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Some of Ecological, Behavioral Aspects and Control of Mediterranean Fruit Flies, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) in Grape Orchards

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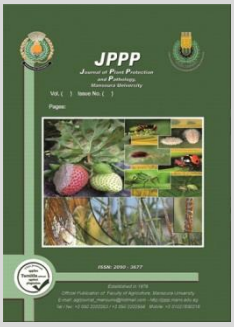

ABSTRACT

Experiments conducted in table grape orchard, variety crimson (late-ripening, red seedless table grape variety) at Nubaria-district, Beheira-Governorate-Egypt, during blooming and fruiting periods (May to October) of seasons, 2019-2020. Results showed that, medfly males were most active during morning 7:00-10:00am (0.98. and 0.905 males/trap/hour in 1st and 2nd seasons, respectively) than other day. Lowest trapped males number (0.012 and 0.028 males/trap/hour in 1st and 2nd seasons, respectively) recorded during period from 19.00pm-7.00am of next-day (night-hours). Results cleared that, high traps captured more male fly's number than low and appropriate trap height for medfly males in grape orchard at 2.5m above ground (0.451 and 0.524 males/trap/hour in 1st and 2nd season, respectively). Minimum trap catch recorded in traps which kept at height 0.5m above ground (0.216 and 0.201 males/trap/hour in 1st and 2nd season, respectively). Infestation grape bunches and berries by medfly studied in relation to adult flies trapping by McPhail traps. Proportion of infested grape bunches and berries increased as grapes maturity, harvest date approached and as increasing of *C. capitata* population. Linear regression equations fitted worked out and coefficient determination (R^2) mostly showed higher indication, hence predictions and forewarning infestation rate by pheromone traps were reliable. Control results showed, significant differences between treatments and control and most effective was spinosad (conserve) insecticide.

Keywords: *Ceratitis capitata*, pheromone traps, table grapes**,** diurnal activity**,** partial bait spray.

INTRODUCTION

The Mediterranean fruit fly (medfly), *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), is considered to be one of the world's most destructive fruit pests because of its global distribution, wide range of hosts and high capability to damage the production (Peñarrubia, 2010). The medfly affects the commercialization and production of the fruits because of its direct damage which reduces both fruit quantity and quality. Also due to the presence of eggs and/ or larvae in the fruits and/or detection of insecticide residues that used for control of this fly there are quarantine restrictions on the international trade of the fresh fruits (Paranhos *et al*., 2008 and Morelli *et al.*, 2012). The medfly has been recorded feeding on over 300 different hosts as fruits, vegetables and nut plant species. The main hosts include stone fruits, citrus, pome fruits, figs, peppers and tomatoes. Plant hosts also include grapes, guavas, avocadoes, persimmons, strawberries, bananas, papayas and blueberries (Woods, *et al*., 2005,). Grape is one of the most important hosts of *C. capitata* (De Lima, 2011 and Baronio, *et al.*, 2018). Grape is one of the most popular and favorite fruits in Egypt. Concerning the acreage and consumption rates grapes rank the second after citrus. The total area of cultivated grapevine area in Egypt reached 196993 feddans with a production of 1686706 tons according to the latest statistics of Egyptian Ministry of Agriculture (2015). The partial bait spray technique is one of the most effective techniques in suppressing the fruit flies populations (Prokopy, *et al.*, 2003 and Moreno and Mangan, 2003). The females of tephritid species attracted to protein source, causing flies to ingest the protein with a lethal dose of insecticide (Mangan, 2009 and Mangan, 2014). The present study aimed to 1) determine the diurnal activity of males of Mediterranean fruit flies, *C. capitata*, 2) the appropriate trap height 3) to study the linear regression between the trapped adults and infestation rates of bunches and berries of table grape and 4) to evaluate the effect of the partial bait spray with different insecticides on suppression of Mediterranean fruit fly at Nubaria district, Egypt to improve its integrated management programs.

MATERIALS AND METHODS

An area of about ten Feddans (Feddan = 4200 m^2) cultivated with table grapes (variety: crimson) at Beheira governorate (Nubaria district), Egypt were selected for the present study during the two fruiting seasons of 2019 and 2020 years. The experimental site is situated between 30° 43´ N latitude and 30° 12´ E longitude. The population of the medfly, *C. capitata* (males) was estimated by using white Jackson traps (Harris *et al.*, 1971) from May 1st and 2nd till October 2nd and 3rd (From the fruit set to end of the harvest) during 2019 and 2020 seasons, respectively. Twelve white Jackson traps powered with the sex attractant of *C. capitata*, were hung at heights of 0.5, 1.5, 2.5 and 3.5 m from ground level. Each height was represented by three traps to evaluate the appropriate height for the male flies in table grapes orchards. The distance between each trap and

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the other was about 50 meters and the sex pheromone capsules were renewed every three weeks.

Diurnal activity:

To study the diurnal activity of males of *C. capitata*, the delta traps (Jackson traps) were inspected six times on the same day of each week for captured males. The surveys of adult flies were conducted at 7:00 am, 10:00 am, 1:00 pm, 4:00 pm, 7:00 pm and 7:00 am of the following day (to determine the number of males /trap /hour). In total, there were 23 Time (days) of observations in each of 2019 and 2020 seasons.

Experimental design

The experimental design was laid out in a split plot design where the times of the day were in main plots and effect of trap heights in the sub-plots. In each inspection throughout the day, the trap heights (sub-plots) were arranged in randomized complete block design with three replications. All obtained data were subjected to the statistical analysis of variance (ANOVA) using least significant difference (L.S.D. at 0.05 levels) according to Snedecor and Cochran (1980).

The linear regression equations between number of captured flies and infestation rate with the medfly, *C. capitatta*:

McPhail traps (Food lure traps) were used in this experiment. For evaluation the progression in field infestation in grape bunches and berries caused by *C. Capitata*. Ten grape plants were previously chosen and marked, on each plant, 10 bunches were chosen and marked. For eight weeks, the percent of damaged bunches were recorded and the damaged berries were counted and removing. The obtained data were averaged and subjected to linear regression analysis.

Incubation of infested berries:

Weekly samples of 100 infested berries were washed and placed in plastic jars (for pupation) covered with blotting paper (to absorb excess moisture). The jars covered with a net and incubated for 2–6 weeks until fruit fly larvae emerged and pupated. Pupae were collected and the number of pupa that emerged from each replicate was counted. The linear regression equations were worked out between number of captured flies and infestation rates with the medfly, *C. capitatta*.

Effect of partial bait spray with different insecticides:

The present experiment was planned to study the effect of partial bait spray with three different insecticides on the population of *C. capitata* in the grape orchard.

Four treatments were used as follow:

T1: mixture of Malathion 57% EC (malathion 57%): buminal: water was 0.5: 1.5: 18, respectively.

T2: mixture of Spinosad (conserve 0.24% CB): water was 1.00: 19.00, respectively

T3: mixture of Lambda-cyhalothrin (Lamdathrin 5% E.C): buminal: water was 0.5: 1.5: 18, respectively

T4: control

The experiment was conducted through the fruit ripening period from mid-July till mid-September (ten weeks). Knap sprayer used to spray trees trunks with the chemical dilutions (150 - 250 ml / tree). The tested insecticides were sprayed every two weeks. The experimental area of this experiment (8 feddans) was divided into sixteen plots (four plots for each treatment). The treatments were replicated four times with 0.5 feddan each (RCBD design). To monitor adult population of Mediterranean fruit fly, *C. capitata* over the control period, McPhail traps baited with buminal solution were hanged at height of 2.5 m above ground in the center of each plot. Traps were reloaded every two weeks (change the solution). The traps were inspected weekly and numbers of males and females of *C. capitata* were counted and recorded. The proper "F" and LSD value at 5 % level was calculated to reveal the significance among the involved treatments.

RESULTS AND DISCUSSION

Diurnal activity of the Mediterranean fruit flies, *Ceratitis capitata* in grape orchard:

The results of study of the diurnal activity of medfly, *C. capitata* are presented in Table 1 and illustrated in Fig. 1. The male flies were most active during the morning hours 7:00 to 10:00 am than the other day hours. During the 1st season, about 59% of the *C. capitata* males were trapped before 10:00 am (from 7:00 – 10:00 am) with a mean number of 0.98 males/trap/hour. Followed by the period from 10.00 am to 13.00 pm (0.306 males flies/trap/hour), the period from 13.00 pm to 16.00 pm (0.17), the period from 16.00 to 19.00 pm with a mean of 0.192 males /trap / hour and finally the lowest mean number (0.012) of trapped males was recorded during the period from 19.00 pm to 7.00 h am of the next day (nocturnal activity).

Table 1. Effect of five different times of the day on the activity (diurnal activity) of the Mediterranean fruit flies, *Ceratitis capitata* in grape orchard at Nubaria district during two successive seasons 2019 and 2020 (Males / Trap / Hour):

Time of day	1st Season, 2019	% of Incidence	2nd Season, 2020	% of Incidence
7.00-10.00	0.98±0.876^{a}	59.036	0.905±0.857^{a}	53.142
10.00-13.00	0.306±0.245^{b}	18.434	0.351±0.355^{b}	20.611
13.00-16.00	0.17±0.199c	10.241	0.174±0.233b^{c}	10.217
16.00-19.00	0.192±0.188^{bc}	11.566	0.245±0.24^{bc}	14.386
19.00pm-7am	0.012±0.023^{d}	0.723	0.028±.0396^{d}	1.644
L.S.D.	0.12045		0.1176	
F value	75.637		55.879	

Means followed by the same letter do not differ significantly at the 5% level of significance (L.S.D. test).

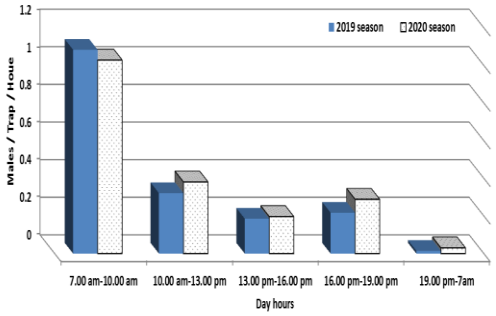

Fig. 1. Effect of five different times of the day on the activity (diurnal activity) of the Mediterranean fruit flies, *Ceratitis capitata* in grape orchard at Nubaria district during two successive seasons 2019 and 2020 (Males / Trap / Hour):

In the 2nd season over 53% of the total male flies were caught during the period from 7:00 to 10:00 am,

numbers of caught male flies began to decrease at 10:00 h and there after fell steadily until 19:00 pm. A few flies apparently were caught at the night hours. Therefore to attract sufficient number of flies during the control programs (baiting and male annihilation techniques) it might be more affective morning hours. These results strongly support the during results of Kazi (1976) who studied the diurnal activity of adults of melon fruit fly, *Dacus* (*Strumeta*) *cucurbitae* (Coquillett) and found that the insects were most active at 10-11 h. Darwish, (2014) in guava orchard found that the significantly highest number of male flies of *C. capitata* were recorded during the period from 7.00 -10.00 am

Trap heights:

The total means of weekly captures of males of Mediterranean fruit flies, *C. capitata* set in four trap heights from May 1st and 2nd till October 2nd and 31rd in table grape orchard (From the fruit set to end of the harvest) during 2019 and 2020 seasons were presented in Table 2 and demonstrated in Fig. 2.

Table 2. Effect of four trap heights on the captured males of Mediterranean fruit flies, *Ceratitis capitata* in grape orchard at Nubaria district during two successive seasons 2019 and 2020 (Males / Trap / Hour).

Trap heights	1st Season, 2019	% of Incidence	2nd Season, 2020	% of Incidence
0.5 M	0.216±0.149^{c}	16.241	0.201±0.138^{c}	14.758
1.5 M	0.276±0.206^{bc}	20.752	0.284±0.208^{bc}	20.852
2.5 M	0.451±0.336^{a}	33.9098	0.524±0.443^{a}	38.473
3.5 M	0.387±0.31^{ab}	29.098	0.353±0.329^{ab}	25.918
L.S.D.	0.14995		0.1735	
F value	3.94		4.929	

Means followed by the same letter do not differ significantly at the 5% level of significance (L.S.D. test).

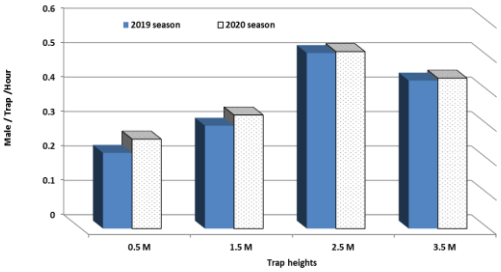

Fig. 2. Effect of four trap heights on the captured males of Mediterranean fruit flies, *Ceratitis capitata* in grape orchard at Nubaria district during two successive seasons 2019 and 2020 (Males / Trap / Hour).

Statistical analysis revealed that there are significant differences among the different treatments (four heights). During the 1st season (2019) the maximum trap catch was recorded in the traps which kept at a height of 2.5 m above the ground level with a mean number of 0.451 male/ trap /hour and this height was significantly superior to all other heights (F =3.94; df= 22; *p*= 0.005). The lowest trap catch was recorded at a height of 0.5 m (0.216 males/trap/hour). The significant difference in trap catches between these vertical distances among the treatments suggests that the choice of an optimum trap height is critical.

Similar results were obtained in the 2nd season, 2020 whereas the appropriate height was 2.5 m above the ground levels (0.524 males / trap /hour) followed by 3.5 m (0.353), 1.5 m (0.284) and finally the less trap height attraction was the height of 0.5 m (0.201). These results are in agreement with the findings of Opp *et al*. (2000) during they field studies in California. They hung two traps per tree; one of the traps was hung at height of 5 m from the ground while the second trap was hung at 2 m from the ground level. They find that the high traps captured greater number of fruit flies (both sexes) than the low traps. Different authors studied the appropriate heights of traps of med fly in different fruit orchards to improve its integrated management programs (monitoring and/ or control) such as, Darwish, (2016) found that a significantly higher numbers of male flies of medfly were captured in the traps hung that at 3 meters than the other heights (1 and 2 meters) in apple, plum, apricot and peach orchards.

Data arranged in Table (3) cleared that, the interaction between the effect of the time of the day and trap heights on the captured males, the medfly was most active during the morning hours at about 2.5 m height above the ground level while the flies was less active in the night hours in a height of 0.5 m. The fact that the Jackson traps at 2.5 m captured more *C. captata* at morning hours than any other heights or day hour's combination provides new information regarding an optimal trap height and time of the day to monitor and control *C. capitata* populations. This information should be useful in developing and testing different action thresholds to determine whether and when insecticides are needed during the season to improve the management of *C. capitata* populations.

Table 3. The interaction between the effect of trap heights and the time of the day on the activity of the males of Miditerrnean fruit flies, *Ceratitis capitata* during two successive seasons 2019 and 2020.

Treatments		1st Season, 2019	2nd Season, 2020
7:00-10:00 am	0.5 M	0.532±0.363^{d}	0.523±0.377^{d}
	1.5 M	0.736±0.563^{c}	0.694±0.493^{c}
	2.5 M	1.431±1.06^{a}	1.403±1.184^{a}
	3.5 M	1.222±1.025^{b}	1±0.88^{b}
10:00 am-13:0 pm	0.5 M	0.213±0.204^{ghi}	0.213±0.173^{ghij}
	1.5 M	0.278±0.199^{fg}	0.306±0.239^{efg}
	2.5 M	0.407±0.272^{e}	0.556±0.483^{d}
	3.5 M	0.324±0.268^{ef}	0.329±0.366^{ef}
13:00-16:00 pm	0.5 M	0.194±0.165^{ghi}	0.12±0.098^{ijkl}
	1.5 M	0.199±0.22^{ghi}	0.167±0.161^{hij}
	2.5 M	0.144±0.228^{hi}	0.245±0.365^{fgh}
	3.5 M	0.148±0.184^{hi}	0.162±0.217^{hij}
16:00-19:00 pm	0.5 M	0.134±0.135^{i}	0.13±0.159^{ijk}
	1.5 M	0.148±0.142^{hi}	0.227±0.195^{fghij}
	2.5 M	0.259±0.212^{fg}	0.375±0.287^{e}
	3.5 M	0.227±0.226^{fgh}	0.25±0.244^{fgh}
19:00 pm- 7:00 am	0.5 M	0.007±0.0123^{j}	0.021±0.032^{l}
	1.5 M	0.016±0.032^{j}	0.026±0.034^{kl}
	2.5 M	0.013±0.023^{j}	0.042±0.054^{l}
	3.5 M	0.013±0.023^{j}	0.024±0.034^{l}
L.S.D.		0.1055	0.108

Means followed by the same letter do not differ significantly at the 5% level of significance (L.S.D. test).

Linear regression studies

The regression equations worked out for trapped of *C. capitata* flies per day (x) and number of damaged bunches in each 100 bunches (y) was Y = 2.647+ 0.290x which indicated that the number of damaged bunches of each 100 bunches increased by 0.29 bunch for every one

male increase in the medfly whereas the regression equation for damaged berries in each bunches was Y = 1.444+ 0.106x which revealed that for every one fly (male and/or female) increase of medfly the damaged berries per one bunch increased by 0.106. On the other hand, the linear regression analysis reveals to for every one fly increase of medfly there are increasing in the emerged adults of medfly from 100 infested berries by 0.009 and 0.048 individuals in 1st and 2nd season, respectively. During the 2nd season, 2020 the equation of damaged bunches of 100 bunches was Y = 4.166+0.188x while the equation of damaged berries of each bunch was Y = 1.199+ 0.124x which revealed that for every unit increase in trapped flies the damaged berries per bunch increased by 0.124.

Table 4. Linear regression coefficients between *C. capitata* and infested bunches per 100 punches, infested berries per bunch and emerged adults.

Season	2019	R^2	2020	R^2
Infested bunches/100 bunches	Y = 2.647+ 0.29x	0.907	Y = 4.166+0.188x	0.317
Infested berries/bunch	Y = 1.444+ 0.106x	0.943	Y = 1.199+ 0.124x	0.867
Emerged flies/100 infested berries	Y = 3.348+ 0.009x	0.055	Y = 1.479+ 0.048x	0.424

Effect of partial bait spray (as a low environmental impact method) with different insecticides:

The results obtained in Table (5), and illustrated in Figs. (3 and 4) and Table 5 clearly showed that the partial bait spray with three different insecticides (malathion, spinosad and lambda-cyhalothrin) were significantly effective in suppression the population density of males and females of *C. capitata*. In the 1st season, 2019 the general means of adult females of *C. capitata* recorded 8.1, 3.05 and 6.65 females /McPhail trap/week in case of treatment with malathion, spinosad and lambda-cyhalothri, respectively in comparison with the traps in control plots which recorded 29.1 female/trap/week. In the other hand the population densities of males were recorded 14.725, 10.925 and 12.775 males/ trap / week in the plots treated with malathion, spinosad and Lambda-cyhalothrin, respectively in comparison with control plots which were significantly high (25.025 males/trap/week). During the 2nd season, 2020 the same trends were repeated where the general means of adults males were recorded 34.725, 20.9, 13.4, 18.3 males/ trap/ week in control and plots treated with malathion, spinosad and lambda-cyhalothrin, respectively. Concerning the statistical differenced in the reduction percentages between the three treatments, the results indicated that the treatment with spinsad (conserve) insecticide offer tangible benefits when compared with the other two treatments. Similar results were obtained by Moustafa, *et al*., 2009 who evaluated the efficacy of three insecticides (spinosad, lufenuron and malathion) under field conditions against the olive fruit fly, *Bactrocera oleae*. They found that, in comparison with control the population density of *B. oleae* were obviously low in treated plots with Lufenuron, Spinosad and Malathion, respectively.

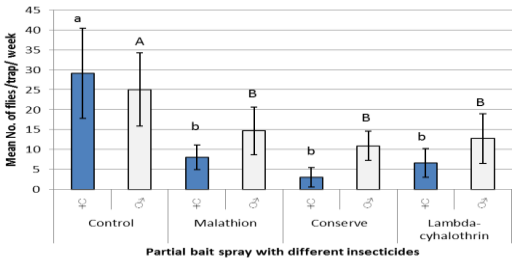

Fig. 3. The general means of population densities of males and females of *C. capitata* in malathion, spinosad and lambda-cyhalothrin treated plots as well as in control plot during 2019 season.

(F= 35.429, L.S.D.= 5.6746 for females; F= 9.240, L.S.D.= 5.9467 for males).

Bars with the same letter(s) are not significantly different at P > 0.05, lower cases for females and upper cases for males)

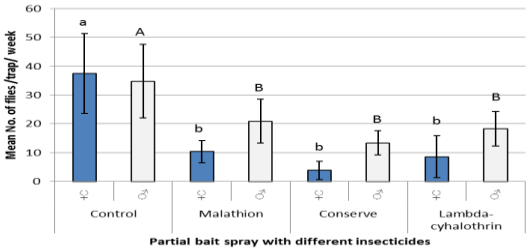

Fig. 4. The general means of population densities of males and females of *C. capitata* in malathion, spinosad and lambda-cyhalothrin treated plots as well as in control plot during 2020 season.

(F= 34.184, L.S.D.= 7.4553 for females; F= 12.163, L.S.D.= 7.5175 for males).

Bars with the same letter(s) are not significantly different at P > 0.05, lower cases for females and upper cases for males)

Table 5. The general means of reduction percentages of males and females of *C. capitata* in malathion, spinosad and lambda-cyhalothrin treated plots as well as in control plot during 2019 and 2020 seasons.

Weeks	2019 season						2020 season					
	Malathion		Spinosad		Lambda-cyhalothrin		Malathion		Spinosad		Lambda-cyhalothrin	
	♀	♂	♀	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	74.67	41.57	97.14	58.14	91.25	48.07	72.84	46.25	99.04	59.78	100	53.75
2	60.86	38.3	82.15	57.54	79.43	55.61	71.55	38.18	88.44	69.16	84.5	50.95
3	71	56.32	100	61.53	79.58	55.28	69.6	41.64	97.79	48.6	95.98	39.84
4	84.53	45.99	95	58.72	86.56	45.7	71.25	47.76	93.98	62.29	92.33	43.63
5	56.91	45.31	93.45	48.13	74.03	48.44	73.63	33.2	93.65	59.13	76.49	34.55
6	57.3	41.41	87.74	43.91	68.69	62.69	72.65	34.97	90.89	58.08	81.29	43.68
7	73.11	31.69	86.7	53.64	73.07	56.82	74.02	39.62	87.15	58.45	67.09	53.16
8	72.68	39	89.88	59.25	74.28	44.9	74.01	34.81	91.2	58.68	73.67	41.95
9	77.29	41.81	85.28	56.18	74.53	40.73	72.26	42.78	84.82	68.92	70.28	52.36
10	69.73	39.25	84.69	59.67	73.19	44.13	71.85	41.46	85.22	62.79	65.44	51.25
General Mean	69.81	42.07	90.21	55.67	77.46	50.24	72.37	40.07	91.22	60.59	80.71	46.51

In the 1st season: F= 19.608, L.S.D.= 6.7514 for Females F= 11.640, L.S.D.= 5.8249 for males

In the 2nd season: F= 15.190, L.S.D.= 7.0332 for Females F= 32.215, L.S.D.= 5.3652 for males

Also, many author such as Prokopy, *et al.* (2003) and Halawa, *et al.* (2019) used the partial bait spray as a low toxic method in comparison with the cover spray.

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بعض الاتجاهات البيئية والسلوكية ومكافحة ذبابة ثمار فاكهة البحر المتوسط *Ceratitis capitata* في بساتين العنب

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اجريت هذه التجارب لدراسة النشاط النهاري والليلي وتأثير ارتفاع المصيده علي معدل اصطياد ذكور حشرة ذبابة فاكهة البحر المتوسط *Ceratitis capitata* وذلك في بستان عنب المائده صنف كريمسون Crimson (وهو صنف متاخر النضج احمر اللون عديم البذور) في منطقة النوبارية، محافظة البحيرة، جمهورية مصر العربية خلال موسمي التزهير والاثمار (مايو – اكتوبر) للموسمين المتتاليين ٢٠١٩ ، ٢٠١٨م. أوضحت النتائج أن ذكور الحشرة كانت أكثر نشاطا في الفترة من الساعه ٧ صباحا الي الساعه ال ١٠ صباحا (٠,٩٨ و ٠,٩٠٥ ذكر / مصيده / ساعة خلال الموسم الاول والثاني، علي الترتيب). بينما كان أقل نشاط للحشرة تم تسجيله خلال ساعات الليل في الفترة من ٧ مساءا الي الساعه ٧ صباحا بمعدل (٠,٠١٢ و ٠,٠٢٨ ذكر / مصيده / ساعة خلال الموسم الاول والثاني، علي الترتيب). كذلك أوضحت النتائج أن كفائة المصائد علي ارتفاعات ٢,٥ و ٣,٥ متر أكثر كفائة عن المصائد التي تم تعليقها علي ارتفاعات ١,٥ و ٠,٥ متر. وكان افضل ارتفاع للمصيدة في جذب الحشرة هو الارتفاع ٢,٥ متر (٠,٤٥١ و ٠,٥٢٤ ذكر / مصيده / ساعة في موسمي الدراسة الاول والثاني). بينما كانت اقل ارتفاعات المصيده جذبا للحشرات هو ارتفاع نصف متر (٠,٢١٦ و ٠,٢٠١ ذكر / مصيده / ساعة في موسمي الدراسة الاول والثاني، علي الترتيب). كذلك تم دراسة معادلات الانحدار الخطي البسيط بين معدل الاصابة لكل من العناقيد وحبات العنب وبين أعداد الحشرات التي تم اصطيادها في المصائد وقد وجد ان معدل الاصابة يزداد بارتباط معنوي موجب بزيادة عدد الحشرات في المصايد. وأيضا تم استخدام طريقة الرش الجزئي كوسيلة لمكافحة آمنة للحشرة. وكانت المبيدات المستخدمة هي مبيد الاسبينوساد Spinosad ومبيد اللمبادا- سيهالوثرين Lambda-cyhalothrin ومبيد الملاثيون Malathion وكانت طريقة الرش الجزئي بالمبيدات الثلاث فعال في مكفحة الحشرة بالمقارنة بالكنترول. هذا وكان أكثر المبيدات كفائة بهذا الطريقة في خفض تعداد الحشرة هو مبيد الاسبينوساد Spinosad.