Field Evaluation of Attraction Efficiency of Some Food-Olfactory Attractant Mixtures and Mass Trapping Technique Compared to Partial Spray for Controlling *Ceratitis capitata* in Orange Orchards

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Abstract

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The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), is one of the most destructive fruit pests in the world, especially on economical crops such as oranges. This study was carried out to evaluate the attraction efficiency of food-olfactory combined with food attractants as well as the mass trapping technique on the reduction rate of *C. capitata* adults population. The food attractant Buminal (Bu) and two olfactory compounds, diammonium phosphate (DAP) and ammonium acetate (AA) were used and compared to a partial spray in a citrus orchard located in El-Gharbia governorate, Egypt. The results obtained showed that all tested mixtures had more attraction efficiency than the other tested compounds alone. The mixture solution of Bu + DAP + AA at a ratio of 1:1:1 significantly attracted the highest average numbers of *C. capitata* adults throughout the four weeks of investigation compared to other tested compounds. The tested mixture and DAP, Bu, and AA alone trapped 8.64, 1.83, 1.78, and 0.61 flies per trap per day, respectively. Thus, this mixture was evaluated as a mass trapping technique comparable to a partial spray. The partial spray treatment was significantly different compared to mass trapping, showing a reduction of 56.71 and 24.60%, respectively.

Key words: *Ceratitis capitata*, mass trapping, partial spray, food attractant, ammonium compounds.

Introduction

Global horticulture crop production and export are significantly impacted by the tephritid fruit flies (Diptera) belonging to the genera *Bactrocera* and *Ceratitis* (Papadopoulos, 2014; Vargas *et al*., 2016). Adult fruit flies react to both smell and visual signals while seeking host plants and food sources (Epsky & Heath, 1998). The research priorities have focused on elucidating sources of attraction that can be exploited to create new or enhance existing pest management techniques, such as attract and kill systems (Navarro-Llopis & Vacas, 2014; Piñero *et al*., 2014; Vargas *et al*., 2014).

According to Franco *et al*. (2006), the Mediterranean fruit fly, *C. capitata* (Wiedemann) (Diptera: Tephritidae), is a species of afro-tropical origin that has adapted to Mediterranean region climate. Infesting over 350 different types of fruits and vegetables worldwide, it is one of the most devastating insect pests (White & Elson-Harris, 1992; Papadopoulos, 2014). In Egypt, the existence of successive hosts for *C. capitata* is an important reason for the wide spread of this pest. It occurs all over the year and increases during the fruiting seasons of the orchards (Ghanim, 2016; 2017; Hashem *et al*., 2001). This pest causes a serious decline in both quantity and quality of fruit yield (Hassanein *et al*., 1995), where females lay their eggs inside fruits and the hatched maggots devour the pulp and feed on the fruit contents. Secondary infestations with bacterial and fungal diseases mostly exist, and then the infested fruits drop down. The infested fruits become unfavorable for marketing and exportation (Borge & Basedow, 1997; White & Elson-Harris, 1992). In Egypt, Medfly can develop in several plants belonging to different families, but when citrus are present, Medfly is the key pest compared to *B. zonata* (El-Gendy & Nassar, 2014).

The control of *C. capitata* in the Mediterranean regions takes place through several methods, such as the mass trapping technique, food attractants, and partial sprays using different groups of insecticides in citrus. The technique is based on placing a high density of traps with an attractant and a toxicant, aiming to capture the highest numbers of adults, especially females, in the groves (Martinez-Ferrer *et al*., 2012). Food sources that are rich in nitrogen have a strong influence on the physiology and behavior of tephritid flies (El-Metwally, 2018; Hemeida *et al*., 2017). Accordingly, protein bait acts as a food attractant, and its effectiveness relies on the fact that the newly emerged females need a protein meal to reach sexual maturity and for the development of eggs to maturity (Epsky *et al*., 2014; Piñero *et al*., 2015).

In the lure and kill strategy, volatile semio-chemicals are used to attract pests to specific locations to kill them. For tephritid fruit flies, attract-and-kill systems can be broadly categorized into three main groups: bait stations (Piñero *et al*., 2014), mass trapping (Navarro-Llopis & Vacas, 2014), and protein bait sprays (Epsky *et al*., 2014; Mangan, 2014). Current control measures against this pest are mainly based on applications of insecticides mixed with protein baits. Among the interesting alternative measures of control, mass trapping techniques have proven to be a powerful tool in the

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control of medflies, and their use has increased in Mediterranean countries (Navarro-Llopis *et al*., 2008). Ammonium acetate plays a role in the foraging behavior of female fruit flies of certain species (Hull & Cribb, 2001; Piñero *et al.,* 2015; 2017). The addition of ammonium acetate to some commercially available protein-based bait and other materials has increased the attractiveness of those baits to female *C. capitata* to a level comparable to that elicited by the spinosad-based protein bait GF-120 NF fruit fly bait (Piñero *et al*., 2015; 2017).

Therefore, the purpose of this study was to evaluate the efficiency of various mixtures of Buminal-ammonia food lures with varying rates on the attraction of *C. capitata* adults, and to compare the most attractive mixture as a mass-trapping technique with a partial bait spray for controlling medflies in a citrus orchard.

Material and Methods

Compounds and mixtures used

The commercial product of Buminal (Bu), hydrolyzed protein 39.78% used at a rate of 5.0% (v/v), was brought from NABA GmbH Company, Germany, and two compounds of ammonia, ammonium acetate (AA) and di-ammonium phosphate (DAP), were brought from El-Gomhoria for Drugs and Chemicals Company, Egypt. Mixtures were prepared by adding each compound of ammonia to Buminal at a concentration of 3.0%. AA and DAP were used in the form of solid states, so they were added as weight/volume (w/v).

Food attractant solution (Bu) and olfactory attractant solution (DAP and AA) were separately used at the following rates: Buminal (Bu) at 5% (v/v), di-ammonium phosphate (DAP) at 3% (w/v) and ammonium acetate (AA) at 3% (w/v). Ten mixture solutions with different ratios were prepared from the above mentioned three attractants as follows (v/v): Bu + DAP at a ratio of 1:1, Bu + DAP at a ratio of 2:1, Bu + DAP at a ratio of 1:2, DAP + AA at a ratio of 1:1, DAP + AA at a ratio of 2:1, DAP + AA at a ratio of 1:2, Bu + AA at a ratio of 1:1, Bu + AA at a ratio of 2:1, Bu + AA at a ratio of 1:2, Bu + DAP + AA at a ratio of 1:1:1.

Field trials

Experiments were conducted in an orange, *Citrus sinensis* L. var. "Navel" orchard, El-Gharbia governorate, Egypt, during the period from 15th of September until 7th of December 2021.

Attraction efficiency of mixtures

Selected mixture solutions were distributed in a completely randomized design inside the orchard using the modified plastic McPhail traps (Hanafy *et al*., 2001). Every treatment was replicated three times, and each trap contained 200 ml of the mixed solution. Traps were hung at 1.5–2.0 meters above the ground in a shaded area among the trees canopy. Traps were spaced around 15 meters apart to prevent lure contact. Traps were weekly inspected throughout four successive weeks to monitor the number of captured flies. After that, traps were alternatively replaced. The mixed solutions or attractants were biweekly changed. The purpose of this experiment was to determine which solution was the most attractable.

Mass trapping compared to partial spray

The best attractive solution (Bu: DAP: AA at 1:1:1) was compared to partial bait spray including 500 ml of Tracer (Spinosad 24% SC) +1 liter of Buminal+18.5 liters of water applied at every two rows. The most attractive solution was dispersed over roughly half acre in mass trapping technique where ten traps were distributed 15 meters apart. The solution was changed every two weeks during four successive weeks. On the other hand, the partial spray was weekly applied where tree's trunk and part of canopy every two rows were sprayed with 200 ml of bait per tree in approximately half acre. Half acre was left without treatment as a control. In each treatment three plastic modified McPhail traps including DAP were randomly hung to monitor the Mediterranean fruit fly population, inspected weekly for four weeks.

Statistical analysis

The data obtained were analyzed using a one-way ANOVA, and the least significant difference (LSD) was determined at P=0.05. CoHort Software was used for statistical analysis (CoHort Software, 2004). Also, Henderson and Tilton equation to determine the percentage decrease of adults *C. capitata* was used (Henderson & Tilton, 1955).

Results and Discussion

Attraction of *C. capitata* adults to three food attractants

Food attractant Buminal combined with the olfactory attractants diammonium phosphate and ammonium acetate (Bu + DAP + AA at a ratio of 1:1:1) significantly attracted the highest mean numbers of *C. capitata* adults throughout the four weeks of investigation of 8.71, 5.52, 8.62, and 11.71 flies/trap for the 1st, 2nd, 3rd, and 4th weeks, respectively, followed by DAP, Bu, and AA. The average number of captures in four weeks was 1.78, 1.83, 0.15, and 8.64 flies/trap in Bu, DAP, AA, and mixed solution (Bu + DAP + AA at a ratio of 1:1:1), respectively. The mixture solution was more effective in attracting the flies than each of the compounds given alone (Table 1).

***C. capitata* adults attraction to buminal and diammonium phosphate**

The results obtained (Table 1) illustrate the average number of *C. capitata* adults attracted by the McPhail traps containing a mixture of protein bait and ammonium compound (DAP) and inspected for four weeks in an orange orchard. The highest average number of insect adults attracted to the mixture of Bu+DAP (ratio 1:1) was 3.82±0.71flies/trap, whereas the lowest average number found in the traps containing the mixture of Bu + DAP (ratio 2:1) reached 3.13±0.44 flies/trap. The combination of protein bait and ammonium compound (DAP) enhanced the insect's attraction compared to Buminal or diammonium phosphate alone.

C. capitata adults attraction to different ratios of ammonium compounds

Results obtained (Table 1) also showed that AA was the weakest attractant (0.61 flies/trap/day), followed by DAP with an average number of 1.83flies/trap/day. The results also showed that the mixture of DAP and AA at a ratio of 1:1 attracted the highest number of adult insects, with an average of 4.49 flies/trap/day. In the fourth week of monitoring, there was a high population in the trapped adult insects of all tested attractants, which may be due to the change in nitrogen content in the mixture solution.

***C. capitata* adults attraction to buminal combined with ammonium acetate at different ratios**

Data in Table 1 showed that the number of adult insects attracted to McPhail traps with a mixture of Bu and AA at different ratios was higher than that attracted by Bu or AA alone. The mixture of Bu and AA at a ratio of 2:1 attracted the highest number of adult insects, with an average of 4.8 flies, followed by the ratios of 1:2 and 1:1, which attracted 4.37 and 3.64 flies, respectively.

Comparative evaluation of the attraction of adult *C. capitata* by food olfactory attractants and their different combinations

Results obtained (Table 2) showed a comparison between insect populations attracted by McPhail traps that contain a mixture of food attractants (Bu) and olfactory ammonium compounds (DAP and AA) at different ratios compared to Bu, DAP, and AA alone. The mixture at a ratio of 1:1:1 was the strongest attractant, with an average number of 8.64 attracted adult insects per trap per day. Whereas, the weakest attractant was the mixture of DAP and AA at a ratio of 2:1, the average number was 2.04 flies/trap/day.

Table 1. Average number of *C. capitata* adults (flies/trap/day (FTD) attracted to three food attractants and inspected during four successive weeks.

	Inspection period after treatment				
Attractants and ratios	**1st week**	**2nd week**	**3rd week**	**4th week**	**Average number of FTD**
Buminal	0.67±0.42 b	2.00±0.70 b	2.00±0.16 b	2.43±0.30 b	1.78±0.27 b
DAP	1.24±0.05 b	1.95±0.53b	0.90±0.13 b	3.24±0.42 b	1.83±0.31 b
AA	0.00±0.0 b	0.38±0.09 b	0.86±0.16 b	1.19±0.30 b	0.15±0.00 b
Bu + DAP + AA (1:1:1)	8.71±2.48 a	5.52±1.53 a	8.62±1.65 a	11.71±3.28 a	8.64±1.20 a
Bu + DAP (1:1)	4.81±1.82 a	6.48±0.62 a	2.33±0.29 a	1.67±0.13 b	3.82±0.71 a
Bu + DAP (2:1)	1.48±0.42 b	4.38±0.83 b	2.76±0.70 a	3.90±0.63 ab	3.13±0.44 a
Bu + DAP (1:2)	1.71±0.46 b	2.71±0.22 bc	2.71±0.30 a	6.14±1.36 a	3.32±0.60 a
DAP	1.24±0.05 b	1.95±0.53 b	0.90±0.13 b	3.24±0.42 ab	1.83±0.31 bc
AA	0.00±0.00 b	0.38±0.09 b	0.86±0.22 b	1.19±0.21 b	0.61±0.15 c
DAP + AA (1:1)	3.19±1.02 a	5.24±1.75 a	3.43±0.84 a	6.10±1.98 a	4.49±0.73 a
DAP + AA (2:1)	1.19±0.21 b	1.67±0.25b	2.19±0.65 ab	3.10±0.62 ab	2.03±0.24 bc
DAP + AA (1:2)	0.90±0.10 b	1.05±0.17 b	3.52±0.58 a	5.81±1.24 a	2.82±0.68 ab
Bu	0.67±0.42 b	2.0±0.70 ab	2.00±0.16 b	2.43±0.30 b	1.78±0.27 bc
Bu + AA (1:1)	2.14±0.30 b	2.81±0.85 ab	2.38±0.27 b	7.24±0.59 a	3.64±0.67 ab
Bu + AA (2:1)	1.14±0.14 b	3.57±0.62 a	6.67±1.65 a	7.24±2.57 a	4.80 ±0.95 a
Bu + AA (1:2)	7.48±1.86 a	4.14±1.21 a	1.81±0.42 b	4.05±0.25 ab	4.37±0.78 ab

Values followed by the same letter in the same column are not significantly different at P=0.05.

Table 2. A comparative evaluation of the attraction of adult *C. capitata* by food olfactory attractants and their different combinations.

		Folds compared to attraction by		
Treatment	**Average**	**Bu**	**DAP**	**AA**
Bu	1.77	-	-	-
DAP	1.83	-	-	-
AA	0.61	-	-	-
Bu + DAP (1:1)	3.82	2.16	2.09	-
Bu + DAP (2:1)	3.13	1.77	1.71	-
Bu + DAP (1:2)	3.32	1.88	1.81	-
DAP + AA (1:1)	4.49	-	2.45	7.36
DAP + AA (2:1)	2.04	-	1.10	3.34
DAP + AA (1:2)	2.82	-	1.54	4.62
Bu + AA (1:1)	3.64	2.06	-	5.97
Bu + AA (2:1)	4.80	2.63	-	7.87
Bu + AA (1:2)	4.37	2.47	-	7.16
Bu + DAP + AA (1:1:1)	8.64	4.88	4.72	14.16

Comparison of attraction by trapping technique in relation to partial spray

Results obtained (Table 3) indicated that the partial spray significantly reduced the population of *C. capitata* adult numbers after a week of treatment, with a 44.10% reduction. The reduction rate throughout the following three weeks was 49.92, 63.20, and 69.6 flies/trap/day, respectively. On the other hand, the mass trapping (about 20 traps/acre) technique showed low reduction rate in *C. capitata* population throughout the four weeks recorded at 24.2, 18.3, 26.9, and 29 %, respectively. The average number of *C. capitata* mass trapping techniques in the treatment differed significantly from those observed for the untreated control, showing an average reduction rate of 24.6%. The partial spray was significantly more effective on *C. capitata* adults' reduction than that recorded in the mass trapping technique, compared to the control.

The mixture of Buminal and either DAP or AA was more attractive for adults of *C. capitata* than those recorded for the three compounds alone, but the mixture of the three compounds (Bu+DAP+AA) at 1:1:1 ratio was the most attractive. Such results are in agreement with those obtained by Piñero *et al.* (2015). Our findings indicated that the addition of ammonium acetate to commercially available proteinaceous baits greatly improved their attractiveness to *C. capitata,* thus increasing the bait's effectiveness for fruit fly monitoring and suppression. Tlemsani & Boulahia-Kheder (2015) evaluated four trapping systems for the control of the Medfly *C. capitata*. They found that Cera Trap® containing a protein solution showed significant effect in mass trapping *C. capitata* after mixing Conetrap® with a dry-food-bait and cypermethrin system. Hemeida *et al.* (2017) used McPhail traps in a mango orchard containing mixtures of protein bait and ammonium compound in comparison with either protein bait or ammonium compound alone. Results showed that the *B. zonata* flies were attracted to all mixtures, with buminal and di-ammonium phosphate giving significantly higher attraction than buminal alone. Results of this study were in agreement with those obtained by Bayoumy *et al.* (2021) who examined the effectiveness of several mixtures of the protein-based bait, Buminal, and ammonia compounds (ammonium acetate, ammonium chloride, di-ammonium phosphate, and phosphoric acid) in attracting the Mediterranean fruit fly in Navel orange. They found the highest captures of *C. capitata* were by mixture of Buminal 5%+di-ammonium phosphate 1%.

Results obtained in this study agree with those obtained by Jouda *et al.* (2010), who reported that adult Medfly males captures, were reduced by 62.86 and 47.29% for the mass trapping based on lufenuron and Tri-pack®, respectively. Jemâa *et al*. (2010) evaluation of mass trapping with Tripack® as alternative to malathion bait-spraying against Mediterranean fruit fly in citrus orchards. In addition, results reported in this study are close to those obtained by Elsanosy *et al.* (2020) who carried out a study on mango to investigate the efficacy of Spinosad as a partial spraying pesticide to control measure to the fruit flies. Results indicated that the application of Spinosad highly decreased the fruit flies' numbers. Our selection of mass trapping and partial bait for controlling *C. capitata* agree with those of Hafsi *et al.* (2020) who stated that mass trapping with CeraTrap® and Starce® attractants as well as insecticide treatments ensured low populations of *C. capitata,* not exceeding the economic threshold (3 males/trap/day).

Table 3. Average number (mean±SE) of adults trapped and reduction rate (%) of *C. capitata* by using mass trapping technique with Bu + DAP + AA (1:1:1) compared to partial spray.

Investigation period and reduction rate	Control	Mass trapping	Partial spray
1st week	3.24±0.68 a	2.57±0.30 ab	2.1±0.29 b
Reduction rate (%)	-	24.20	44.10
2nd week	2.62±0.30 a	2.24±0.13 a	1.48±0.17 b
Reduction rate (%)	-	18.30	49.92
3rd week	3.05±0.44 a	2.33±0.25 a	1.38±0.13 b
Reduction rate (%)	-	26.90	63.20
4th week	3.33±0.36 a	2.48±0.25 b	1.14±0.22 c
Reduction rate (%)	-	29.00	69.60
Average of four weeks	3.06±0.44 a	2.41±0.23 b	1.52±0.20 c
Average reduction rate (%)	-	24.60	56.71

Values followed by the same letter in the same row are not significantly different at P=0.05.

الملخص

الشبراوي، حمدي عبد الصمد، فاتن عطوة عقل بدر، طاهر محمود أماره وماجدة حنا ناروز. 2025. التقييم الحقلي لكفاءة جذب بعض المخاليط الغذائية والشمّية الجاذبة وتقنية تكثيف المصائد مقارنةً بالرشّ الجزئي لمكافحة ذبابة فاكهة البحر المتوسط في بساتين البرتقال. مجلة وقاية النبات العربية، 43(4):541–546. https://doi.org/10.22268/AJPP-001353

تعدّ ذبابة فاكهة البحر المتوسط من أخطر آفات الفاكهة في العالم وبخاصةٍ على المحاصيل الاقتصادية مثل البرتقال. في هذه الدراسة، تمّ تقييم كفاءة جذب مواد شمية وغذائية جاذبة، وتقييم تقنية تكثيف المصائد باستخدام الجاذب الغذائي (بومينال) واثنتين من المركبات الشمية، فوسفات الأمونيوم وأسيتات الأمونيوم، مقارنةً بالرشّ الجزئي في خفض تعداد الحشرات الكاملة لذبابة فاكهة البحر المتوسط. أوضحت النتائج أن بعض المخاليط المختبرة كانت أكثر كفاءةً في الجذب مقارنةً باستخدام المركب بدون خلط. أظهر محلول الخليط المكون من بومينال وفوسفات الأمونيوم وأسيتات الأمونيوم بنسبة 1:1:1 أعلى كفاءة في جذب الحشرات الكاملة لذبابة الفاكهة طوال الأسابيع الأربعة من الدراسة مقارنة بالمركبات الأخرى التي تمّ اختبارها مفردةً، وهي فوسفات الأمونيوم والبومينال وأسيتات الامونيوم، حيث تمّ اصطياد 8.64، 1.83، 1.78 و 0.61 حشرة/المصيدة/اليوم، على التوالي. عند تقييم هذا الخليط بطريقة تكثيف المصائد مقارنةً بالرش الجزئي، أظهرت معاملة الرشّ الجزئي اختلافاً معنوياً عن تقنية تكثيف المصائد، حيث بلغت نسبة الخفض 56.71 و 24.60%، على التوالي.

كلمات مفتاحية: ذبابة فاكهة البحر المتوسط، تكثيف المصائد، الرشّ الجزئي، الجاذب الغذائي، مركبات الأمونيا.

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