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# Comparative performance of food and olfactory attractants for monitoring *Ceratitis capitata* Wiedemann and *Bactrocera zonata* Saunders, and the efficacy of modified insecticide application strategies in a peach orchard

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## Abstract
Fruit flies, particularly *Ceratitis capitata* and *Bactrocera zonata*, are among the most destructive pests affecting fruit crops worldwide. This study was conducted in Nubaria region, Beheira Governorate, Egypt during the 2023 and 2024 seasons to evaluate the effectiveness of different attractants and control methods under field conditions. Four attractants were tested: di-ammonium phosphate, ammonium acetate, buminal, and amadene. Results showed that ammonia-based lures (di-ammonium phosphate and ammonium acetate) consistently attracted significantly more *C. capitata* and *B. zonata* adults, particularly females, compared to food-based lures. Di-ammonium phosphate recorded the highest capture rates across both seasons. In parallel, three control techniques were evaluated: complete cover spray, partial bait application, and thermal fogging (at 75% and 50% doses from the recommended rates). Partial bait spray and thermal fogging at 75% dose achieved the highest reduction rates for both fly species, maintaining over 80% efficacy up to 15 days post-treatment. In contrast, full cover spraying showed the lowest efficacy and rapid decline over time, indicating limited residual activity. Thermal fogging at 50% dose offered moderate initial control but with reduced longevity. The findings highlight the superiority of ammonia-based attractants for monitoring and support the adoption of bait spray and thermal fogging (at reduced doses) as effective, low-input strategies for fruit fly management as part of integrated pest management (IPM) strategies.

**Keywords:** Fruit flies, *Ceratitis capitata*, *Bactrocera zonata*, ammonia compounds, bait spraying, thermal fogging, integrated pest management

## Introduction
Fruit flies (Diptera: Tephritidae) are among the most devastating pests affecting fruit and vegetable crops globally. Their larvae feed on the pulp of fruits, causing extensive damage that leads to direct yield losses, premature fruit drop, and severe post-harvest deterioration. Additionally, infestations by fruit flies result in strict quarantine restrictions on fruit exports, negatively impacting international trade and farmer livelihoods (White and Elson-Harris, 1992; Vargas *et al*., 2015) [30, 28]. Two of the most economically important species in this family are the peach fruit fly (*Bactrocera zonata* Saunders) and the Mediterranean fruit fly (*C. capitata* Wiedemann). Both species are invasive and polyphagous, with a wide distribution range encompassing Egypt and much of the Mediterranean Basin. *B. zonata* is particularly aggressive on stone fruits such as peaches and mangoes, while *C. capitata* attacks a broader spectrum of hosts, exceeding 250 plant species (Liquido *et al*., 1991; Darwish, 2016; De Meyer *et al*., 2010) [17, 3, 4]. Their rapid life cycles, high fecundity, and ability to adapt to diverse environments make their control especially challenging under open field conditions. In the context of monitoring and managing fruit fly populations, olfactory and food-based attractants play a critical role. Chemical lures such as ammonium acetate, diammonium phosphate, and protein hydrolysates are widely used to attract adult fruit flies to bait stations or traps. These attractants are essential for both surveillance and mass trapping efforts, serving as cost-effective and environmentally friendly tools that reduce reliance on broad-spectrum

insecticides. Food-based lures like Buminal, and Amadene, are particularly effective in drawing adult flies seeking protein-rich food sources, especially females prior to oviposition (Epsky *et al*., 1993; Navarro-Llopis *et al*., 2008; El-Metwally, 2017) [9, 22, 7]. The integration of attractants into pest management programs not only enhances monitoring precision but also contributes to early detection and targeted control strategies, thereby improving the sustainability of fruit production systems. Organophosphorus insecticides remain one of the main pillars in controlling fruit fly populations in conventional fruit production systems. These compounds, including malathion and dimethoate, act as cholinesterase inhibitors and are highly effective against adult fruit flies when applied correctly (Ekesi and Billah, 2007) [6]. Despite their efficacy, excessive or improper use of organophosphates has raised environmental and toxicological concerns, including potential harm to pollinators, natural enemies, and human health (Pimentel, 2005; Damalas and Eleftherohorinos, 2011) [24, 2]. Moreover, field application efficiency is often low, with studies indicating that over 90% of applied pesticides fail to reach the target pest due to drift, runoff, or poor canopy penetration (Matthews, 2008) [20]. To address these issues, researchers and practitioners have investigated alternative application strategies that reduce pesticide usage without compromising efficacy. Partial spraying has emerged as a promising tactic in this regard. This technique does not involve full canopy coverage, but rather targets the tree trunk and inner canopy while leaving outer foliage untreated. Furthermore, it is implemented by spraying alternate trees only, creating a treated-untreated pattern across the orchard. In this design, the sprayed trees act as baited traps, combining an organophosphate insecticide with a food attractant such as Buminal, thus drawing and eliminating fruit flies within the orchard ecosystem (Leblanc *et al*., 2013) [16]. Typically, the mixture of the protein bait and insecticide is applied as a spot treatment at a rate of approximately 50 ml for each individual tree. This application method significantly reduces the overall amount of insecticide released into the environment compared to traditional cover spray methods (Prokopy *et al*., 2003) [25]. In parallel, thermal fogging has gained attention as a low-volume application method capable of delivering insecticide particles in aerosol form. Devices such as the German-made IGEBA® TF 35, equipped with a 5.7-liter tank, allow the distribution of fine droplets that penetrate dense foliage efficiently and uniformly (Gazia, *et al*., 2019) [11]. This method minimizes pesticide losses and can be particularly effective when conducted in the early morning, under stable atmospheric conditions (FAO, 2001; Hoffmann *et al*., 2008) [10, 14]. In this study, we investigated the effectiveness of complete cover spray and partial bait applications and thermal fogging at 75% and 50% of the recommended rates for controlling *B. zonata* and *C. capitata* in a peach orchard in El-Nubaria region, Egypt. Moreover, the study also aimed to evaluate the attractiveness and efficiency of two food-based attractants (Buminal and Amadene) and two olfactory attractants (ammonium acetate and di-ammonium phosphate) in capturing adult males and females of *C. capitata* and *B. zonata*. We aimed to assess whether reduced pesticide input through modified application techniques could still achieve effective suppression of fruit fly populations while mitigating the risks associated with extensive insecticide use. This work contributes to the development of safer, economically feasible, and ecologically sound approaches to integrated pest management in fruit orchards.

## Materials and Methods

This study was conducted during two consecutive seasons (2023 and 2024) in an 8-feddan commercial peach orchard located in the Nubaria region, Beheira Governorate, Egypt. The orchard was planted with 11-year-old trees, irrigated using a drip irrigation system, and maintained under standard horticultural practices. No insecticide applications were made throughout the study period except for the experimental treatments described below. The used insecticides was Malathion (Malatox 57% EC).

### Comparative assessment of food and olfactory attractants in trapping *C. capitata* and *B. zonata*

To assess the performance of various attractants in monitoring fruit fly populations, five types of lures were tested under field conditions, including two olfactory (chemical) attractants and two food-based attractants. The chemical attractants used were ammonium acetate (3% w/v) and di-ammonium phosphate (3% w/v), both known for their ability to capture both male and female fruit flies through volatile emission. The food-based lures included Buminal 3% (v/v) and Amadin 3% (v/v), all commercially available protein hydrolysates designed to attract fruit flies via fermentation odors. The trial was arranged in a Randomized Complete Block Design (RCBD) with four traps for each attractant, totaling 16 traps. All traps were hung at a uniform height of 1.5 meters above ground level to ensure consistency in lure exposure. The traps were evenly distributed across the experimental area to reduce positional bias. This setup aimed to attract and capture both males and females of *C. capitata* and *B. zonata*, which are the two primary species of concern. Trap catches were recorded every three days, and consistent data collection over the study period (one month) allowed for assessment and comparison of the attractiveness and overall performance of each lure type in capturing adult flies under identical environmental conditions.

### Evaluation of full cover spray, partial bait application, and thermal fogging for fruit fly control

### Experimental Design

The study site was subdivided into six equal plots, each receiving one of the following six treatments:

1. **$T_1$ - Full-dose cover spray using a 20-liter knapsack sprayer**: Trees were sprayed thoroughly with the recommended dose as per the Egyptian Ministry of Agriculture recommendations. (100 ml/100 L water)
2. **$T_2$ - Partial bait spraying using a 20-liter knapsack sprayer**: Only the inner canopy and trunk were sprayed using a bait solution (1.5 L Buminal 5% + 500 mL Malathion + 18 L water). Furthermore, only alternate trees in each row were treated, with each sprayed tree surrounded by five untreated ones. (Each tree with about 100-150ml)
3. **$T_4$ - 75% of the recommended dose thermal fogging**: Trees were treated using a thermal fogging machine (IGEBA® TF 35, Germany) with a tank capacity of 5.7 liters (and solar solution as a carrier).
4. **$T_5$ - Half-dose thermal fogging**: Trees were treated using the same fogging machine but with only half the recommended dose (and solar solution as a carrier).
5. **$T_6$ - Control**: Trees were sprayed with water only using a 20-liter knapsack sprayer.

All spraying operations were carried out early in the morning.

**Monitoring and Sampling**

To monitor fruit fly populations, four McPhail traps baited with Buminal protein hydrolysate were randomly installed as a treatment plots. The traps were spaced 20 meters apart and hung at a height of 1.5 meters. Each trap attracted and captured both male and female fruit flies. Insect counts were conducted at 3, 6, 10, and 15 days after treatment in both seasons. Adult captures of C. capitata and B. zonata were recorded separately for each trap. The experiment was arranged in a randomized complete block design (RCBD), with each trap representing a replicate (n = 4 per treatment). The reduction percentage of the total live adults of each fruit fly species was calculated using the Henderson and Tilton (1955) formula:

$$\% \text{ Reduction} = (1-(Ta \times Cb)/(Tb \times Ca)) \times 100$$

Where:

- Cb= Number of flies in the control before application
- Ca= Number of flies in the control after application
- Tb = Number of flies in the treatment before application
- Ta = Number of flies in the treatment after application

**Statistical Analysis**

Data were subjected to one-way ANOVA, and mean comparisons were performed using the LSD test at a 5% level of significance ($p<0.05$) using the COSTAT statistical software (version 6.4, 2005).

**Results and discussion**

**Evaluation of attractant efficiency for *C. capitata* and *B. zonata* under field conditions during 2023 and 2024 seasons**

**Mediterranean fruit fly, *C. capitata***

The results from both the 2023 and 2024 seasons revealed clear differences in the responses of *C. capitata* adults to the tested attractants (Tables 1 and 2). In 2023, di-ammonium phosphate and ammonium acetate stood out, capturing significantly more individuals compared to the food-based lures. Di-ammonium phosphate recorded an average of 28.47 adults CTD (capture/trap/day), while ammonium acetate achieved 30.16 CTD, both of which were statistically superior to Buminal (17.44) and Amadene (21.91). The disparity was especially pronounced among females, with ammonium acetate capturing 21.88 females per trap, indicating a stronger olfactory response among female flies to ammonia-based volatiles. This is consistent with findings by Katsoyannos *et al*. (1999) [15], who noted that ammonia-releasing compounds tend to mimic proteinaceous fermenting odors that are particularly attractive to female *C. capitata*, which require proteins for egg development. Interestingly, in 2024 (Table 2), the same two lures maintained their leading performance, with di-ammonium phosphate reaching a peak of 33.03 CTD, the highest across both years, followed by ammonium acetate with 27.0. The female bias persisted, with di-ammonium phosphate attracting 22.31 females, further supporting its reliability as a female-targeted lure. The increase in total catches in 2024 may reflect either a true population increase or more favorable microclimatic conditions enhancing the volatilization of the lures (Epsky *et al*., 1995) [8]. Additionally, the performance of Amadene improved moderately between seasons, especially for males (from 8.22 in 2023 to 9.84 in 2024), suggesting a possible role for this food-based lure under certain field conditions. Nevertheless, it remained statistically less effective than ammonium salts. The low male captures by Buminal in both seasons (5.38 and 6.44) reinforce previous studies indicating that food-based lures are generally less attractive to males compared to protein or ammonia-based attractants (Papadopoulos *et al*., 2001). These results suggest that protein-deprived females are more responsive to nitrogen-based attractants, aligning with their nutritional needs for ovary development and survival (Prokopy and Roitberg, 2001) [26].

**Peach fruit fly, *B. zonata***

The responses of *B. zonata* were somewhat more variable, particularly in the 2023 season. Despite the higher total catches observed for di-ammonium phosphate (19.47) and ammonium acetate (16.56), no statistically significant differences were detected ($P > 0.05$), likely because of the high variability among replicates. However, these two lures consistently outperformed Buminal (13.13), indicating a potential preference of *B. zonata* females for ammonia-based volatiles as well. This is in agreement with studies like those by Shelly *et al*. (2017) [27] and Ghanim, *et al*. (2021) [12], which observed that Bactrocera species also respond to ammonia odors, albeit with lower sensitivity than Ceratitis.

In the 2024 season, a more defined pattern emerged. Di-ammonium phosphate again ranked highest with a significant total of 25.19 CTD, supported by high female (16.31) and male (8.88) captures. This reinforces its broad-spectrum attractiveness and effectiveness under varying seasonal conditions. Ammonium acetate followed with 21.19 total flies, showing relatively balanced attraction to both sexes. These results suggest that ammonia-based lures may have practical utility for monitoring *B. zonata*, especially during population peaks.

Notably, Buminal and Amadene continued to attract fewer flies compared to the ammonia-based lures. The relatively moderate performance of Amadene (18.5 CTD in 2024) might still justify its use in certain field scenarios, particularly where ammonium-based lures are unavailable or cost-prohibitive. However, the evident superiority of di-ammonium phosphate aligns with recent reports by Mahmoud *et al*. (2022) [18], who demonstrated its higher attractiveness for *B. zonata* in peach and guava orchards, especially under high humidity conditions that may facilitate odor dispersion. Additionally, the greater male responsiveness in 2024 compared to 2023 across all lures may indicate shifts in male behavioral dynamics or an age-structured population with more sexually active males. This could have implications for timing lure deployment relative to the reproductive biology of *B. zonata*.

**Table 1:** Mean CTD of the total captured females and males of *C. capitata* and *B. zonata* over one month by food and olfactory attractants in peach orchards during 2023 season

| Treatment | *Ceratitis capitata* | | | *Bactrocera zonata* | | |
|---|---|---|---|---|---|---|
| | Males | Females | Total | Males | Females | Total |
| Buminal | 5.38±2.17b | 12.06±2.29b | 17.44±3.98c | 4.59±2.04a | 8.53±3.66b | 13.13±5.63b |
| Amadene | 8.22±2.43ab | 13.69±3.36b | 21.91±5.7bc | 5.94±2.38a | 9.92±3.38ab | 15.84±5.49ab |
| Di-ammonium phosphate | 9.69±4.91a | 18.78±6.38a | 28.47±9.81ab | 6.69±1.83a | 12.78±3.32a | 19.47±4.38a |
| Ammonium acetate | 8.28±2.1ab | 21.88±4.47a | 30.16±5.75a | 6.03±2.1a | 10.53±4.21ab | 16.56±5.93ab |
| F values | 2.677 | 8.513 | 6.267 | 1.417 | 1.878 | 1.873 |
| LSD | 3.2029 | 4.50093 | 6.82476 | 2.13776 | 3.74585 | 5.51852 |

Means assigned the same letter do not show significant differences at the 5% significance level, based on the LSD test.

**Table 2:** Mean CTD of the total captured females and males of *C. capitata* and *B. zonata* over one month by food and olfactory attractants in peach orchards during 2024 season

| Treatment | *Ceratitis capitata* | | | *Bactrocera zonata* | | |
|---|---|---|---|---|---|---|
| | Males | Females | Total | Males | Females | Total |
| Buminal | 6.44±2.47b | 13.56±4.21c | 20±6.53c | 5.88±2.5b | 9.78±4.04b | 15.66±6.08b |
| Amadene | 9.84±2.29a | 15.66±3.06bc | 25.5±4.43bc | 6.78±2.29ab | 11.72±3.87ab | 18.5±5.28ab |
| Di-ammonium phosphate | 10.72±4.56a | 22.31±3.71a | 33.03±6.94a | 8.88±2.41a | 16.31±4.53a | 25.19±6.47a |
| Ammonium acetate | 8.97±2.61ab | 18.03±3.99b | 27±6.34ab | 8.13±3.02ab | 13.06±5.46ab | 21.19±8.2ab |
| F values | 2.802 | 7.938 | 6.101 | 2.184 | 2.961 | 3.041 |
| LSD | 3.19628 | 3.86075 | 6.2829 | 2.632149 | 4.62735 | 6.73857 |

Means assigned the same letter do not show significant differences at the 5% significance level, based on the LSD test.

**Evaluation of full cover spray, partial bait application, and thermal fogging for fruit flies control**

**Mediterranean fruit fly, *C. capitata***

The complete cover spray achieved the lowest reduction percentages among all tested methods, with an overall mean of 67.01% in 2023 and 61.89% in 2024 (Tables 3 and 4). While the initial reduction was moderately high (71.7% and 69.0% after 3 days), a clear decline in efficacy was observed over time, reaching only 58.2% and 55.8% after 15 days. This decline may be attributed to rapid degradation of the insecticide under prevailing environmental conditions and the absence of an attractant, which would otherwise draw flies to the treated area. Additionally, this method requires spraying the entire canopy, increasing pesticide usage, labor, and the risk of residue on fruits, with limited long-term impact, making it less suitable for sustainable pest management. The partial bait spray emerged as one of the most effective strategies, with mean reductions of 85.63% in 2023 and 91.24% in 2024, showing consistent performance across all sampling dates. Notably, performance improved in 2024, reflecting enhanced stability and control. Its success can be attributed to the use of an insecticide-protein bait mixture, which effectively attracts and kills adult flies while minimizing pesticide use. The partial bait spray technique not only reduces chemical input but also enhances safety and environmental compatibility. This approach is highly recommended for IPM programs and even organic orchards when compatible insecticides are used.

The thermal fogging at 75% dose treatment recorded the highest mean reduction in 2023 (86.89%) and the second highest in 2024 (89.72%). It maintained high efficacy throughout the observation period and reached up to 83.8% reduction after 15 days, highlighting a strong residual effect. Thermal fogging with a slightly reduced dose (75%) allows for deeper canopy penetration and effective coverage of hidden resting sites of the flies. The use of lower concentrations without compromising efficacy offers a balance between efficiency and environmental safety, making it an excellent choice in high-infestation areas. Thermal Fogging at 50% Dose: Although this method produced relatively good early results (81.2% and 84.7% after 3 days), its efficacy significantly declined over time, especially after 15 days (48.3% and 60.5%). Overall means were 70.2% in 2023 and 76.4% in 2024, indicating a limited residual effect. This suggests that reducing the dose to 50% compromises long-term effectiveness and may only be suitable for preventive programs or in areas with low pest pressure. Nonetheless, it provides a promising low-input strategy, especially when paired with attractants or used during early infestation stages.

Therefore the partial bait spray and thermal fogging at 75% were the most effective treatments, maintaining high suppression rates throughout the evaluation period. Despite full canopy coverage, the Complete Cover Spray yielded the lowest control efficiency, highlighting that application strategy and bait inclusion are more critical than volume alone. Thermal fogging with 50% dose demonstrated short-lived efficacy, reinforcing the importance of maintaining a minimum threshold of active ingredient for long-term control. These findings are consistent with previous studies (e.g., Manrakhan and Price, 1999; Mazomenos *et al*., 2002) [19, 21] which reported that combining attractants with insecticides significantly enhances pest suppression while reducing pesticide input.

**Table 3:** Residual reduction percentages of *C. capitata* under four treatment methods during the 2023 season.

| **Treatments** | Reduction residual | | | | General means |
|---|---|---|---|---|---|
| | Three days | Six days | Ten days | Fifteen days | |
| Completely cover spray | 71.72±4.61c | 70.3±7.63b | 67.85±7.23b | 58.17±13.36b | 67.01±9.58b |
| Partial bait spray | 91.01±4.79a | 94.28±2.83a | 83.93±4.64a | 73.31±5.01a | 85.63±9.19a |
| Thermal fogg (75%) | 88.26±5.5ab | 92.44±2.4a | 88.46±4.52a | 78.4±4.28a | 86.89±6.6a |
| Thermal fogg (50%) | 81.23±4.74b | 87.67±2.27a | 63.74±15.49b | 48.25±7.62b | 70.22±17.85b |
| F values | 12.220 | 24.839 | 6.947 | 10.954 | 12.575 |
| L. S. D. | 7.5827 | 6.766498 | 14.07814 | 12.88791 | 8.20442 |

Means assigned the same letter do not show significant differences at the 5% significance level, based on the LSD test.

**Table 4:** Reduction percentages of *C. capitata* under four treatment methods during the 2024 season.

| **Treatments** | **Reduction residual** | | | | **General means** |
|---|---|---|---|---|---|
| | **3 days** | **6 days** | **10 days** | **15 days** | |
| Three days | Six days | Ten days | Fifteen days | 55.78±17.62c | 61.89±10.99c |
| Partial bait spray | 94.13±3.05a | 96.15±1.35a | 89.68±1.46a | 85±4.69a | 91.24±5.17a |
| Thermal fogg (75%) | 92.75±2.38a | 90.47±6.8ab | 91.81±4.22a | 83.84±8.7a | 89.72±6.48a |
| Thermal fogg (50%) | 84.65±5.66b | 86.97±4.25b | 73.62±6.51b | 60.5±7.21b | 76.44±12.09b |
| F values | 37.090 | 37.519 | 16.868 | 8.148 | 35.629 |
| L. S. D. | 5.83779 | 7.8221 | 10.64488 | 16.5205 | 6.4819 |

Means assigned the same letter do not show significant differences at the 5% significance level, based on the LSD test.

**Peach fruit fly, *B. zonata***

The completely cover spray exhibited the lowest efficacy among all tested treatments across both seasons. In 2023, the general mean reduction reached only 56.94%, while in 2024 it decreased further to 54.33% (Tables 5 and 6). This decline in performance could be attributed to climatic factors affecting the persistence of the insecticide on foliage or the behavioral avoidance of the target pest. The sharp drop in residual activity after day 6 in both years suggests a limited residual effect and highlights the inefficiency of this method in controlling *B. zonata* under field conditions. Partial bait spray achieved high reduction percentages in both years, with general means of 84.07% (2023) and 83.02% (2024). The residual activity remained above 70% even at 15 days post-application, indicating excellent persistence and attractiveness of the bait formulation. These results support the notion that baiting techniques are superior to contact sprays for fruit flies, as they exploit the feeding behavior of adults (Vargas *et al*., 2010) [29]. The slightly lower performance in 2024 compared to 2023 may be due to variations in environmental conditions or fly pressure; however, the differences are statistically non-significant due to the overlap in standard errors.

Thermal fogging at 75% of the recommended dose proved to be highly effective, with general mean reductions of 81.74% in 2023 and 84.46% in 2024. This method showed a robust and consistent suppression of the pest population over the 15-day period. Notably, the highest reduction percentages were recorded during the early intervals (3-6 days), but efficacy remained high up to 15 days These findings are consistent with previous research indicating that thermal fogging provides uniform coverage and enhanced penetration into tree canopies (Britch, *et al*. 2010; Hoffmann, *et al*. 2008) [1, 14], making it a promising alternative to full-coverage sprays. Thermal fogging (50% dose): At half the recommended dose, thermal fogging still achieved relatively high levels of control, with general means of 66.38% in 2023 and 67.82% in 2024. However, a notable drop in residual efficacy was observed after 10 days, particularly in 2024 where the reduction declined sharply to 39.91% on day 15. This suggests that while the lower dose is initially effective, its residual persistence is inferior compared to the 75% dose or the bait spray. Thus, although fogging at 50% may offer cost savings and reduced pesticide load, it may require more frequent applications to maintain control levels. This trade-off between efficacy and dose aligns with integrated pest management (IPM) principles that aim to minimize chemical inputs without compromising control (Desneux *et al*., 2007) [5].

Therefore across both seasons, the relative performance ranking of treatments remained consistent: partial bait spray ≈ thermal fogging (75%) > thermal fogging (50%) > completely cover spray. However, slight year-to-year variations were evident, potentially due to fluctuating weather parameters or differences in pest pressure. The consistent superiority of thermal fogging and bait spraying underscores the importance of targeting pest behavior and optimizing delivery methods over merely increasing chemical input.

**Table 5:** Reduction percentages of *B. zonata* under four treatment methods during the 2023 season.

| Treatments | Reduction residual | | | | General means |
|---|---|---|---|---|---|
| | Three days | Six days | Ten days | Fifteen days | |
| Completely cover spray | 58.93±7.12c | 62.14±9.67c | 60.67±3.511b | 46±6.49b | 56.94±9.14c |
| Partial bait spray | 86.57±6.23a | 90.81±3.42a | 86.34±4.86a | 72.55±6.76a | 84.07±8.63a |
| Thermal fogg (75%) | 83.14±3.42a | 86.88±3.53a | 80.19±9.16a | 76.75±7.63a | 81.74±6.94a |
| Thermal fogg (50%) | 74.65±4.44b | 74.54±3.8b | 62.29±10.64b | 54.02±8.43b | 66.38±11.17b |
| F values | 20.102 | 20.390 | 11.316 | 15.932 | 32.132 |
| L. S. D. | 8.47152 | 8.8539 | 11.7608 | 11.346 | 6.4344 |

Means assigned the same letter do not show significant differences at the 5% significance level, based on the LSD test.

**Table 6:** Reduction percentages of *B. zonata* under four treatment methods during the 2024 season.

| Treatments | Reduction residual | | | | General means |
|---|---|---|---|---|---|
| | Three days | Six days | Ten days | Fifteen days | |
| Completely cover spray | 59.62±6. 4c | 55.13±11.15b | 52.53±5.7c | 50.06±12.05b | 54.33±9.05c |
| Partial bait spray | 85.96±4.15a | 91.47±3.56a | 82.42±4.55a | 72.25±7.77a | 83.02±8.63a |
| Thermal fogg (75%) | 87.73±4.44a | 89.46±4.22a | 89.31±4.4a | 71.34±8.3a | 84.46±9.32a |
| Thermal fogg (50%) | 78.06±3.65b | 87.29±6.46a | 66.03±4.57b | 39.91±10.43b | 67.82±19.36b |
| F values | 28.990 | 24.158 | 46.889 | 10.727 | 20.908 |
| L. S. D. | 7.3582 | 10.7965 | 7.4466 | 15.08 | 8.7902 |

Means assigned the same letter do not show significant differences at the 5% significance level, based on the LSD test.

## Conclusion

The results of this study emphasize the critical role of attractants and optimized control strategies in managing *C. capitata* and *B. zonata* populations. Among the tested attractants, ammonia-based lures (particularly di-ammonium phosphate) proved to be the most effective in attracting both male and female fruit flies, making them reliable tools for population monitoring and early detection. In terms of control measures, partial bait sprays and thermal fogging at a 75% dose exhibited superior and prolonged efficacy compared to complete cover spraying, which demonstrated limited and short-lived effectiveness. These findings support the implementation of targeted, cost-effective methods such as bait applications and reduced-dose fogging in sustainable integrated pest management (IPM) programs. Adopting such strategies can help reduce chemical input, lower resistance development, and maintain effective control over fruit fly populations in fruit orchards.

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