



Population Activity and Control of the Olive Fruit Fly in Olive Orchards using Food Attractants and Pheromone Traps in Arid Region (Algeria)

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Abstract: The olive fruit fly, *Bactrocera oleae*, is one of the most destructive pests of olive orchards worldwide, causing substantial economic losses through reduced yield and fruit quality. Effective management of this pest remains a major concern for olive growers due to its high reproductive potential and rapid population buildup under favorable conditions. The present study was carried out in three orchards located in the arid region of M'Sila, Northeast Algeria, from August to December 2023. The objectives were to monitor population dynamics, assess infestation levels, and evaluate control strategies against the olive fruit fly. Adult activity was monitored using McPhail traps baited with food attractants (3% aqueous diammonium phosphate and 3% aqueous ammonium bicarbonate solutions). Pheromone traps were simultaneously deployed for comparative assessment of trapping efficiency. The first adults emerged at the end of August, and the pest continued to emerge until the end of December. The first population development peak was observed in mid-October in all three orchards. Three generations of *B. oleae* appeared in the M'Sila area. The infestation rates of the pest were 38.5% (at Ouled Mansour) and 31.5% (at District Ksob and Ouled Sidi Amor). The McPhail traps (+ 3% ammonium bicarbonate) caught more flies than the McPhail traps (+ 3% diammonium phosphate) and Pheromone traps (Lure - Russell IPM). At every orchard olive site, were observed significant interactions between the week and the trap were observed for the total, male, and female flies. The activity of the fruit flies depended on environmental conditions. Traps baited with ammonium bicarbonate attracted more females.

Key words: *Bactrocera oleae*, McPhail-type traps, pheromone, food attractants, infestation, control, arid region.

The olive fruit fly *Bactrocera oleae* (Rossi, 1790) (Diptera: Tephritidae), is the major pest of olive cultivation in Algeria, causing great economic damage to production. The distribution of *B. oleae* is largely confined to areas where both

cultivated and wild olive trees grow (Daane and Johnson, 2010). Olive fruit flies adapted to Mediterranean-type climates with dry summers and mild, humid winters (Abd El-Salam *et al.*, 2019). The infestations of olives caused by fruit flies vary greatly among regions, years, and olive varieties (Gonçalves *et al.*, 2012). Females lay their eggs in the mesocarp of unripe and maturing olives, with the larvae feeding on the pulp and damaging the fruit. Without timely control measures, typically using bait sprays, up to 40% of the olive crop can be lost (Gianessi and Williams, 2011).

Effective monitoring, integrated pest management (IPM), and understanding climate-related impacts are critical for sustainable control and the long-term viability of olive production (Ashraf *et al.*, 2021; Katsikogiannis *et al.*, 2023; Rondoni *et al.*, 2024; Koufakis *et al.*, 2023). To date, pest control in olive farming has primarily relied on the widespread and intensive use of chemical pesticides (Vasconcelos *et al.*, 2022). Different countries have developed various traps to monitor olive fruit fly, including yellow sticky panels, sticky panels with food or sex attractants, and McPhail-type traps with food attractants (Sciarretta *et al.*, 2024). McPhail traps, which use ammonium salts (ammonium sulfate, phosphate, and bicarbonate) or protein food lure, have been widely used as successful monitoring tools for both female and male olive fruit flies (Sciarretta *et al.*, 2024; Varikou *et al.*, 2014). The McPhail traps are extensively employed and provide information on the sexual behavior of *B. oleae* females, which is utilized to plan the control of the olive fruit fly (Varikou *et al.*, 2013).

These traps are gaining popularity and are even permitted in organic olive farming (Noce *et al.*, 2009). Insect trapping systems are now one of the most widely used tools in both biosystematic research (Diller *et al.*, 2023) and biological control of fruit flies (Bali *et al.*, 2025). The main hypothesis of this study is that trap types with different food attractants and pheromones are effective tools for controlling olive grove pests. The McPhail traps are not commonly used in Algerian olive groves for monitoring *B. oleae*, as they contain different attractants: diammonium phosphate, ammonium bicarbonate, and pheromone (specific to *B. oleae* from IPM Russel). The study was conducted in three fields in the M'Sila

region of Algeria. The objectives of this study were: (i) to examine the population of *B. oleae*, (ii) to assess olive fruit infestation rates, and (iii) to directly compare the effectiveness of different McPhail traps.

Materials and Methods

M'Sila is located in Northeastern Algeria. The area is characterized by a Mediterranean arid bioclimatic stage with a mild winter (Mimeche *et al.*, 2018). Agriculture, which is still the primary occupation in the M'Sila region, focuses on the production of vegetables, cereals (barley and corn) and olive orchards, which adapt to the available water supplies. The arable land area covers an area of 50,000 ha, 50% of which is irrigated (Mimeche *et al.*, 2024; Abdesselam *et al.*, 2013). Three sites of olive growing in the M'Sila region (Algeria) were used for the trapping (Fig. 1). Site Ouled Mansour is situated at 35°48'59''N latitude and 4°27'07''E longitude. It has 160 trees of Chemlal variety, 140 trees Sigoise, and 150 trees other varieties of olive trees, totaling 450 trees (Table 1). The irrigation methods used are by channel and drip, and the trees were planted in 2002. Ouled Sidi Amor, the second site, is located at 35°56'51''N latitude and 4°22'58''E longitude. This station has 95 Chemlal olive trees, and used drip irrigation. This orchard is located next to a pine forest. The trees were planted in 2009. The third site, District KSob is located at 35°49'07''N latitude and 4°33'55''E longitude. It contains 105 Chemlal and 50 Azeradj olive trees, irrigated by drip. The implantation date for this station was 2010. All stations do not receive phyto-sanitary treatments, this site is located near a dam that bears the same name.

The research was conducted from August to December 2023, as shown in the flowchart (Fig. 1). This timeframe was selected because it aligns with the peak activity period of the olive fruit fly, *B. oleae*. The captured specimens were transported to the lab and carefully preserved in tubes containing 70% alcohol, each labeled with important details like the collection date, trap type, and specific location. Once in the lab, the samples were sorted, counted, and identified using specialized identification keys. The flight activity of adult *B. oleae* was tracked using five plastic McPhail traps (dimensions: 22×17 cm; funnel opening: 90 mm) featuring a transparent top half and a yellow bottom half.

These traps were baited with a food lure that attracted both male and female flies, the site of Ouled Mansour are baited with a 3% aqueous solution of ammonium bicarbonate, the District KSob are baited with a 3% aqueous solution of diammonium phosphate. The Ouled Sidi Amor are baited with *B. oleae* Pheromone (Lure - Russell IPM manufactures), a pheromone traps that specifically attracted males. The food attractant and pheromone traps were used separately.

Five McPhail traps were installed at each site, with the bait solution renewed every 10 to 15 days. The traps were fastened beneath the shade of the branches within the leafy canopy, facing southwest, and at a height accessible to humans. They were randomly placed throughout the olive orchard, with a 50-m gap between each trap. Weekly checks were conducted to count, identify the sex, and eliminate the olive flies captured. The total number of flies caught per trap each week was used to estimate the population, expressed as captures per trap per week on each date (Gonçalves *et al.*, 2012). Samples were identified using standard morphological keys

under a stereomicroscope. The sex ratio was determined by calculating the ratio of males to females.

From early September, when the temperature starts to decrease and after the olives have formed, until the beginning of December when the harvest takes place, we collected fruit samples from 5 trees of each type of olive tree to evaluate the infestation rate and fruit size. We harvested forty olives from each tree at a height of about the head from 4 different directions (North, South, East, and West), with 10 olives from each direction. The olives we collected were then taken to the laboratory and examined under a binocular stereo-microscope to identify oviposition stings and insect exit holes. The infestation rate of *B. oleae* was calculated as the percentage of infested olives compared to the total olives collected. Following the guidelines of Burrack *et al.* (2011), olives with oviposition stings were considered infested. To determine fruit size, 50 olives (10 from each tree) were randomly selected, and their widest dimension was measured in millimeters using a digital caliper (Fig. 2).

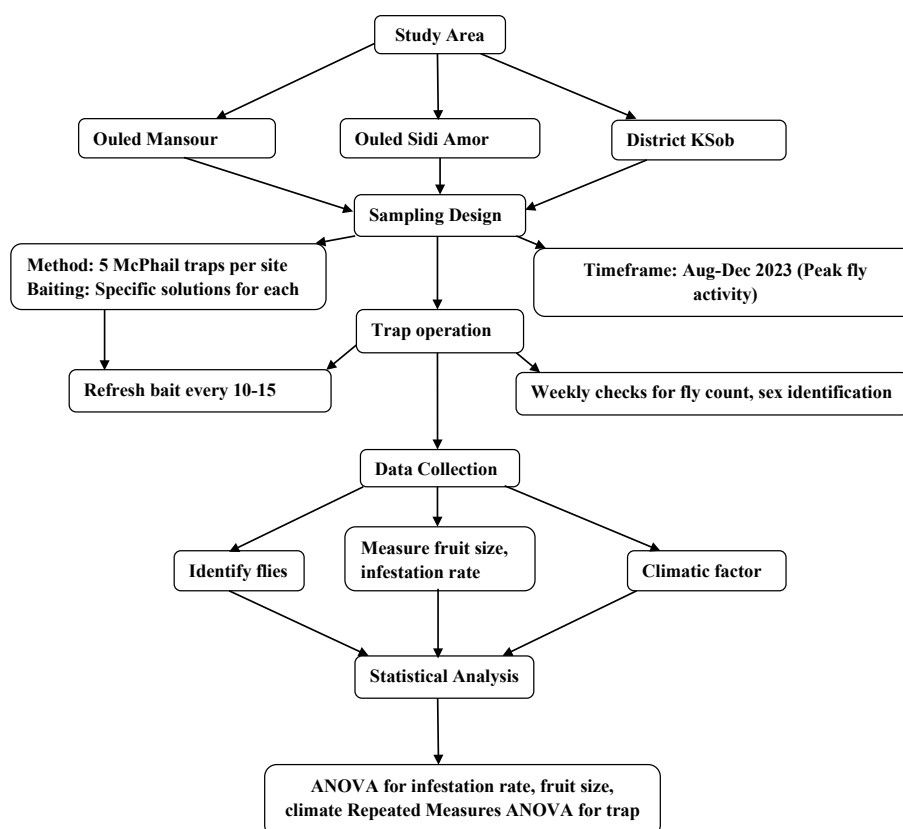


Fig 1. Flowchart of the sampling and trapping methodology

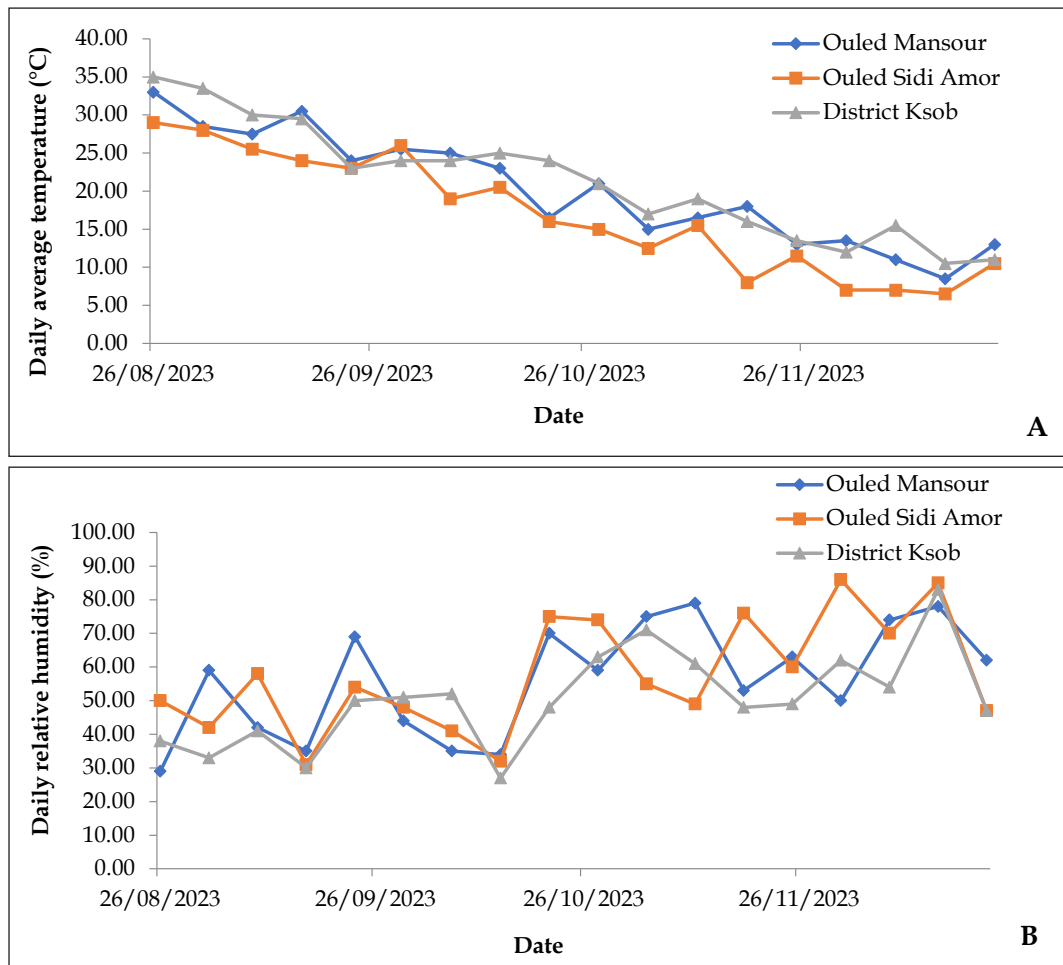


Fig 2. A: Mean daily temperature (°C), and B: relative humidity (%); at three olive orchards (Ouled Mansour, Ouled Sidi Amor, and District Ksob) from August to December 2023.

Weekly variations and differences in the sex ratio were analyzed using a Chi-square test. Differences in climatic factors, fruit size, and infestation rate descriptors among sampling sites were assessed using one-way ANOVA. Trap capture data were analyzed by repeated-measures ANOVA with week, trap type, and their interaction as fixed effects. Week was treated as the repeated factor. Analyses were performed using PAST version 4.03. Locations, as well as male, female, and total fly captures for each orchard, were analyzed separately. The significance level was set at $p < 0.05$ for all tests.

Results and Discussion

Environmental conditions

Temperature and relative humidity information from the three sites were summarized in Fig. 2. The region experienced high summer temperatures typical of arid

Mediterranean conditions, with the mean daily temperature of end August and September starting at 23°C and the maximum at 35°C in District Ksob, and relative humidity varied between 29% and 69% in three sites.

There were statistically significant differences in the average temperatures ($F_{2,52} = 3.25$; $p = 0.04$) between the analyzed sites. However, no significant differences were found in average daily relative humidity ($F_{2,52} = 0.98$; $p = 0.38$). Above 29°C, Yasin *et al.* (2014) has been reported to halt the flying and reproductive activity of *B. oleae*. Above 30°C, olive fly eggs, larvae, and adults start to die, and temperatures above 35°C may be highly detrimental to the population (Tzanakakis, 2003; Volakakis *et al.*, 2012). Katsikogiannis *et al.* (2023) reported that a decrease in humidity led to an increase in the population of *B. oleae* when the air temperature was 20°C.

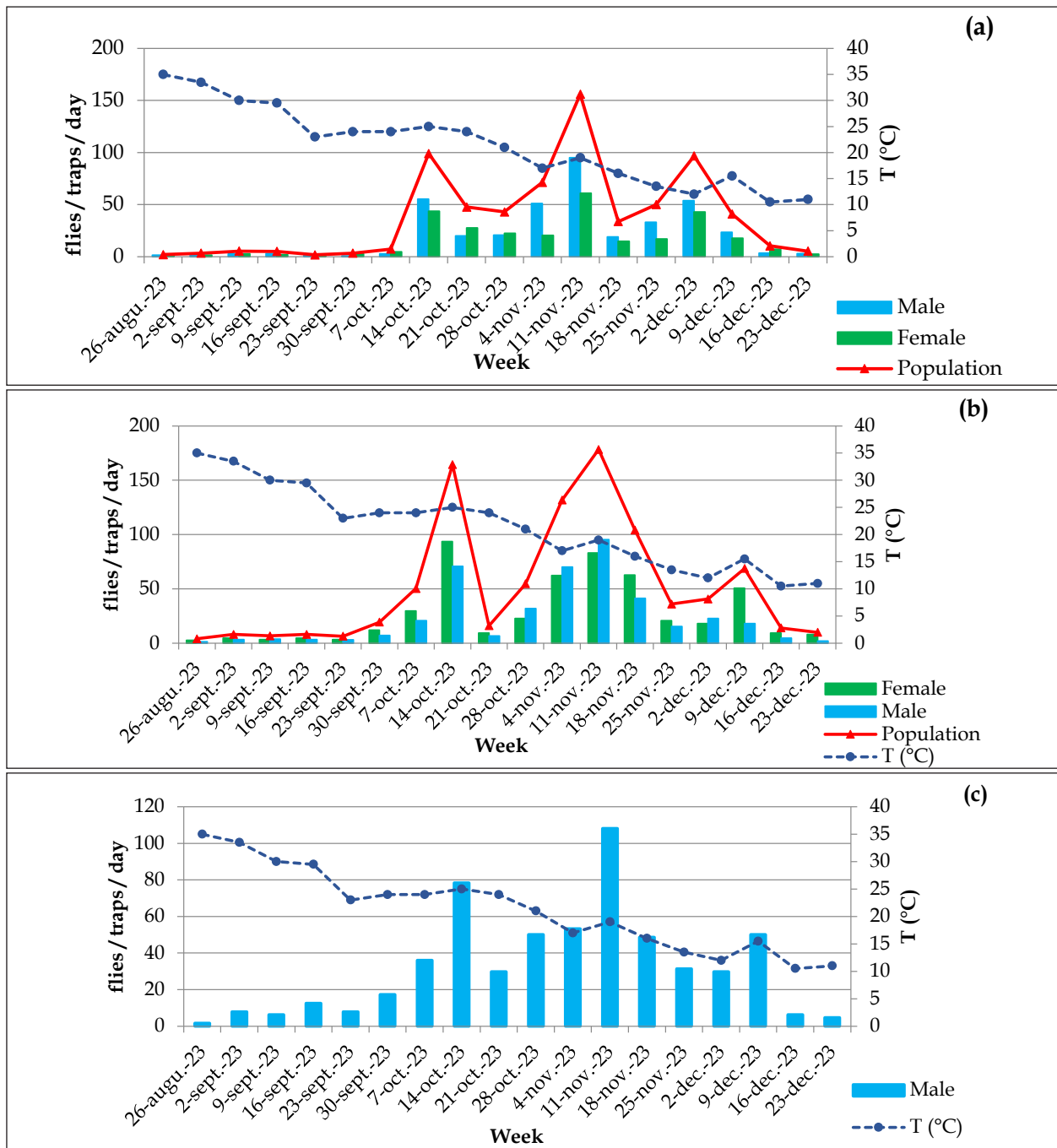


Fig. 3. Daily average temperature and the weekly trapping of olive fruit flies per trap in the three different trap types at three experimental olive orchards (a: District K'sob, b: Ouled Mansour, c: Ouled Sidi Amor).

The seasonal effects of weather and ongoing changes in climate conditions will directly result in modifications to the distribution and growth of insect pest species. Natural enemies, host plant availability, and species demography were all impacted both directly and indirectly by temperature and humidity levels (Wakil *et al.*, 2025).

Population dynamics of *B. oleae*

The numbers of flies captured by different trap types and attractants at the three study sites are presented in Figure 3. Overall, fly abundance varied among locations, with the highest captures recorded at Ouled Mansour ($4-178 \text{ fliestraps}^{-1} \text{ week}^{-1}$; mean \pm SE = 51.16 ± 13.30), followed by District Ksob ($1-61 \text{ fliestraps}^{-1} \text{ week}^{-1}$;

Table 1. Mean of fruit size and infestation rate

		Ouled Mansour	Ouled Sidi Amor	District Ksob
Fruit size (mm) (n=200)	Mean± SE (Min-Max)	15.46±1.18 (17.95-13.07)	12.85±1.21 (15.81-9.55)	13,72±1.02 (13.72-10.58)
	F		282.5	
	p		<0.0001	
Infestation rate	Infestation (%)	38.5	31.0	31.5
	F		1.58	
	p		0.2	

SE: Standard error, millimeters, F: Fischer, p: Probability.

37.88 ± 10.29), and the lowest at Ouled Sidi Amor (1-23 fliestrap⁻¹week⁻¹; 32.20 ± 6.79). Thus, the olive fly population remained moderate at Ksob, relatively low at Ouled Sidi Amor, and markedly higher at Ouled Mansour.

The first peak population development was observed in mid-October in all orchards. The dynamics of adult flights exhibited three peaks at each of the three sites, corresponding to the number of generations. Mohammadipour *et al.* (2023) reported that the olive fruit fly can reproduce for 3-5 generations depending on the environmental conditions. Generational turnover is intricately associated with cumulative temperature (degree-days) and the duration of the warm season (Nehmeh *et al.*, 2025).

In the final week of November, coinciding with the table olive harvest, the traps captured the last notable number of adult flies. No catches were reported in the weeks that followed the last population pick in December because the temperature in the area dropped significantly and the pest went into the overwintering stage; a similar situation was reported by Noori and Shirazi (2012). The life cycle of *B. oleae* is closely linked to environmental conditions, particularly local climatic conditions (Marchini *et al.*, 2017).

Sex ratio: The sex ratio of adults was 0.57:0.43 ($\chi^2=22.86$, $p=0.16$) in favor of males at District Ksob orchard. In the Ouled Mansour orchard, the sex ratio in favor of females was 0.46:0.54 ($\chi^2=31.01$, $p<0.05$). At Ouled Sidi Amor), all captured individuals were males, because the trap is a *B.oleae* pheromone. Mohammadipour *et al.* (2023) and Sciarretta *et al.* (2025) reported the sex ratio of the captured population, a 1:1 ratio. The variation in the sex ratio of entrapped adult olive flies has been noted by several other scientists. Bourakna *et al.* (2022), reported that

the sex ratio in northwestern of Algeria is in favor of males (0.63 males and 0.37 females).

Depending on the type of attractant and local population dynamics, some studies use food-based lures and report nearly equal or slightly male-biased sex ratios, while others use pheromone traps and report female-biased ratios or strong male bias (López *et al.*, 2023; Živković *et al.*, 2025).

The male-biased trap catches of *B. oleae* are largely influenced by the type of trap used (Moreno-Alcaide *et al.*, 2025; Sciarretta *et al.*, 2024). Trap color also contributes to this bias, as yellow and orange traps tend to attract more males (Katsoyannos and Kouloussis, 2001; Sciarretta *et al.*, 2024)). Moreover, conventional male lures, such as sex pheromones and phenylbutanoids are specifically formulated to target males, thereby enhancing male-biased captures (Shelly and Cloonan, 2023). Male responsiveness to sex pheromone traps increases particularly during periods of sexual activity (Giunti *et al.*, 2020).

Infestation rate: Fruit size varied significantly among sites, as shown in Table 1. The fruit size was greater at Ouled Mansour than at the other sites throughout the study period. The high rate of fruit size at Ouled Mansour is due to the presence of the “Sigoise” variety. Bourakna *et al.* (2022), in North-West Algeria, reported fruit sizes of 18.48 ± 0.24 mm for the ‘Sigoise’ variety and 13.24 ± 0.19 mm for the ‘Chemlal’ variety.

Olive fruits collected in the autumn (November 2023), which coincided with the flight peak, accounted for 38.5% (at Ouled Mansour), and 31.5% (at District Ksob and Ouled Sidi Amor) the active infestations (Table 1), and demonstrated the ability of *B. oleae* females to generate new generations

Table 2. Mean weekly olive fruit fly trap captures and repeated measures ANOVA test results for trap comparisons

Site	Type of trap	Count	Mean±SE	Treatment Parameters	df	F	P
Ouled Mansour	McPhail trap + 3% ammonium bicarbonate	Total	52.93±13.08	week	17	51.11	< 0.0001
				trap	2	0.126	< 0.0001
				week x trap	2	2.231	< 0.0001
		Male	24.39±6.55	week	17	85.34	< 0.0001
				trap	2	2.466	< 0.0001
				week x trap	2	0.0847	< 0.0001
		Female	28.57±6.83	week	17	55.39	< 0.0001
				trap	2	0.1603	< 0.0001
				week x trap	2	3.067	< 0.0001
Ouled Sidi Amor	Pheromone (Lure - Russell IPM)	Male	30.89±6.66	week	17	6.63	< 0.0001
				trap	2	0.7692	< 0.0001
				week x trap	2	2.213	< 0.0001
District Ksob	McPhail trap + 3% ammonium phosphate	Total	37.89±10.30	week	17	283.7	< 0.0001
				trap	2	0.3828	< 0.0001
				week x trap	2	0.004019	< 0.0001
		Male	21.72±6.25	week	17	141.1	< 0.0001
				trap	2	2.57	< 0.0001
				week x trap	2	0.05386	< 0.0001
		Female	16.20±4.18	week	17	132.8	< 0.0001
				trap	2	0.4443	< 0.0001
				week x trap	2	0.009889	< 0.0001

SE: Standard error, df: Degrees of freedom, F: Fisher, p: Probability.

(Marchini *et al.*, 2017). Our results are similar to those of El Haidani *et al.* (2004) in Sefrou Hamache and Kari Ba Mohammed (Morocco), where the infection rate reached about 40%, and Gonçalves *et al.* (2012) in Portugal with the Verdeal Transmontana variety where the infection rate reached the mean of infestation 41.50%. The olive reached the fruit enlargement and stone hardening stage, which is considered the receptive stage for oviposition by the olive fly (Bourakna *et al.*, 2022), which coincides with the ovarian maturation period of females (Tzanakakis, 2003).

The adult flies captured in traps at the end of August coincided with the hardening of the fruit, marking the first generation of olive fruit flies in the region. This generation found plenty of hosts (olive fruits) and favorable environmental conditions, allowing the population to grow rapidly and cause significant damage to the orchards (Noori and Shirazi, 2012). By early November, most farmers had harvested their olives to prevent further losses, and the presence of traps likely

helped to minimize the damage. Pertíñez and Vélez (2020) suggested that the proportional increase in damage was caused by an increase in population size, whereas reductions in population size maintained the total amount of damaged olives.

Peaks in female fly captures typically coincide with the most critical periods for olive fruit infestation. Female captures in traps are particularly important because only females lay eggs in the fruit, which leads directly to infestation (Hamdan, 2016; Ortega *et al.*, 2021; Bourakna *et al.*, 2022). The olive cultivar, the size of the fruit, and the local climate all influence the timing and intensity of these peaks cultivars with larger fruits tend to experience higher infestation levels, while years with lower fruit yield often show increased pest pressure (Hamdan, 2016; Bourakna *et al.*, 2022).

Performance of various traps: There were notable interactions between the week and trap for total, male, and female flies across all locations (Table 2). A significant interaction indicates that the impact of trap type on

insect numbers varies depending on the week rather than remaining consistent throughout the sampling period. This suggests that factors such as insect behavior, population dynamics, environmental conditions or attractant efficacy fluctuate over time, thereby altering the effectiveness of each trap in capturing insects during different weeks. The effectiveness of traps may vary depending on when peak activity occurs (Kirse *et al.*, 2025).

As a result, the weekly data for each site are shown separately (Fig. 3). McPhail traps baited with ammonium bicarbonate were most effective than the McPhail traps baited with ammonium phosphate or the Pheromone (Lure - Russell IPM). The McPhail traps + 3% ammonium bicarbonate caught more females than males. Therios (2009) reported that the ammonium bicarbonate component is more effective for *B. oleae* females, whereas a pheromone (Lure - Russell IPM), is more effective for *B. oleae* males (López *et al.*, 2023).

Traps baited with diammonium phosphate capture a very small number of olive fruit flies (Martínez *et al.*, 2007). Considering the differences in male and female captures in McPhail traps, and the high number of females caught between mid-October and mid-November, it's important to note that most fruit infestations are caused by females (Gonçalves and Torres, 2013). This increase is linked to the dietary needs for maturing their eggs (Economopoulos *et al.*, 1982), which typically aligns with the period when conditions are ideal for oviposition (Paparatti, 1991).

Field and laboratory studies have shown that traps baited with ammonium compounds attract significantly more females, particularly when combined with specific male-produced volatiles, thereby enhancing overall trap efficacy (López *et al.*, 2023; Germinara *et al.*, 2024).

Pheromones play a crucial role in male behavior by facilitating the detection of receptive females. Female-emitted pheromones serve as the primary attractants for males (López *et al.*, 2023; Canale *et al.*, 2014), and the male olfactory system is finely tuned to detect these signals, thereby improving mate localization and reproductive success (Canale *et al.*, 2014).

Conclusion

Olive fruit fly (*B.oleae*) activity was strongly influenced by environmental conditions and trap type. The practical application of Integrated Pest Management (IPM) and monitoring systems for *B. oleae* lies in enabling informed, timely, and targeted management decisions that minimize environmental and economic damage.

Ammonium compounds primarily attract females, while pheromones are crucial for male attraction, highlighting their distinct biological roles in the chemical ecology of this species.

Among the parameters tested, trap types combining different food attractants and pheromones proved to be effective tools for managing olive grove pests. Slight variations were observed among the various food attractants, with ammonium bicarbonate-baited traps attracting more females and pheromone traps capturing more males.

Based on these findings, further studies are recommended to optimize the use of eco-friendly attractants and safer formulations in order to reduce reliance on chemical pesticides. Enhancing the sustainability of olive fly control is increasingly essential for preserving environmental balance and ensuring the productivity of olive orchards.

A deeper understanding of olive fruit fly dynamics in Algerian olive orchards, particularly regarding the interaction between climate, olive cultivar characteristics, and pest management strategies, will be key to predicting population fluctuations and mitigating infestation impacts.

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