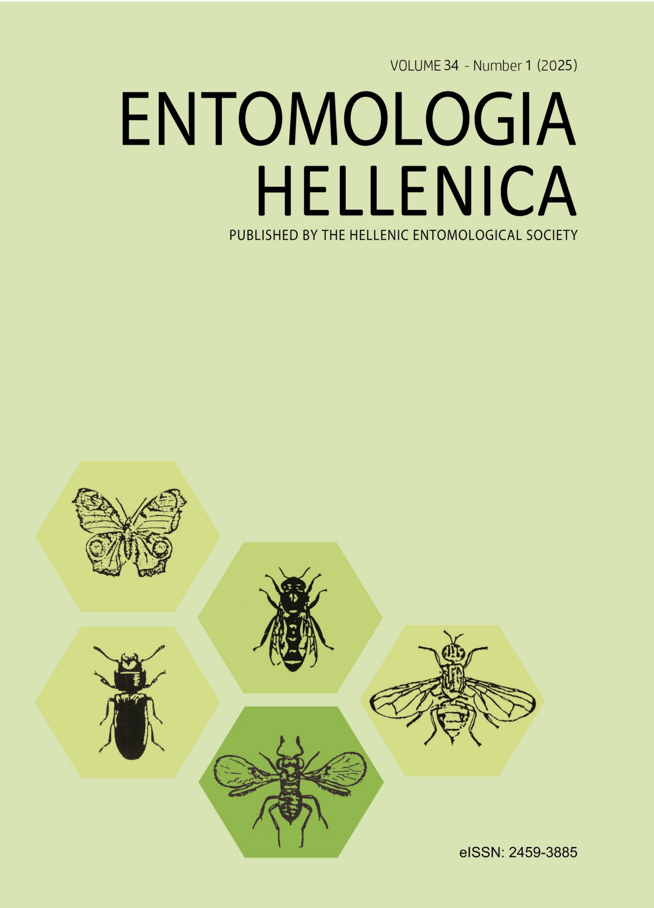
ENTOMOLOGIA HELLENICA

Vol 34, No 1 (2025)

Entomologia hellenica 34(1)



Pollinator Diversity and Their Role in Boosting Melon and Cucumber Yields in Khenchela

Noudjoud MAGHNI, Lynda RAIS, Malika SAIDI, Fransisco Javier Ortiz-Sánchez

doi: [10.12681/eh.39364](https://doi.org/10.12681/eh.39364)

ENTOMOLOGIA HELLENICA **34** (2025): 83-99

Received 15 November 2024 Accepted 05 May 2025 Available online 11 May 2025

Pollinator Diversity and Their Role in Boosting Cucumber and Melon Yields in Khenchela

Noudjoud Maghni[*1], Lynda Rais[1], Malika Saidi[1] & Francisco Javier Ortiz-Sánchez[2]

[1]Department of Biology, Abbes Laghrour University Khenchela -Algeria- (BP 1252 Road of Batna Khenchela 40004)

[2]Grupo de Investigación "Transferencia de I+D en el Área de Recursos Naturales", Universidad de Almería, E04120 La Cañada (Almería), Spain

ABSTRACT

The present study was undertaken in the municipality of El Hamma, Khenchela, Algeria to investigate insect pollination of cucumber (*Cucumis sativus* L.) and melon (*Cucumis melo* L.) grown in a semi-arid region. The results showed that cucumber and melon flowers attracted different pollinator species. A total of 547 individuals, belonging to 47 insect species, 23 families and five insect orders (Hymenoptera, Diptera, Coleoptera, Lepidoptera, and Hemiptera) were recorded. However, honeybees (*Apis mellifera* L.) were the most important pollinators during the flowering period. They visited five flowers per minute, whereas *Megachile rotundata* F. was the quickest visitor (8 flowers/min). The abundance of floral resources was positively correlated with flower species richness. The diversity of pollinator communities was calculated using Shannon index (H') values ranging from 1.14 to 4.01, while the evenness index ranged from 0.03 to 0.06. This study highlights the pivotal role of entomophilous pollination in ensuring food security, as it constitutes a fundamental ecosystem service. It underscores the significance of insect biodiversity in sustaining crop pollination. Consequently, it is imperative to establish nests designated for pollinating insects, plant wildflowers and shrubs, minimize pesticide use, provide clean water sources, and educate farmers on pollinator-friendly practices to enhance agricultural crop quality.

KEY WORDS: *Entomophilous pollination, flowers, diversity, Algeria*

Introduction

Pollination is an organized ecological service of vital importance to nature and agriculture (Goldstein, 2017). The great majority of flowering plant species throughout the world depend on pollination. Pollinators are a crucial contributor to food security and essential for conserving biodiversity, contributing significantly to improving the quality and quantity of crop production (Patel et al., 2021). Consequently, pollinators have a fundamental role in plant reproduction and are a critical key in food agricultural processes (Aizen et al., 2019). Globally, 87% of the world's cultivated species benefit from animal pollination, which accounts for 35% of the world's food supply (Klein et al., 2007).

During pollination, plants rely on pollinators or vectors, such as birds, butterflies, bees, beetles, bats, moths, and wasps, along with abiotic agents like water

*Corresponding author: noudjoud.maghni@univ-khenchela.dz ORCID: 0009-0002-3561-9674

and wind, as well as small mammals for the transfer of microscopic pollen structures (Dar et al., 2017). Inadequate pollination may lead to poor fruit growth. Conversely, increasing the frequency of pollinator visits ensures fruits with superior agronomic quality (Sáez et al., 2018). Angiosperms and their pollinator partners have co-evolved over millions of years, which may explain the huge diversity of floral traits and pollinator adaptations (Sreekala, 2017; Burkle & Runyon, 2017). The great diversity observed in the morphology, coloration, and fragrance of flowers is only a direct result of an intricate relationship between flowers and pollinators (Kantsa et al., 2017). Furthermore, it has been reported that seed production in flowering plant species decreases when there is a decline in animal pollinators (Rodger et al., 2021). Seeds are not only important for plant reproduction but also a crucial food source for animals.

Cucumber (*Cucumis sativus* L.) and melon (*Cucumis melo* L.) are important cucurbits globally, contributing to human nutrition. Both have monoecious flowers, with the male ones appearing before the female, which are distinguished by their fruit-like ovary (Jeffrey, 1990). Reduced pollination may lead to diminished seed production, impacting the long-term reproductive success (Wilcock & Neiland, 2002).

Various groups of currently known insect pollinators belong to the insect orders Hymenoptera, Diptera, Lepidoptera, Coleoptera, Hemiptera, Thysanoptera and Neuroptera (Devi et al., 2017), with the first standing out as the most sophisticated and specialized. This order includes wasps that usually recognize only one color and floral fragrance (Kugimiya et al., 2010), ants that primarily target carbohydrates within nectar sugars, utilizing them as essential energy sources (Vidal-Cordero et al., 2019), and bees, classified in Apoidea. The latter are widely recognized as the most influential agricultural pollinators, contributing significantly to the cultivation and yield of many crops. Bees possess a wide range of behaviors and morphological traits, enabling them to efficiently find and collect nectar and pollen. They can detect scents that help them distinguish the flowers they are frequently visited by other species (Dötterl & Vereecken, 2010).

The most effective dipteran pollinators are Syrphidae species, which are frequently observed in agricultural crops and offer dual benefits: pollination and natural pest regulation (Ssymank et al., 2008; Dunn et al., 2020). The suborders Nematocera and Brachycera feed on pollen and nectar. Thanks to their small size, they reach the inner part of the flowers (Merritt et al., 2009).

Lepidopterans are divided into butterflies and moths, which differ in behavior than morphology. Most adult butterflies prefer to feed on floral nectar (Goldstein, 2017). However, the efficiency of butterflies in pollinating flowers is significantly low, as reported by Khan et al. (2021), because they don't have special body structures to collect pollen and their legs are long and thin. Compared to bees and flies, butterflies and hawkmoths represent minor pollinators in probably all terrestrial ecosystems (Ollerton, 2017; Wardhaugh, 2015).

Coleoptera comprises the suborders Archostemata, Myxophaga, Adephaga, and Polyphaga. Amongst these, some species live on flowers that are eventually pollinated, however less specifically. In addition, these insects can only extract nectar and pollen from flat and open flowers (Dasgupta et al., 2018).

Hemipterans, characterized by their piercing-sucking mouthparts, primarily gain nourishment from plant sap; however, in rare instances, certain species exhibit predatory behavior, extracting nutrients from insect hemolymph or vertebrate blood (Javaid et al., 2016).

This study endeavors to conduct a comprehensive study of the influence of insect pollination on melon and cucumber crop yield performance, emphasizing on the diversity of pollinator species and critically assessing their indispensable role in optimizing the cultivation of these plant species.

Materials and Methods

Study area. This study was conducted from June to September 2022 at an agricultural site in the municipality of El-Hamma, situated Northwest of the capital of Khenchela province, Algeria (35°28'22.79"N, 7°03'53.80"E, 962 m). The area extends from the Aures Massif to the Southeast of the R'mila Plain in the north, covering an area of 168.21 km². The region is characterized by a semi-arid climate, with relatively cold, rainy winters and hot, dry summers.

The experimental field was sown with cucumber and melon seeds (Fig. 1) on May 6, 2022. Two varieties were selected for the study: Super Marketer Cucumber and Yellow Canary Melon, for cucumber and melon, respectively. The two plots, approximately 2 m apart, each measured 3 m × 10 m and contained 80 plants per cultivar, amounting to a total of 160 plants. The experimental plots were divided into two parts: one containing uncaged plants, which were accessible to insect pollinators and visitors, and the other containing caged plants, isolated using tulle fabric that was permeable to air, light and water. The caged sections covered an area of approximately 5m2, effectively preventing insect interaction, while providing adequate space for plant growth. The setup was maintained throughout the 71 days of the flowering period.

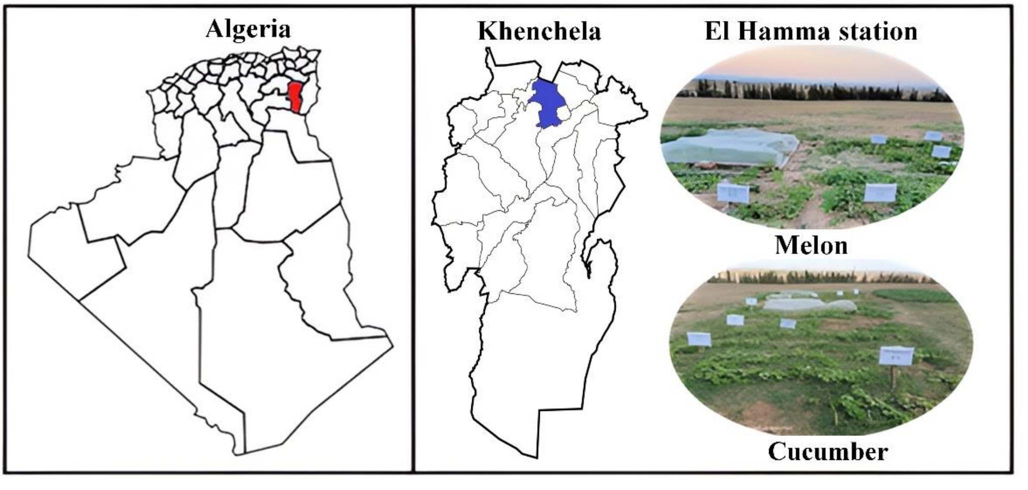


FIG. 1: The location of the experimental area -El Hamma.

Floral phenology. The floral phenology of cucumber and melon was studied by recording the number of flowers produced daily per plant over the flowering period across two seasons (spring and summer), with data collected from the 80 uncaged plants. Due to the difficulty of accurately assessing covered flowers without removing the tulle fabric, counting flowers under the cages was not feasible.

Inventory and density of pollinating insects. For the observation and identification of flower-visiting insects, the widely used quadrat method, as described by Alignier et al. (2023). This method allows systematic sampling and provides a clear framework for observing and recording insect activity on flowers. Quadrats of 1m² were established in the study area. Each quadrat was observed for 10 minutes during peak insect activity. Flower visitors were recorded through visual identification. Not all species were collected to minimize handling. This method ensured efficient and precise data collection. Bee specimens were identified by using different keys (among others, Michez et al., 2019), comparing them with the authors' collections and sending other specimens to specialists for species identification.

Statistical Analysis. Shannon's diversity index (H') was calculated to evaluate the diversity of pollinating species. The foraging activity of key pollinators visiting flowers was analyzed using analysis of variance (ANOVA). Additionally, the weight of fruits produced by melon and cucumber plants was assessed in both open and caged quadrats. Student's t-test was applied for this comparison using Minitab 16 software.

Table 1. Check-list of species pollinating melon and cucumber flowers.

	Species name	Order	Family	Cucumber	Melon	Total
1.	***Andrena florea* (**Fabricius, 1793)	Hymenoptera	Andrenidae	0	10	10
2.	*Apis mellifera* (Linnaeus, 1758)		Apidae	95	115	210
3.	*Eucera eucnemidea* Dours, 1873			0	12	12
4.	*Ceratina callosa* (Fabricius, 1794)			6	14	20
5.	*Ceratina chalybea* (Chevrier, 1872)			7	13	20
6.	*Ceratina cucurbitina* (Rossi, 1792)			0	30	30
7.	*Ceratina saundersi* (Daly 1983)			0	10	10
8.	*Halictus fulvipes* (Klug, 1817)		Halictidae	5	2	7
9.	*Halictus scabiosae* (Rossi, 1790)			3	4	7
10.	*Lasioglossum discus* (Smith, 1853)			0	5	5
11.	*Lasioglossum malachurum* (Kirby, 1802)			3	0	3
12.	*Lasioglossum villosulum* (Kirby, 1802)			0	4	4
13.	*Rhodanthidium siculum* (Spinola, 1838)		Megachilidae	0	6	6
14.	*Megachile centuncularis* (L., 1758)			2	0	2
15.	*Megachile pilidens* Alfken, 1924			4	8	12
16.	*Megachile rotundata* (Fabricius, 1787)			15	0	15
17.	*Ammophila heydeni* Dahlbom, 1845		Sphecidae	1	0	1
18.	*Polistes dominula* (Christ, 1791)		Vespidae	5	10	15
19.	*Scolia hirta* (Schrank, 1781)		Scoliidae	0	4	4
20.	*Camponotus herculeanus* (L., 1758)		Formicidae	3	3	6
21.	*Eristalinus aeneus* (Scopoli, 1763)	Diptera	Syrphidae	3	0	3
22.	*Eristalis arbustorum* (L., 1758)			2	11	13
23.	*Eupeodes corollae* (Fabricius, 1794)			0	4	4
24.	*Tolmerus atricapillus* (Fallén, 1814)		Asilidae	1	0	1

Table 1 continues in next page

Table 1 continues from previous page

25.	*Acontia lucida* (Hufnagel, 1766)	Lepidoptera	Noctuidae	2	0	2
26.	*Cucullia umbratica* (L., 1758)			2	0	2
27.	*Colias crocea* (Geoffroy, 1785)		Pieridae	6	9	15
28.	*Euchloe ausonia* (Hübner, 1804)			3	0	3
29.	*Pontia edusa* (**Fabricius**, 1777)			4	11	15
30.	*Iphiclides feisthamelii* (Duponchel, 1832)		Papilionidae	0	7	7
31.	*Lampides boeticus* (L., 1767)		Lycaenidae	2	8	10
32.	*Lycaena phlaeas* (L., 1761)			0	4	4
33.	*Polyommatus celina* (Austaut, 1879)			0	3	3
34.	*Tarucus theophrastus* (Fabricius, 1793)			4	4	8
35.	*Melitaea didyma* (Esper, 1778)		Nymphalidae	0	3	3
36.	*Vanessa cardui* (L., 1758)			2	0	2
37.	*Achyra nudalis* (Hübner, 1796)		Crambidae	3	2	5
38.	*Scopula ornata* (Scopoli, 1763)		Geometridae	1	0	1
39.	*Carcharodus alceae* (Esper, 1780)		Hesperiidae	2	0	2
40.	*Gegenes nostrodamus* (Fabricius, 1793)			3	0	3
41.	*Pyrgus alveus* (Hübner, 1803)			0	2	2
42.	*Utetheisa pulchella* (L., 1758)		Erebidae	0	3	3
43.	*Coccinella septempunctata* (L., 1758)	Coleoptera	Coccinellidae	12	8	20
44.	*Henosepilachna elaterii* (Rossi, 1794)			6	0	6
45.	*Dicranocephalus agilis* (Scopoli, 1763)	Hemiptera	Stenocephalidae	0	2	2
46.	*Liorhyssus hyalinus* (Fabricius, 1794)		Rhopalidae	1	2	3
47.	*Spilostethus pandurus* (Scopoli, 1763)		Lygaeidae	0	6	6
	Total	5	23	208	339	547

Results

Diversity of flower visitors and pollinators. Several species of insects visited the flowers of both crops (Table 1). These potential pollinators belonged to five insect orders (Hymenoptera, Diptera, Coleoptera, Lepidoptera, and Hemiptera).

Pollinator species recorded. During this study, we recorded 547 flower-visiting individual insects in the peak season from June to September. Table 1 presents the total number of species (47), families (23) and orders (5) visiting each plant (cucumber and melon). Several flower visitors are illustrated in Figure 2.

Among all insects, most pollinators belonged to the order Hymenoptera (Fig. 3). Particularly *A. mellifera* (honeybees) were the most abundant at a 72.94% abundance ratio, Lepidoptera (butterflies and moths) and Coleoptera (beetles) the second and third more notable orders, with abundances at 16% and 5%, respectively. Diptera (flies) and Hemiptera (true bugs) were less abundant, making up 4% and 2% of total pollinators.

Cucumber and melon flowering. During the observation period, cucumber and melon flowering began on June 11 and 16, respectively. Insect colonization of the plot was observed immediately upon the first appearance of the flowers. The number of insect visitors gradually increased over time, corresponding with the flowering progress for both plant species. Indeed, the highest number of visits was recorded during the full flowering period of the plants, reaching its peak on August 24, 2022, with peaks of 400 for cucumber and

232 visits for melon (Fig.4). Flowers began to open around 40 days for cucumber and 35 days for melon, after planting, and continued for 71 days.

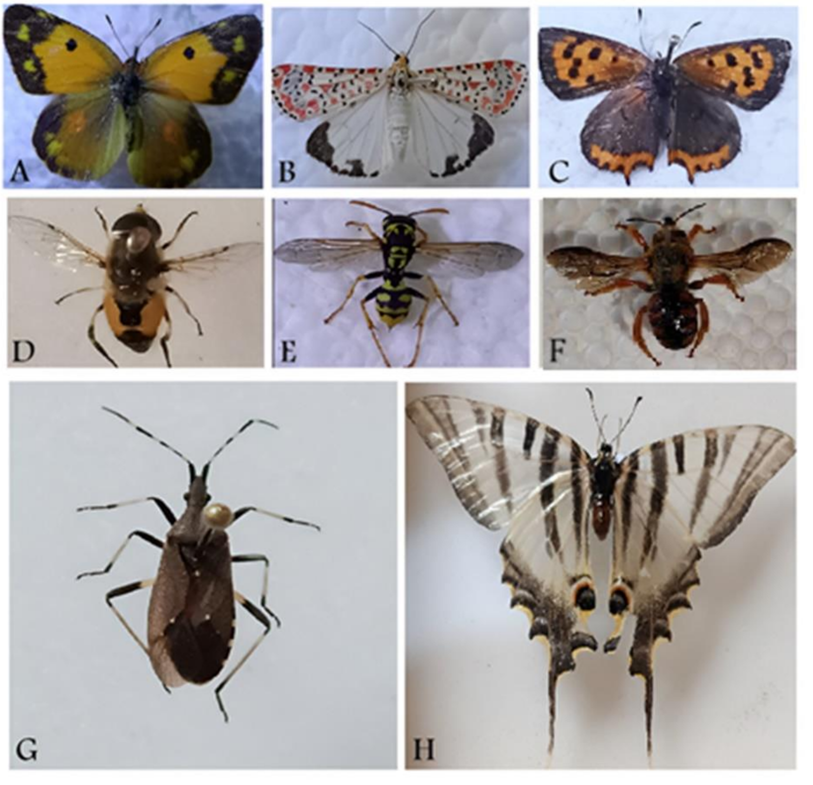


FIG. 2: Some flower visitors on melon and cucumber flowers. A: *Colias crocea* B: *Utetheisa pulchella* C: *Lycaena phlaeas* D: *Eristalis arbustorum* E: *Polistes dominula* F: *Rhodanthidium siculum* G: *Dicranocephalus agilis* H: *Iphiclides feisthamelii*. (Original photos).

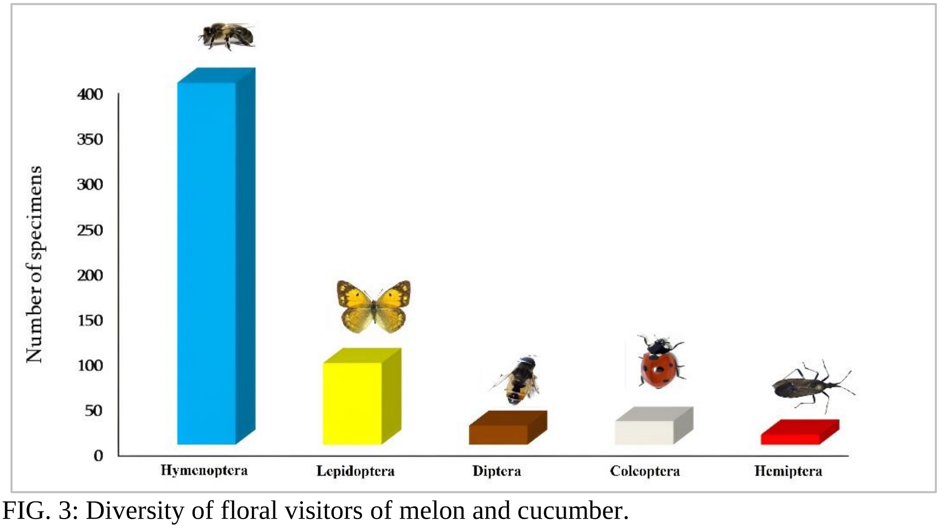


FIG. 3: Diversity of floral visitors of melon and cucumber.

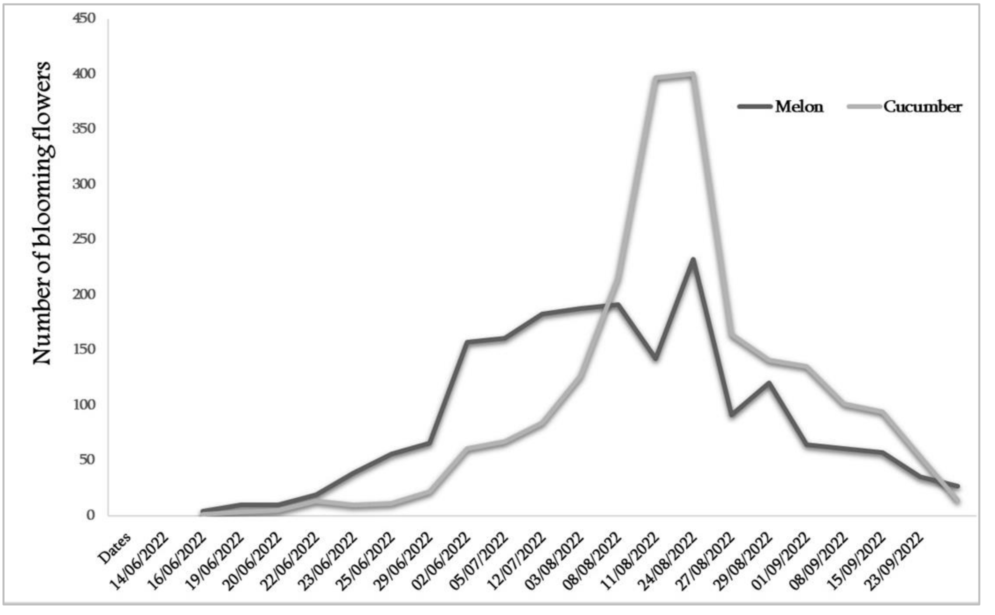


FIG. 4: Flowering phenology of melon and cucumber.

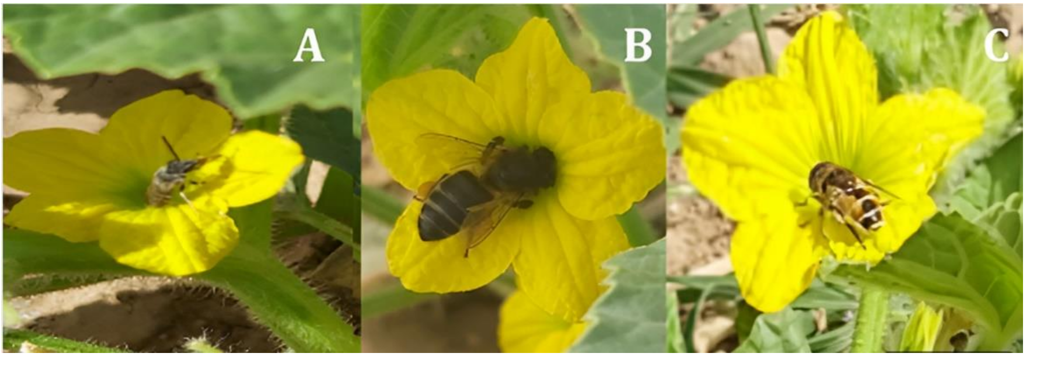


FIG. 5: Some pollinator species visiting *Cucumis melo*. A: *Andrena florea* B: *Apis mellifera* C: *Eristalis arbustorum*. (Original photos).

Figure 5 shows some bee species, such as *Andrena florea* or *A. mellifera* and the hoverfly *Eristalis abustorum*, known for their role in pollinating melon, particularly attracted to flowers with ample pollen.

Figures 6 and 7 indicate that insects foraged on cucumber flowers from 6:00 (flower opening) until 19:00 (flower closing). The pollinators exhibit their highest activity levels between 9:00 and 12:00, with significantly reduced activity during the early morning (6:00 – 9:00) and late afternoon (15:00 – 18:00) on both cucumber and melon plants.

A one-way ANOVA revealed a significant difference in pollinator activity across species at different times of the day ($F = 3.35$, $p = 0.0377$). *Apis mellifera* exhibited significantly higher activity, particularly in the morning (9:00–12:00), while *E. arbustorum* showed consistently lower activity levels throughout the day. These results indicate temporal variation in species-specific foraging behavior (Fig.7).

Foraging activity of dominant pollinators visiting flowers. Foraging rates of the insect pollinators were recorded in terms of the number of flowers visited per minute. *Apis mellifera* initiated activity at 08:00 and remained active throughout the entire observation period, until 17:00. In the experimental region, honeybees were the most prevalent flower visitors, accounting for 46% and 34% on cucumber and melon, respectively. The abundance of flower visitors increased with increasing floral density across the flowering period.

FIG. 6: Flowers collected at different study times of the anthesis day in cucumber. Selected Flowers are taken at A: 10:00am B: 11:00am C: 12:00 D: 18:00. (Original photos).

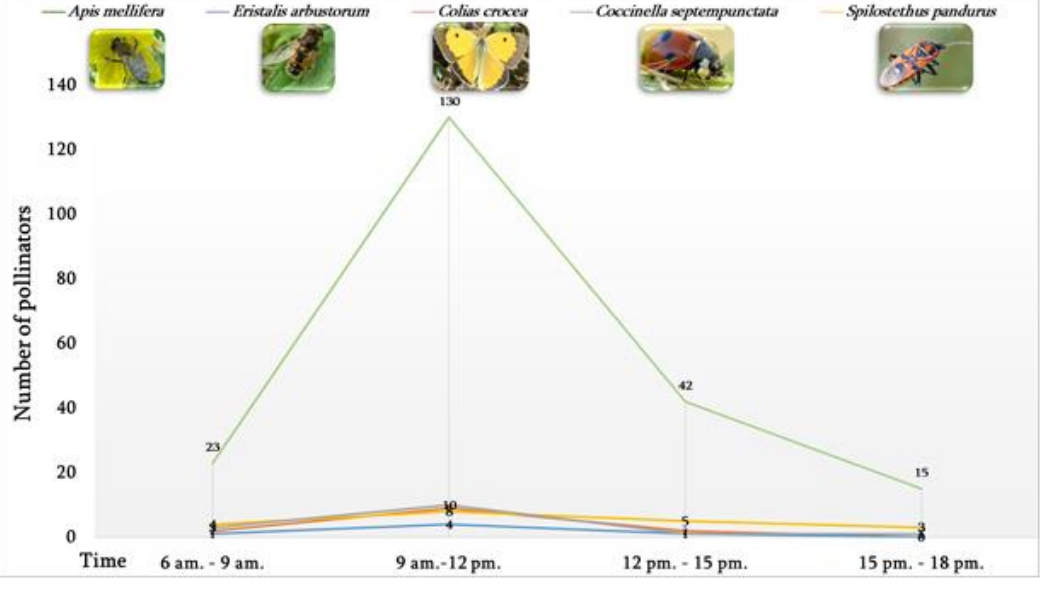


FIG. 7: The activity of different pollinator species at various times of the day.

The bees presented in Table 2 were observed under controlled conditions, where the number of flowers visited per minute was meticulously recorded using one-minute observational intervals. Multiple observations were conducted to ensure data accuracy and reliability. Notably, Megachilidae bees visited more flowers per minute compared to other insect species. *Megachile rotundata*, the most efficient species, visited an average of 8 flowers per minute, which is more than twice the visitation rate of *C. cucurbitina*, the slowest species, visiting an average of 4 flowers per minute.

Table 3 provides an overview of Shannon's index, a widely used ecological metric that quantifies community diversity by considering both species richness and the evenness of their distribution (Cazzolla et al., 2020). The H' values varied between 1.14 and 4.01, while the Evenness index ranged from 0.03 to 0.06.

Table 3. Change in diversity indices based on the number of specimens in both crops in 2022.

Crops / **Indices**	**Melon**	**Cucumber**
SHANNON-WIENER index (H')	4,01	1,14
Equitability (E)	0,03	0,06

Table 4. Average weight (W±s, n=5) (g) of fruits.

	Uncovered quadrats						**Covered quadrats**					
Quadrats (Q)	Q1	Q2	Q3	Q4	Q5	W±	Q1	Q2	Q3	Q4	Q5	W±
Melon (g)	3340	2450	2870	2790	2790	2848±319	300	290	330	140	150	242±89.8
Cucumber (g)	2540	2170	2430	2290	2730	2432±218	250	160	260	370	180	244±82.6

Impact of pollinator insects on fruit yields of both crops. The average weight of fruits produced by cucumber and melon plants was calculated, for both the open and caged quadrats, and the results are presented in Table 4. The average weight of melon fruits in the open quadrats (2848 g ± 319) was significantly greater than that of fruits produced under the netting in the five caged quadrats (242 g ± 89.8). A Student's t-test showed a highly significant difference in fruit weight across both types of plants ($t = 17.57$, $p < 0.0001$, DL = 4).

Similar results were observed for cucumber fruits, where the average weight of fruits in the open conditions (2432 g ± 217.8) was significantly higher than that in the caged conditions (244 g ± 82.6). Student-t test showed a statistically significant difference in fruit weight for both species of plants ($t = 21.02$, $p < 0.0001$ DL=5).

Discussion

Cucumber (*Cucumis sativus*) and melon (*C. melo*) belong to the Cucurbitaceae family. Both crops are monoecious vegetables, bearing male and female flowers on separate parts of the same plant (Kawagoe & Suzuki, 2002).

In the present study, it was observed that the first male flower of melon appeared five days before the male flower of cucumber (June 11 and June 16, respectively). The number of flowers increased gradually over time, correlating with the flowering progression of melon and cucumber. The abundance peaked on August 24, 2022, reaching values of 232 for melon and 400 flowers for cucumber. The observation that melon flowers open around 35 days after planting and cucumber flowers around 40 days, with a flowering period continuing for 71 days until fruiting, indeed provides valuable insights into their growth cycles. These results confirm the study of Revanasidda & Belavadi (2019) and further strengthen the knowledge on the interactions between the plant and its pollinators.

Hymenoptera is an integral order of insects, with several species differing in floral preferences, number of flight hours and/or dependence on climatic conditions. *Apis mellifera* and solitary bees are the main visitors of cucumbers (Abbasi et al., 2023). Bencharki et al. (2023) confirm our results that honeybees are the dominant floral visitors in melon and are highly effective for pollination.

From our observations, *Megachile rotundata* is shown to have the highest foraging speed, visiting 8 flowers per minute, followed by the dipteran *E. arbustorum*, with 6 flowers per min. On the other hand, *A. mellifera* and *C. cucurbitina* have lower foraging speed comparing to *M. rotundata*, specifically 6 and 4 flowers per minute respectively. By comparing the results of pollinator efficiency of *A. mellifera* and *C. cucurbitina* with those of Louadi (1999) and Maghni (2006), we note that our results confirm previous data.

In the present study, honeybees were represented by 115 specimens on melon flowers (which represents 34% of the melon visitors) and 95 on cucumber flowers (representing 46% of the cucumber visitors) collected during the flowering period of both crops. According to Rukshanda et al. (2022), *A. mellifera* is the most abundant, comprising over 72.94% of all pollinating insects. Ramesh (2007) and Sarwar et al. (2008) noticed that bees significantly enhance the qualitative and quantitative characteristics of fruits and yield in both open-pollinated and caged plants. Other abundant Apidae species recorded during our study include *Eucera eucnemidea*, *Ceratina callosa*, *C. chalybea*, *C. cucurbitina*, and *C. saundersi*.

Cucumber and melon flowers are visited by 15 wild bee species, which are generally very effective pollinators. This study recorded wild bee species belonging to 4 families: Apidae (as previously mentioned), Megachillidae (*M. rotundata*, *M. pilidens*, *M. centuncularis* and *Rhodanthidium siculum*); Halictidae (*Halictus fulvipes*, *H. scabiosae*, *Lasioglossum discus*, *L. malachurum and L. villosulum;* and Andrenidae, represented by only one species (*Andrena florea*). This coincides with other studies that have pointed out these families as key pollinators of melon crops (Pérez-Marcos et al., 2023).

We agree with the hypothesis proposed by Bencharki et al. (2023) that the floral displays of melon are likely adapted to facilitate pollination by small bees with short tongues, such as *Lasioglossum* sp. Only a single species from the Andrenidae family, *A. florea* was collected during our experiment. This species is very specialized and depends on the presence of food plants for its larvae, specifically the dioecious bryone (*Bryonia dioica*), a native plant in Algeria widely used to treat several ailments including cancer (Benarba, 2015). The species frequently visits melon flowers, likely due to the resemblance in their floral structure, which is predominantly characterized by shallow flowers.

Lepidopteran insects are among the most important pollinators of flowering plants. In our study, we identified 18 species from 8 families, *i.e.* Noctuidae, Pieridae, Lycaenidae, Nymphalidae, Cram bidae, Geometridae, Hesperiidae & Erebidae. Rukshanda et al. (2022) reported three species of Lepidoptera on cucumber in India. Yeboué et al. (2022) indicated that butterflies not only visit flowers during their pollinating travels, but females take the opportunity to lay their eggs on the underside of the leaves. At this stage of development, eggs do not pose a threat to cucumber plants. It is during the larval stage that these insects become a significant concern.

During the present study, four species of the order Diptera were recorded, three from the family Syrphidae and only one species from Asilidae, known as robber flies, which are primarily predators. However, some species also play a role in pollination, including *Tolmerus atricapillus*. Conversely, hoverflies, also called flower flies or syrphids, are perceived as less effective pollinators (Jauker et al., 2011) and less specialized visitors (Cowgill et al., 1993).

The order Coleoptera was represented only by the family Coccinellidae, particularly, the species *Coccinella septempunctata*, the significant bio-control agent with strong predatory ability against many important types of pests, including aphids, whiteflies, spider mites, leafhoppers, and psyllids (Cheng et al., 2020). While they may help with pollination, they are not actively seeking out flowers for this purpose.

The last order, Hemiptera, included three species that interestingly play a role in pollination. According to Lemaitre et al. (2014), hemipteran insects inhabit fields and meadows where plants are growing but contribute to pollination minimally.

In our study, it was observed that insects foraged on flowers from 6:00 (when the flowers opened) until 19:00 (when the flowers closed). The peak foraging activity occurred between 9:00 and 12:00. Sujatha et al. (2024), in their study on the foraging behavior of honeybee species on fenugreek (*Trigonella foenum-graecum*), reported that *A. mellifera* began foraging at 06:40 and continued until 18:00 during the spring season.

One-way ANOVA ($F = 3.35$, $p = 0.0377$) revealed significant differences in pollinator activity among species. Apis mellifera showed peak activity in the morning, likely due to optimal environmental conditions (Scaven & Rafferty, 2013). Meanwhile, *E. arbustorum* maintained steady activity throughout the day, reflecting its generalist behavior (Inouye et al., 2021). Temporal niche partitioning reduces competition and enhances pollination efficiency (Bartomeus et al., 2019), with important implications for optimizing agricultural practices (Brittain et al., 2013).

Our study's findings, with Shannon's index values ranging from 1.14 to 4.01 and Evenness index values from 0.03 to 0.06, indicate a significant dominance of *A. mellifera*. These findings align well with the study by Montoya-Pfeiffer et al. (2021), who also observed that honeybees effectively exploit diverse landscapes. This suggests that in environments with higher biodiversity, honeybees can take advantage of the variety of floral resources available, enhancing their foraging success.

Our results confirm that the average weight of fruits of the uncovered plants was greater than that of the covered for both crops (cucumber and melon). This difference in yields is unequivocally attributed to flower pollination by insects during the reproductive phase. Our study highlights that insect pollination is crucial for producing high-quality fruits and reveals a statistically significant difference in fruit weight, supporting the findings by Buchmann & Nabhan (1996), who suggested that wild insects pollinate 80% of the 100 most important staple crops. However, in contrast to our findings, Tschoeke et al. (2015) reported only a moderate correlation between bee visitation rate and fruit weight.

Cucurbit yield can increase as diverse floral resources are introduced around the fields, potentially enhancing the species richness and abundance of wild pollinators and contributing to the improvement of pollination services (Hoehn et al., 2008). In Indonesia, the loss of pollinators led to a 75% reduction in cucumber yield compared to its potential maximum (Motzke et al., 2015). Melon crops are heavily dependent on insect pollinators for reproduction.

Our findings regarding fruit yield of melon and cucumber confirmed that covered plants, which lacked visits from pollinating insects, did not develop as well as those that were uncovered and accessible to pollinators. This aligns with the findings of Khan et al. (2021), who observed increased yields in plots assumed to have pollinator involvement, while plots without access to pollinators exhibited lower yields. Bohart (2006) suggested that pollination contributes to the healthy functioning of unmanaged terrestrial ecosystems.

Conclusion

This study revealed a high density of pollinator insects, which correlated with acceptable levels of fruit production. Consequently, we conclude that maintaining a substantial population of pollinator insects is essential to ensure fruit productivity. Our findings emphasize the significant role of pollination in plant community dynamics and underscore the necessity for further detailed research to elucidate how pollination contributes to the lifetime reproductive success of plants, including aspects such as fruit set, seed development, and overall plant health.

The present study shows that enhancing the effectiveness of pollinating insects by establishing insect hotels is essential to increase the chance of natural visits to our gardens and thus the efficiency of pollinators in improving the quality of agricultural crops. Furthermore, maintaining continuous flowering resources across the seasons over the entire farmland would contribute to supporting large pollinator populations and, therefore, improve overall pollination effectiveness.

Authors' contribution

The first and second authors provided financial support for this research, and they also contributed to writing the abstract, describing the methodology, presenting the results, discussing the findings, and formatting references and citations. The third author played a key role in structuring the manuscript and writing the introduction. The fourth author supervised and corrected the last version of the article, mainly the presentation of results and discussion.

Conflict of interest

The authors declare that they have no conflict of interest related to the publication of this paper.

Acknowledgements

The authors express their gratitude to Pr S. Djelleb and N. Ouchtati for their assistance with identification. We also extend our thanks to the reviewers for their valuable insights and suggestions during the preparation of this article.

References

Abbasi, K.H., Anjum, N., Arslan, M., Zubair, M., Sami, A., Feroze, M.A., Afzal, M.B.S., Iqbal, J., Mazhar, R., Hussain, M., Khan, M.F., Ashraf, S., Aslam, M.Z. & Ali, S. 2023. Estimation of honeybees (*Apis mellifera* L.) impact in pollination of cucumber (*Cucumis sativus* L.) crops for yield enhancement and seed quality. Journal of Survey in Fisheries Sciences, 10 (3S): 5935-5945.

Aizen, M.A., Aguiar, S., Biesmeijer, J.C., Garibaldi, L.A., Inouye, D.W., Jung, C., Martins, D.J., Medel, R., Morales, C.L., Ngo, H., Pauw, A., Paxton, R.J., Saéz, A. & Seymour, C.L 2019. Global agricultural productivity is threatened by increasing pollinator dependence without a parallel increase in crop diversification. Global Change Biology, 25: 3516–3527.

Alignier, A., Lenestour, N., Jeavons, E., Baaren, J. van, Aviron, S., Uroy, L., Ricono, C. & Le-Lann, C. 2023. Floral resource maps: a tool to explain flower-visiting insect abundance at multiple spatial scales. Landscape Ecology, 38: 1511–1525. https://doi 10.1007/s10980-023-01643-9

Bartomeus, I., Ascher, J. S., Gibbs, J., Danforth, B. N., Wagner, D. L., Hedtke, S. M., & Winfree, R. (2019). Historical changes in northeastern US bee pollinators related to shared ecological traits. Proceedings of the National Academy of Sciences (PNAS), 110(12), 4656–4660. https://doi.org/10.1073/pnas.1218503110

Benarba, B. 2015. Ethnomedicinal study of Bryonia dioica, a plant used as anti-breast cancer herbal therapy in Northwest Algeria. Journal of Medicinal Herbs and Ethnomedicine, 1: 113-115. https://www.researchgate.net/publication/284182729

Bencharki, Y., Christmann, S., Lhomme, P., Ihsane, O., Sentil, A., El Abdouni, I., Hamroud, L., Rasmont, P. & Michez, D. 2023. Farming with alternative pollinators' approach supports diverse and abundant pollinator community in melon fields in a semi-arid landscape. Renewable Agriculture and Food Systems, 38, e6, 1-12, https://doi.org/10.1017/S1742170522000394

Bohart, C.R. 2006. Role of pollinators in ecosystem and their impact on crop yield in the field. Journal of Economical Entomology, 56 (7): 425-429.

Brittain, C., Kremen, C., & Klein, A. M. (2013). Biodiversity buffers pollination from changes in environmental conditions. Global Change Biology, 19(2), 540–547. https://doi.org/10.1111/gcb.12043

Buchmann, S.L. & Nabhan, G.P. 1996. The Forgotten Pollinators. Island Press, Washington, DC. 292 pp.

Burkle, L.A. & Runyon, J.B. 2017. The smell of environmental change: Using floral scent to explain shifts in pollinator attraction. Applications in Plant Sciences, 5 (6), 1600123. https://doi.org/10.3732/apps.1600123

Cazzolla Gatti, R., Amoroso, N. & Monaco, A. 2020. Estimating and comparing biodiversity with a single universal metric. Ecological Modelling, 424, 109020. https://hdl.handle.net/11585/869277

Cheng, Y., Zhi, J.R., Li, F.L., Wang, H., Zhou, Y. & Jin, J. 2020. Transcriptome sequencing of *Coccinella septempunctata* adults (Coleoptera: Coccinellidae) feeding on artificial diet and *Aphis craccivora*. PLoS One, 15 (8): e0236249. https://doi.org/10.1371/journal.pone.0236249

Cowgill, S.E., Sotherton, N.W. & Wratten S.D. 1993. The selective use of floral resources by the hoverfly *Episyrphus balteatus* (Diptera: Syrphidae) on farmland. Annals of Applied Biology, 122 (2): 223–231. https://doi.org/10.1111/j.1744-7348.1993.tb04029.x

Dar, S.A., Hassan, G.I., Padder, B.A., Wani AbR. & Parey, S.H. 2017. Pollination and evolution of plant and insect interaction. Journal of Pharmacognosy and Phytochemistry, 6 (3): 304-311.

Dasgupta, J., Pal, T.K. & Hegde, V.D. 2018. An Appraisal of Range and Evolutionary Significance of Flower-Beetle Association, with Special Reference to Sap Beetles (Coleoptera: Nitidulidae). Proceedings of the Zoological Society, 71: 170–177. https://doi.org/10.1007/s12595-017-0213-3

Devi, M., Sharma, H.K., Raj, K. Thakur, Satish, K.B., Kiran R., Meena T. and Budhi R. 2017. Diversity of Insect Pollinators in Reference to Seed Set of Mustard (*Brassica juncea* L.). Int.J.Curr.Microbiol.App.Sci. 6(7): 2131-2144. doi: https://doi.org/10.20546/ijcmas.2017.607.250

Dötterl, S. & Vereecken, N.J. 2010. The chemical ecology and evolution of bee–flower interactions: a review and perspectives. Canadian Journal of Zoology, 88: 668–697. https://doi.org/10.1139/Z10-031

Dunn, L., Lequerica, M., Reid, C., and Latty, T. 2020. Dual ecosystem services of syrphid flies (Diptera: Syrphidae): Pollinators and biological control agents. Pest Manage. Sci. 76, 1973–1979. https://doi.org/10.1002/ps.5807

Goldstein, P.Z. 2017. Diversity and significance of Lepidoptera: A phylogenetic Perspective. In: Insect Biodiversity: Science and Society. Vol. 1, pp. 463-495.

Hoehn, P., Tscharntke, T., Tylianakis, J.M., & Steffan-Dewenter, I. 2008. Functional group diversity of bee pollinators increases crop yield. Proceedings of the Royal Society B: Biological Sciences 275, 2283–2291. https://doi.org/10.1098/rspb.2008.0405

Inouye, D. W., Larsen, J., & Renner, S. S. 2021. Flies and flowers III: Ecology of foraging and pollination. Journal of Pollination Ecology, 28(6), 1–20. https://doi.org/10.26786/1920-7603(2021)651

Jauker, F., Bondarenko, B., Becker, H.C. & Steffan-Dewenter, I. 2011. Pollination efficiency of wild bees and hoverflies provided to oilseed rape. Agricultural and Forest Entomology, 14: 81-87. https://doi.org/10.1111/j.1461-9563.2011.00541.x

Javaid, S., Amin, I., Jander, G., Mukhtar, Z., Saeed, N.A. & Mansoor, S. 2016. A transgenic approach to control hemipteran insects by expressing insecticidal genes under phloem-specific promoters. Scientific Reports, 6: 34706. https://doi.org/10.1038/srep34706

Jeffrey, C. (1990). Systematics of the Cucurbitaceae. Botanical Journal of the Linnean Society, 93(1), 1–233. https://doi.org/10.1111/j.1095-8339.1986.tb01981.x

Kantsa, A., Raguso, R.A., Dyer, A.G., Sgardelis, S.P., Olesen, J.M. & Petanidou, T. 2017. Community-wide integration of floral colour and scent in a Mediterranean scrubland. Nature, Ecology & Evolution, 1 (10): 1502-1510. doi: 10.1038/s41559-017-0298-0

Kawagoe, T. & Suzuki, N. 2002. Floral sexual dimorphism and flower choice by pollinators in a nectarless monoecious vine *Akebia quinata* (Lardizabalaceae). Ecological Research 17: 295–303. https://doi.org/10.1046/j.1440-1703.2002.00489.x

Khan, F., Ullah, W., Muhammad, M., Ullah, I., Basit, A., Ahmad, M., Uddin, B., Ullah, A., Zaib, A., Ullah, I., Khan, M.A., Ali, A., & Ain, Q.U. 2021. Surveillance of insect pollinators on cucumbers and their effect on its yield.

Natural Volatiles and Essential Oils, 8 (6): 5753-5762. https://www.researchgate.net/publication/360054567

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C. & Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B, 274: 303–313. https://doi.org/10.1098/rspb.2006.3721

Kugimiya, S., Shimoda, T., Tabata, J. & Takabayashi, J. 2010. Present or Past Herbivory: A Screening of Volatiles Released from *Brassica rapa* Under Caterpillar Attacks as Attractants for the Solitary Parasitoid, *Cotesia vestalis*. Journal of Chemical Ecology, 36: 620–628. https://doi.org/10.1007/s10886-010-9802-6

Lemaitre, A.B., Pinto, C.F. & Niemeyer, H.M. 2014. Generalized pollination system: Are floral traits adapted to different pollinators? Arthropod-Plant Interactions 8, 261–272. https://doi.org/10.1007/s11829-014-9308-1

Louadi, K. 1999. Systématique, relation avec l'agrocénose dans la région de Constantine. Doctoral thesis in sciences, Mentouri University, Constantine. 168 pp.

Maghni, N. 2006. Contribution à la connaissance des abeilles sauvages (Hymenoptera; Apoidea) dans les milieux naturels et cultivés de la région de Khenchela. Magister's thesis in entomology, Constantine 1 University, Constantine. 149 pp.

Merritt, R.W. Cummins, K.W. & Berg, M.B. 2009. An Introduction to the Aquatic Insects of North America; Kendall/Hunt Publishing Company. Dubuque, IA, USA. 1214 pp.

Michez, D., Rasmont, P., Terzo, M., & Vereecken, N.J. 2019. Bees of Europe. Hymenoptera of Europe (Vol. 1) édition N.A.P., Paris, 548 pp.

Montoya-Pfeiffer, P.M., González-Chaves, A. & Nates-Parra, G. 2021. Effects of landscape structure and climate seasonality on pollen intake by honeybees in Neotropical highland agroecosystems. Agricultural and Forest Entomology, 23 (4): 452–462. https://doi.org/10.1111/afe.12446

Motzke, I., Tscharntke, T., Wanger, T.C. & Klein, A.M. 2015. Pollination mitigates cucumber yield gaps more than pesticide and fertilizer use in tropical smallholder gardens. Journal of Applied Ecology, 52: 261-269. https://doi.org/10.1111/1365-2664.12357

Ollerton, J. 2017. Pollinator diversity: distribution, ecological function, and conservation. Annu. Rev. Ecol. Evol. Syst. 48, 353–376. DOI: 10.1146/annurev-ecolsys-110316-022919

Patel, V., Pauli, N., Biggs, E., Barbour, L., & Boruff, B. 2021. Why bees are critical for achieving sustainable development. Ambio, 50: 49–59. https://doi.org/10.1007/s13280-020-01333-9

Pérez-Marcos, M., Ortiz-Sánchez, F.J., López-Gallego, E., Ibáñez, H., Carrasco, A. & -Sánchez, J.A. 2023. Effects of Managed and Unmanaged Floral Margins on Pollination Services and Production in Melon Crops. Insects, 14 (3): 296; https://doi.org/10.3390/insects14030296

Ramesh, R.G. 2007. Pollination potentiality of honeybee species in ridge gourd (*Luffa acutangula* L.). M.Sc. Master's Thesis, University of Agricultural Science, Bangalore, 149pp.

Revanasidda, R. & Belavadi, V.V. 2019. Floral biology and pollination in *Cucumis melo* L., a tropical andromonoecious cucurbit. Journal of

Asia-Pacific Entomology, 22: 215–225. https://doi.org/10.1016/j.aspen.2019.01.001

Rodger, J. G., Bennett, J. M., Razanajatovo, M., Knight, T. M., van Kleunen, M., Ashman, T. L., Steets, J. A., Hui, C., Arceo-Gómez, G., Burd, M., Burkle, L. A., Burns, J. H., Durka, W., Freitas, L., Kemp, J. E., Li, J., Pauw, A., Vamosi, J. C., Wolowski, M., Xia, J. & Ellis-Allan, G., 2021. Widespread vulnerability of flowering plant seed production to pollinator declines. Science Advances, 7 (42): eabd3524. https://doi.org/10.1126/sciadv.abd3524

Rukshanda, H., Munazah, Y., Liyaqat A., Sheikh, S.I., Masrat, S., Fazil, FW., Sheeba, B., Umar, B.F., Sheikh, M.A., Jameela, R. & Mathumitaa, P., 2022. Role of insect pollinators in pollination of cucumber. The Pharma Innovation International Journal, 11 (4S): 1348-1354. https://www.thepharmajournal.com/archives/2022/vol11issue4S/PartQ/S-11-4-34-737

Sáez, A., Morales, J.M., Morales, C.L., Harder, L.D. & Aizen, M.A. 2018. The costs and benefits of pollinator dependence: empirically based simulations predict raspberry fruit quality. Ecological Applications, 28: 1215–1222. https://doi.org/10.1002/eap.1720

Sarwar, G., Aslam, M., Munawar, M.S., Raja, S. & Mahmood, R. 2008. Effect of honeybee (*Apis mellifera* L.) pollination on fruit setting and yield of cucumber (*Cucumis sativus* L.). Pakistan Entomology, 30 (2): 185-191. https://www.researchgate.net/publication/237136714

Scaven, V. L., & Rafferty, N. E. 2013. Physiological effects of climate warming on flowering plants and insect pollinators. Current Zoology, 59(3), 418–426. https://doi.org/10.1093/czoolo/59.3.418

Sreekala, AK., 2017. Importance of plant reproductive biology in conservation. In: Conference Paper. National Conference on "Bioresources: Conservation, Utilization and Future Prospects" GRI-DU, Gandhigram, Tamil Nadu. https://www.researchgate.net/publication/314364124

Ssymank, A., Kearns, C. A., Pape, T., and Thompson, F. C. (2008). Pollinating flies (Diptera): A major contribution to plant diversity and agricultural production. Biodiversity 9, 86–89. doi: 10.1080/14888386.2008.9712892

Sujatha, G.S., Manoj, K., Mandar, V.T., Mareedu, G.P., Ranjitha, S.M., Shashank, D.U., Gadde, A.K. & Katta-Subramanya, S.T. 2024. Foraging behaviour of honeybee species on fenugreek (Kasuri Methi). International Journal of Advanced Biochemistry Researvch, 8 (8S):1365-1368. DOI: 10.33545/26174693.2024.v8.i8Sr.2091

Tschoeke, P.H., Oliveira, E.E., Dalcin, M.S., Silveira, M. & Rodrigues dos Santos, G. 2015. Diversity and flower-visiting rates of bee species as potential pollinators of melon (*Cucumis melo* L.) in the Brazilian Cerrado. Scientia Horticulturae, 186, 207–216. https://doi.org/10.1016/J.SCIENTA.2015.02.027

Vidal-Cordero, J.M., Arnan, X., Rodrigo, A., Cerdá, X. & Boulay, R. 2019. Four-year study of arthropod taxonomic and functional responses to a forest wildfire: Epigeic ants and spiders are affected differently. Forest Ecology and Management, 520: 120379. DOI: 10.1016/j.foreco.2022.120379

Wardhaugh, C. W. 2015. How many species of arthropods visit fowers? Arthropod. Plant. Interact. 9, 547–565. DOI: 10.1007/s11829-015-9398-4

Wilcock, C. & Neiland, R. 2002. Pollination failure in plants: why it happens and when it matters. Trends in Plant Science, 7 (6): 270-277. http://dx.doi.org/10.1016/j.foreco.2022.120379

Yeboué, L.N., Tra, C.S.B., Fondio, D. & N'Goran, A.P. 2022. Inventaire des papillons (Insecta: Lepidoptera) ravageurs du concombre (*Cucumis sativus* L.) à Daloa (Centre-Ouest, Côte d'Ivoire). International Journal of Biolological and Chemical Sciences, 16 (4): 1522-1535. DOI: 10.4314/ijbcs.v16i4.14.

Ποικιλομορφία Επικονιαστών και ο Ρόλος τους στην Ενίσχυση των Αποδόσεων Αγγουριού και Πεπονιού στην Khenchela

Noudjoud Maghni*[1], Lynda Rais[1], Malika Saidi[1] & Francisco Javier Ortiz-Sánchez[2]

[1]Department of Biology, University of Abbes Laghrour, Khenchela, Abbes Laghrour University Khenchela -Algeria- (BP 1252 Road of Batna Khenchela 40004)

[2]Grupo de Investigación "Transferencia de I+D en el Área de Recursos Naturales", Universidad de Almería, E04120 La Cañada (Almería), Spain

ΠΕΡΙΛΗΨΗ

Η παρούσα μελέτη πραγματοποιήθηκε στον Δήμο El Hamma, στην περιοχή Khenchela της Αλγερίας, με σκοπό τη διερεύνηση της εντομοεπικονίασης στο αγγούρι (*Cucumis sativus* L.) και το πεπόνι (*Cucumis melo* L.) που καλλιεργούνται σε μια ημι-άνυδρη περιοχή. Τα αποτελέσματα έδειξαν ότι τα άνθη αγγουριού και πεπονιού προσέλκυσαν διαφορετικά είδη επικονιαστών. Καταγράφηκαν συνολικά 547 άτομα, που ανήκαν σε 47 είδη εντόμων, 23 οικογένειες και πέντε τάξεις (Υμενόπτερα, Δίπτερα, Κολεόπτερα, Λεπιδόπτερα και Ημίπτερα). Ωστόσο, οι μέλισσες (*Apis mellifera* L.) ήταν οι σημαντικότεροι επικονιαστές κατά την περίοδο ανθοφορίας και επισκέφτηκαν πέντε άνθη ανά λεπτό, ενώ το είδος *Megachile rotundata* F. ήταν ο ταχύτερος επισκέπτης (8 άνθη/λεπτό). Η αφθονία των ανθικών πόρων συσχετίστηκε θετικά με την βιοποικιλότητα των φυτικών ειδών. Η ποικιλομορφία των κοινοτήτων επικονιαστών υπολογίστηκε χρησιμοποιώντας τιμές δείκτη Shannon (H') που κυμαίνονταν από 1,14 έως 4,01, ενώ ο δείκτης ομοιομορφίας κυμαινόταν από 0,03 έως 0,06. Η μελέτη υπογραμμίζει τον καθοριστικό ρόλο της εντομόφιλης επικονίασης στη διασφάλιση της επισιτιστικής ασφάλειας, καθώς αποτελεί θεμελιώδη υπηρεσία των οικοσυστημάτων και τη σημασία της βιοποικιλότητας των εντόμων στη διατήρηση της επικονίασης των καλλιεργειών. Συνεπώς, είναι επιτακτική ανάγκη να δημιουργηθούν εστίες που προορίζονται για την επικονίαση εντόμων, να φυτευτούν αγριολούλουδα και θάμνοι, να ελαχιστοποιηθεί η χρήση φυτοφαρμάκων, να παρέχονται καθαρές πηγές νερού και να εκπαιδεύονται οι αγρότες σε πρακτικές φιλικές προς τους επικονιαστές, με στόχο τη βελτίωση της ποιότητας των γεωργικών καλλιεργειών.

