E) with a surface of 2 hectares. In those sites . Seedlings were realized on November 16, 2018, and December 02, 2019.

2. Counting of the bean pollination fauna

In order to perform the counting of the foraging insects and the floral density as well as the foraging behavior observations; seven quadrats of one square meter submitted in the same conditions (sun, watering) were placed in the orchard during all the bloom period from March 27 to April 22, 2019, and from April 04 to 24, 2020. During the two blooms, outings were scheduled from 8 a.m until 4 p.m once every two days, respecting the appropriate conditions for pollinators (minimum temperature 15°, a low wind speed, no rain); counting the pollinators from quadrat to quadrat 8-9 min / m^2 from 8 a.m to 4 p.m to catch some specie to identify in the laboratory. The identification was carried out using a magnifying glass, diverse keys, and many reference boxes.

Correlatively counting, the number of blooming flowers is noted to compare with the density of foraging insects [5].

3. The foraging behavior

The observations of foraging behavior were realized only for the two abundant species in the *Vicia faba* flowers, noting the alimentary purpose of the made visits (collecting pollen, nectar or both at the same time), a visit is considered pollinating or positive if the insect touches the flower stigma what sets off the stamina column and provokes the pollen to break free [19] in contrary to the non-pollinators visits or negative where the insects steal the nectar from the source without going through the stamens due to drilled holes by bumblebees at the base of the corolla.

4. Pollinating efficiency

The average number measure of pollen grains deposited on the flower's stigmas by the abundant pollinator insects was done after covering 30 flowers with tulle that stops the access of foraging insects. In full bloom, the tulle was removed while monitoring it for positive pollination by the insect. After preparing the slides containing the pollen grains, the flower was transported to the laboratory to collect the anthers and count the number of pollen grains deposited by each plant's main foragers.

5. Morphological characteristics of the Vicia faba flower and its visitors

A comparison between the morphology of the bean flower and its visitors was made to bring to the fore the morphological adaptations of the specialist visitor compared to the generalist visitor. Thirty-five flowers were harvested during March after the second flowering; the flowers were stored in the freezer. They were observed under a binocular magnifying glass fitted with a graduated eyepiece to measure the corolla diameter (perimeter divided by 3, 14) and the corolla depth (Figure 1). The morphological study was carried out on the two abundant species on the flowers of *Vicia faba* (*Eucera numida* and *Apis mellifera*); the width of the head and thorax (Figure 2), the tongue length (the length of the gloss + the length of the prementum) (Figure 3-4) are the elements measured on 30 individuals of each species using a binocular magnifying glass fitted with a graduated eyepiece.

Figure 1: A flower of *Vicia faba* with measurements made of the depth of the corolla and the diameter

Figure 2: *Eucera numida* with measurements taken

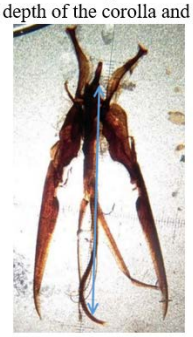

Figure 3: Mouthpiece of *Eucera numida* with measurements taken

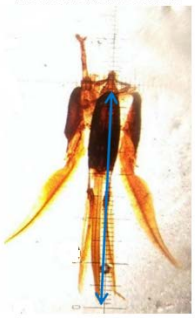

Figure 4: Mouthpiece of *Apis mellifera* with measurements taken

6. Insect role on crop yield

To examine pollinating insects' role in the bean's quantitative and qualitative yield, 50 inflorescences were covered with a tulle; uncovered inflorescences were spotted with colored threads.

Quantitatively and qualitatively, measurements were carried out after harvesting; for each inflorescence, the number of pods formed, the average weight of the obtained seeds, and their shapes were established after the harvest collection.

7. Statistical analyzes

We used the student test to compare the quantitative plant performance with and without pollinators. They allowed us to compare the sample appeared means. The Pearson test was applied to identify the correlation between the number of bloomed flowers during all visits, and the specimen number of *Apis mellifera* and *Eucera numida* attracted to the bean flowers.

RÉSULTATS

1. Vicia faba visitor density

Three insect orders were identified on the plant during the two blooms: Hymenoptera, Diptera and Lepidoptera. The majority of insects foraging on the flowers of Vicia faba are Hymenoptera belonging to four families: Apidae, Megachilidae, Andrenidae, and Halictidae. The two species, *Eucera numida* and *Apis mellifera*, are the most abandoned species on the bean flowers. *Eucera numida* is the most frequent flower species, with an average density of 214 individuals/m2, followed by *Apis mellifera*, which participates in the plant's pollination with an average density of 181 individuals/m2 during the two study periods (Table 1).

Table 1: Average number of *Vicia faba* foragers during the 2019-2020 blooms

	Pollinators	2019	2020
Hymenoptera	1. Apidae		
	Eucera numida (Lepeletier, 1841)	245	184
	Apis mellifera (Linnaeus, 1758)	197	165
	Bombus terrestris africanus (Linnaeus, 1758)	-	42
	2. Megachilidae		
	Rhodanthidium sticticum (Fabricius, 1787)	30	3
	Osmia tricornis (Latreille, 1811)	12	7
	3. Andrenidae		
	Andrena obselata	12	2
	4. Halictidae	1	1
Diptera	Diptera	16	11
Lepidoptera	*Pieris rapae (Linnaeus, 1758)*	7	5
	Parage aegeria (Linnaeus, 1758)	2	-

2. Foraging behavior

These parameters were carried out for the two most frequent species on the flowers of *Vicia faba*: *Eucera numida* and *Apis mellifera*, during the two blooms in 2019 and 2020. All *Eucera numida* visits are pollinating. When the bee goes into the flower to look for the nectar, it penetrates its tongue to the corolla base, and naturally, the whole bee body is covered with pollen which hangs on it and sticks to the hairs. The *Eucera* scratches the flower's anthers with its forelegs, transferring pollen to the hind legs. During 2020, we did not record any positive foraging by the honeybee until it collected the pollen. *Apis mellifera* takes the nectar directly from the holes drilled by the bumblebees; it takes the nectar from the source without going through the stamens, this phenomenon is absent during the first flowering (2019), and it is due to the absolute absence of bumblebees (Table 2).

Table 2: The products collected by *Eucera numida* and *Apis mellifera* on the flowers of *Vicia faba* and their pollinating efficiency in 2019 and 2020

Flowering	Species	N V	V P	P^+	N+	N^-	(P+N)
2019	*Eucera numida*	245	245	22%	68%	0%	10%
	Apis mellifera	197	197	34%	61%	0%	5%
2020	*Eucera numida*	184	184	17%	59%	0%	24%
	Apis mellifera	165	84	49%	0%	50%	1%

N V: Number of visits made; V P: pollinating visit number; P: Pollen; N: Nectar
+: Pollinating visit; - : Non-pollinating visit

3. Pollinating efficiency

To compare the pollinating efficiency of different abundant bees on flowers, we have to consider the average number of pollinating visits rather than the average number of flowers visited per minute. In 2019, 59% of honey bee visits were pollinating, while Eucera numida always makes pollinating visits on the flowers of the bean (Table 3). Concerning the time spent on the plant's flowers, the observations show that the honey bee is significantly slower than *Eucera numida*.

It spent 7.99 seconds on average per flower, and *Eucera numida* spent 5.77 seconds (Table 4). Moreover, the measurements of the pollen grains number deposited by each species that frequent the flowers of *Vicia faba* during the first flowering shows that *Eucera numida* deposited an average of 92.85 pollen grains per visit compared to 69.14 pollen grains deposited by *Apis mellifera* (Table 5). This parameter confirms the *Eucera numida* efficiency in pollinating *Vicia faba*.

Table 3: Foraging speed of *Eucera numida* and *Apis mellifera* on *Vicia faba* flowers during the two blooms

Flowering	N	Visited flowers number/min			
		Eucera numida		*Apis mellifera*	
2019	50	10.26±2.9	100% +	6.68±1.6	59% +
2020	50	9.43±2.3	100% +	7.22±1.5	42% +

+ pollinating visit

Table 4: The spent time on the bean flowers

Flowering	The species	N	Spent time / s
2019	*Eucera numida*	50	5.32±0.25
	Apis mellifera	50	7.54±0.34
2020	*Eucera numida*	50	6.22±0.41
	Apis mellifera	50	8.44±0.33

Table 5: The grains number deposited on the stigmas of flowers by *Eucera numida* and *Apis mellifera* during the year 2019

The species	N	Average number of pollen grains
Eucera numida	27	92.85±6.02
Apis mellifera	27	69.14±5.56

N: Number of flowers studied

4. Activity rhythm of Apis mellifera and Eucera numida on Vicia faba

Activity rhythm study of Eucera numida and *Apis mellifera* during the two blooms in 2019 and 2020 shows activity peaks for both species, which is directly proportional to the number of the blooming flower. The most intense activity of the apoids occurred after the eighth exit on April 12, 2019, and the fourth one on April 1, 2020. a decrease was recorded in parallel with the decrease in open flowers (Figures 5 and 6). The correlation Pearson test indicates a significative relation between the number of bloomed flowers during all the visits, and the domestic bee specimens and *Eucera numida* attracted.

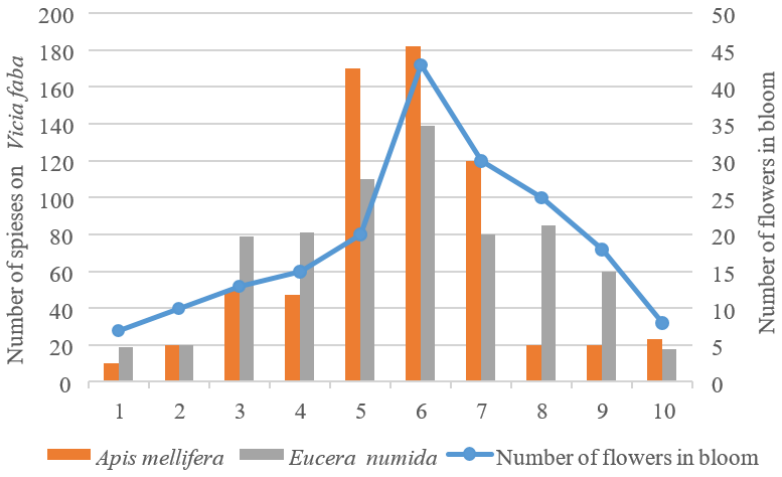

Figure 5: Evolution of the numbers of *Eucera numida* and *Apis mellifera* on the *Vicia faba* flowers and the number of flowers in bloom during flowering 2020

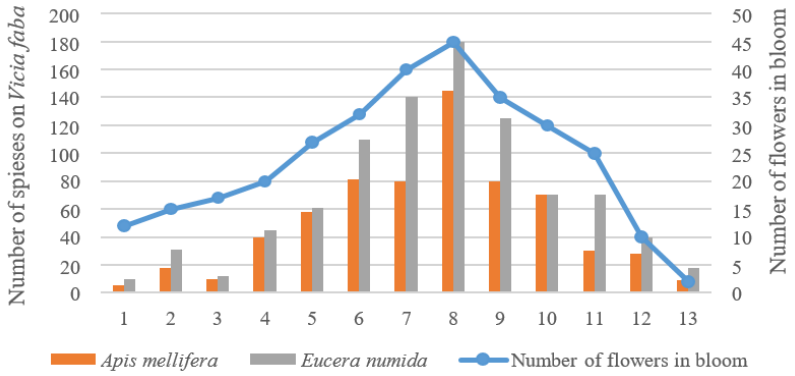

Figure 6: Evolution of the numbers of *Eucera numida* and *Apis mellifera* on the *Vicia faba* flowers and the number of flowers in bloom during flowering 2019

5. Morphological characteristics

The average widths of the thorax and the head of the two species studied (*Eucera numida* and *Apis mellifera*) are not very significantly different; on the other hand. The measured tongue length is significantly different; *Eucera numida* is characterized by a long tongue compared to the honey bee, which has a short tongue (Table 6). The results show that the tongue length of *Eucera numida* is significantly relative to the corolla depth of Vicia faba (Table 7) and is different from the length of the honeybee's tongue due to the difference between the size of the mouthparts of the two taxa. The morphology of the Eucera numida specialist pollinator is better suited to *Vicia faba's* visit than the honey bee (generalist visitor).

Table 6: Morphological characteristics of major visitors of *Vicia faba*

Taxon	N	Thorax width	Head width	Tongue length
Eucera numida	20	4.96±0.22	3.99±0.12	9.12±0.23 mm
Apis mellifera	20	3.89±0.12	3.82±0.11	4.52±0.35 mm

N: studied insects number

Table 7: Morphometric characteristics of *Vicia faba* flowers

Corolla depth	8.6 ± 0.15 mm
Corolla diameter	13.8 ± 0.13 mm

6. Bean efficiency

The bean's yield is extremely improved in the presence of pollinating insects. The rate of fruit set (the number of flowers transformed into pods) by pollinated flowers (not covered by a tulle) is 3-4 times higher than that of unpollinated flowers (covered by tulle). The student test results show a very big difference between productivity in the presence and absence of pollinating insects. There is a great improvement in the plant's productivity ($t=0.007<0.05$). The percentage of grains in good shape is significantly greater at the level of free inflorescences than at caged inflorescences. Inflorescences covered by a tulle give more wrinkled and aborted seeds than uncovered inflorescences. The average seed weight produced by free inflorescences is also greater than caged ones (Table 8). Thus, the main advantage of bean pollination by insects is the quantitative and qualitative improvement of the seed yield of the plant; Harvest losses are thus reduced to a minimum.

Table 8: Pollinators' effect on the yield of *Vicia faba*

Flowering	Pollination	N	NF	Seed number	% seeds of good shape in	% of seed wrinkled	% of seeds aborted	Average seed weight
2019	Free	50	116	350	80.01	9 .42	10.57	3.56±0.41 g
	Auto-pollination	50	25	74	67.57	20.27	12.16	2.92±0.3 g
2020	Free	50	151	464	81.32	10.66	8.02	3.48±0.26 g
	Auto-pollination	50	45	138	72.97	11.88	15.15	2.74±0.55 g

N: Inflorescence number NF: Number of pods formed

DISCUSSION

Studies on *Vicia faba* flowers during the two blooms in 2019 and 2020 show that the plant's major pollinators are Hymenoptera belonging to the Apidae family; *Eucera numida* is the major bean pollinator during the two blooms, followed by the honey bee. These results are very similar to those obtained in Constantine, where the same wild bee played a major role in the pollination of *Vicia faba* [12] and also those in the south of Spain [5]. in the north of Algeria. The species *Eucera pulvacea* was the plant's major pollinator [17]. *Bombus terrestris africanus* is completely absent during the first flowering and is represented with a very low percentage of 10% during the second flowering. This result is explained by the flowering precocity, which coincides with the founding period of the colony [20] [21]. it is considered an abundant pollinator of the same plant in Germany but was ineffective for *Vicia faba* pollination [22].

The study of foraging behavior shows that the visits made by *Eucera numida* are positive whatever of the product harvested (nectar or pollen or both), which means that all its visits could be pollinating in the two blooms. On the other hand, the same observations showed that *Apis mellifera* only made positive visits in 2019 due to the total absence of bumblebees, unlike in 2020, the most frequently observed behavior was nectar collection, so we did not record a positive harvest of nectar; it benefits of the holes drilled by the bumblebees [23]. this behavior was also recorded by Pierre et *al*. [5], Koltowski [24], Free [13], Benachour et *al*. [12].

The attraction of pollinating bees to the bean flowers depends on the number of blooming flowers. Our observations during the two study periods show that the presence of pollinating apoids and, in particular, *Eucera numida* and *Apis mellifera* was maximum in 2019 and 2020 due to the peak in the number of blooming flowers which also corresponds to the opening of new flower buds [19], which confirms that the higher the number of flowers, the more insects come to forage on the flowers. The pollinator efficiency study carried out in 2019 by calculating the number of pollen grains deposited on the stigmas of flowers by the two abundant species has not been studied before in Algeria on the bean. This parameter confirms that *Eucera numida* is the most reliable species for bean flowers.

The comparison between the morphological characteristics of Vicia faba and visitors shows that *Eucera numida* has a morphology better suited to the foraging of the plant; therefore, there is a concordance between the morphology of the specialist *Eucera numida* and the bean flower morphology. Experiments comparing the yield of bagged inflorescences with witnesses indicate that insect pollination improves the quantity and quality of the product harvested; the number of pods formed and the number of seeds obtained by uncovered inflorescences is more significant compared to covered inflorescences. These results are consistent with those obtained by Bartomeus et *al.* [9], Free [10], Nayak et *al*. [11], Pinzauti & Frediani [25], Pritsch [26].

The results indicate that covered inflorescences give more wrinkled and aborted seeds than uncovered inflorescences. Therefore, cross-pollination positively influences the quality of seeds. The pods of pollinated flowers reach maturity, while unpollinated ones abort at the early pod stage. 75% of the world's crops benefit from insect pollination [8]

CONCLUSION

It is important to define the reasons to provide stability in agricultural production. Moreover, the results highlight the importance of preserving pollinator species that can improve the resilience of agricultural production to promote current food security and for the future. This can only be done by protecting the nests of wild bees against external factors and considering the protection means of these pollinators constantly subjected to human pressures such as agricultural practices.

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