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Management strategies of fruit damaging pests of pomegranates: *Planococcus citri*, *Ceratitis capitata* and *Deudorix* (*Virachola*) *livia*

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Pomegranate trees are susceptible to many pests. Marketing quality of pomegranate fruits is mainly affected by the citrus mealybug, *Planococcus citri*; Mediterranean fruit fly, *Ceratitis capitata* and pomegranate butterfly, *Deudorix* (*Virachola*) *livia*. This study aimed to determine successful management strategies for these three fruit damaging pests of pomegranates. Studies were conducted during 2011 to 2012 in 21 pomegranate orchards. Total 225 Wonderful cultivar trees were selected from each orchard as a replication for each treatment. Three replications were used for each treatment and all fruits of 75 randomly selected trees were collected. Results of the experiments suggest that contact insecticides have less efficiency than the systematic insecticides against *P. citri*. Fruit thinning (leaving only one fruit on each spurs) in combination with Spritetramat were found to be the most effective management strategy against *P. citri*. Results also showed that attract-and-kill traps are effective control tools against *C. capitata*. The two years study suggested that 30 traps ha^{-1} are sufficient for the control of *C. capitata*. Indoxacarb was found to be the most effective active ingredient in controlling *D. livia* by reducing the damages from 15% to < 2% with at least two applications.

Key words: *Planococcus citri*, *Ceratitis capitata*, *Deudorix* (*Virachola*) *livia*, Insecticides, Spinosad, attract-and-kill traps.

INTRODUCTION

Pomegranate (*Punica granatum* L.) is one of the oldest known cultivated plants (Lye, 2008), known to be native to central Asia (Morton, 1987; Holland et al., 2009). Pomegranate fruit has been traditionally known to beneficial to human health, confirmed by recent scientific findings (Gil et al., 2000; Aviram and Dornfeld, 2001; Lansky et al., 2005; Jurenka, 2008; Turk et al., 2008; Haidari et al., 2009) which reported that pomegranate is a good source of antioxidants, vitamins, potassium, calcium, magnesium, iron and zinc.

After the scientific confirmation of the health benefits of pomegranates, consumption increased and with a resultant increase in area harvested. Total pomegranate import of the Europen Union coutries showed 56.5% increase in 10 years during 2002 to 2012 (EC Market Access Database, 2013). Increase in the demand for the pomegranates caused the establishment of new plantations in all over the world. Pomegranate trees are easily adapable to different climates and soil conditions and it is known to be grown in many different

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Table 1. Treatments against *Deudorix livia*, *Planococcus citri* and *Ceratitis capitata.*

Orchards	Treatments against:		
	D. livia	***P. citri***	***C. capitata***
1, 2 and 3	Untreated control	Untreated control	Untreated control
4, 5 and 6	Indoxacarb	Cypermethrin	Spinosad
7, 8 and 9	Lamda-cyhalothrin	Chlorpyrifos-ethyl	Cypermethrin
10, 11 and 12	Spinosad		Thiamethoxam
13, 14 and 15	Bacillus thuringiensis	Fruit thinning + Spirotetramat	60 units of traps ha^{-1}
16, 17 and 18		Fruit thinning	30 units of traps ha^{-1}
19, 20 and 21		Spinosad	15 units of traps ha^{-1}
Application times:	Mid Mar – Early Apr	July	End of Aug – Early Sept

geographical regions including the Mediterranean basin, Asia and California. One of the most important problems causing yield and quality reduction in pomegranates is pests and diseases.

Pomegranate trees are known to be susceptible to many pests, for example Mir et al. (2012) reported that pomegranate trees are attacked by 45 species of insects, whereas Ksentini et al. (2011) reported up to 91 pests in India. Stem borer (*Zeuzera pyrina* L., Lepidoptera: Torticidae) is an important pest which attacks stems and trunks causing tree death (Holland et al., 2009). On the other hand, aphids, especially, *Aphis pomi* De Geer (Homoptera: Aphididae) are serious pests as young pomegranate leaves are highly susceptible to aphid attacks (Bhagat, 1986). These pests negatively effect pomegranate production, but marketing quality of pomegranate fruits is mainly affected by citrus mealybug, *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) (Blumenfeld et al., 2000; Ferrández et al., 2000; Oztürk et al., 2005; Yilmaz, 2007; Holland et al., 2009; Bartual et al., 2012), Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) (Oztürk et al., 2005; Yilmaz, 2007; Holland et al., 2009) and pomegranate butterfly, *Deudorix* (*Virachola*) *livia* (Klug) (Lepidoptera: Lycaenidae) (Awadallah et al., 1971; Holland et al., 2009).

Successful management of pomegranate fruit damaging pests is important for the production of marketable fruits. Therefore, this study aimed to determine successful management strategies for the main fruit damaging pests of pomegranates, including citrus mealybug, Mediterranean fruit fly and pomegranate butterfly.

MATERIALS AND METHODS

Experimental field sites

Studies were conducted during 2011 to 2012 on 21 pomegranate orchards each covering at least 0.5 ha and maximum 1.3 ha areas in Cyprus. Orchards were established in 2008 with 1-year old 'Wonderful' cultivar pomegranate trees by 5 × 3 m distance and pruned as globe shape with one trunk. Cyprus has a Mediterranean climate with relatively mild winters and hot summers. The Wonderful cultivar has sweet-tart taste, deep purple-red fruits with not hard seeds and delicious vinous flavor. Irrigation is performed by drip irrigation. The trees of the orchards were of uniform vigour and size.

Experimental studies

P. citri, *C. capitata* and *D. livia* are spreading easily in and around orchards and therefore, each pomegranate orchard was used as a replication for the treatments. Total 225 trees (0.33 ha) were selected from each orchard (replication) for each treatment against one pest. Occurrence and time of damage caused by these three pests differ and treatment against one pest did not affect the other pests (Table 1). However, to reduce side effects, different trees were selected against different pests from the same orchards. Untreated trees were treated with same insecticides and alternative control methods against *D. livia* and *C. capitata*. However, because of the high damage of *P. citri* and ineffectiveness of some insecticides in 2011, un-selected trees were thinned to avoid damages of *P. citri* in 2012. Untreated control treatments are the same trees for all three pests. Un-selected trees of the control orchards were also left untreated to avoid any side effect. Three replications (orchards) were used for each treatment and all fruits of 75 randomly selected trees (out of 225) were collected. Margin trees are not selected to avoid drift and to eliminate border effect. Turbo atomizer with fan type nozzles used at 3 atm. pressure to apply insecticides with a total of 500 L of water was required to spray 0.33 ha orchard (225 trees). All orchards were treated with Acetamiprid in early March against *A. pomi*.

Three insecticides, one alternative control method and water spray as control was tested against *P. citri*. The tested insecticides were: cypermethrin (Imperator® 25 EC [250 g/L], Syngenta, [dose: 30 mL/100 L]), spirotetramat (Movento® SC 100 [100 g/L], Bayer CropScience, [dose: 100 mL/100 L]) and chlorpyrifos-ethyl (Dursban® 4 [480 g/L], Dow AgroSciences: [dose: 150 mL/100 L]). Alternative to chemical methods, fruit thinning is performed by removing fruits touching each other, leaving one fruit on a spur. First insecticide application was done when one *P. citri* was counted on 10 fruits. Second application was performed two weeks after the first application. In 2012, one additional treatment was tested with fruit thinning and one application of spirotetramat combined. In this treatment, insecticide application was performed at the time of the second application of other treatments.

Two chemical insecticides, one biological pesticide, three different numbers of attract-and-kill traps and water spray as control were tested against *C. capitata*. The tested insecticides were: cypermethrin (Imperator® 25 EC [250 g/L], Syngenta, [dose: 30 mL/100 L]), spinosad (Laser® [480 g/L], Dow AgroSciences, [dose: 25 mL/100 L]) and thiamethoxam (Actara® 240 SC [240 g/L], Syngenta, [dose: 25 mL/100 L]). To determine the application time

Table 2. Efficacy of different treaments on mealy bug (*Planococcus citri*).

Treatments	4 years old pomegranate orchard			5 years old pomegranate orchard		
	Total # of fruits	# of damaged fruits	% of damaged fruits	Total # of fruits	# of damaged fruits	% of damaged fruits
Cypermethrin	2050±293ᵃ	206±53ᵇ	10.05ᵇ	2977±384ᵃ	246±10ᵇ	8.34ᶜ
Spirotetramat	1952±463ᵃ	93±7ᶜ	4.90ᶜ	2899±287ᵃ	123±10ᶜ	4.24ᵈ
Chlorpyrifos-Ethyl	2031±287ᵃ	255±70ᵃᵇ	12.40ᵇ	3012±254ᵃ	341±71ᵃᵇ	11.24ᵇ
Fruit thinning	1348±30ᵇ	36±3ᵈ	2.70ᵈ	2319±83ᵇ	64±6ᵈ	2.78ᵉ
Fruit thinning + Spirotetramat	-	-	-	2242±45ᵇ	3±2ᵉ	0.15ᶠ
Untreated control	1889±116ᵃ	297±25ᵃ	15.76ᵃ	2721±175ᵃ	391±79ᵃ	14.30ᵃ

Values followed by the same letter or letters are not significantly different at 1% level (Duncan's multiple range test); #, number.

of the pesticides, yellow sticky traps were hanged on the trees. First insecticide application was done when the first adult fruit fly was observed. Second application was performed two weeks after the first application. Attract-and-kill traps (Ceratiprotect®, mass trapping, SEDQ) were used as alternative control strategies. Ceratiprotect is a dispenser of ammonium acetate, diaminoalkane and trimethylamine vapours. Traps were hanged on the southern parts of the pomegranate trees 90 days before harvest. Three different numbers of traps were tested, these are: 15, 30, 60 traps ha^{-1}. Substances attract insects and they enter the trap through three holes around. Once insects enter the trap, try to fly towards the light and escape through the transparent top, they touch the insecticide, die and fall down into the trap.

Two chemical insecticides and two biological pesticides and water spray as control were tested against *D. livia*. The tested insecticides were: indoxacarb (Avaunt® [150 g/L], DuPont, [dose: 35 mL/100 L]), spinosad (Laser® [480 g/L], Dow AgroSciences, [dose: 25 mL/100 L]), lamda-cyhalothrin (Karate Zeon® [50 g/L], Syngenta, [dose: 25 mL/100 L]) and *Bacillus thuringiensis* (Jawelin® WG [52.9 billion Spodoptera/kg], Certis USA, [dose: 150 g+1 kg sugar/100 L]). First insecticide application was done during flowering and flower bud stage, when the first adult butterfly was observed and second application was performed one week after fruit set. Yellow sticky traps were hanged on the trees to determine application times of the pesticides.

Statistical analysis

Harvested pomegranates from the randomly selected 75 trees were packed at the packing house of Alnar Pomegranates Ltd, Guzelyurt, Cyprus. During packaging, fruits were individualy inspected and the number of damaged fruits was recorded. Data were subjected to analysis of variance and efficacy of insecticides was determined. Mean separations were done by using Duncan's multiple range test at $P < 0.01$.

RESULTS

Results for the efficacy of treaments on *P. citri* are given in Table 2. Significant differences were found for the number of fruits harvested among the chemical treatments and fruit thinning and also for the number and percentages of damaged fruits among the treatments ($P < 0.01$). According to the results, highest damage of *P. citri* on the fruits was recorded for the untreated control for both years. The damage of *P. citri* reached up to 15.76% in 2011. Among the treatments, chlorpyrifos-ethyl gave the least effect on the damages of *P. citri* in both years. Cypermethrin treatment reduced the *P. citri* damage from 15.76 to 10.05% in 2011 and from 14.30 to 8.34% in 2012. Spirotetramat gave the highest effect among the chemical treatments and reduced the percentage of damaged fruits below 5% in both years. However, the highest effect was determined from the fruit thinning performed by hand in 2011. The damage of *P. citri* on the fruits was only 2.70% in 2011 and 2.78% in 2012. In 2012, one additional treatment was used with the combination of fruit thinning and one application of spirotetramat. Results indicated that combination of these treatments gave the highest efficiency in the control of *P. citri* with only 0.15% damage recorded. Fruit thinning reduced the number of fruits per tree, but no significant difference was found among the total yield with the average fruit mass of the thinned trees was 538 g/fruit in comparison to un-thinned trees with 467 gr/fruit in 2012.

Six different treatments were tested against *C. capitata*. Results indicated that all treatments had at least 50% reduction of damaged fruits when comparing with the untreated control. The damage of *C. capitata* in the untreated control was 8.41% in 2011 and 9.21% in 2012 (Table 3). The lowest effect were obtained with spinosad (4.16%), followed by 15 traps ha^{-1} (3.89%) and thiamethoxam (3.81%) with no significant differences among these treatments. Highest efficiency were recorded from the 30 and 60 traps ha^{-1} in both years. The damage of *C. capitata* was only 0.82 and 0.85%, respectively, in 2012. After these treatments, cypermethrin was found to be the third effective treatment, with damaged fruits of 2.50% in 2011 and 2.41% in 2012.

Among the studied pests the most important damage was caused by *D. livia*, with 14.63% in 2011 and 15.57% in 2012 in the untreated control treatments (Table 4). Most effective of the treatments was also obtained for *D. livia*, where the damage decreased below 5% in all treatments. Highest effect was found for the indoxacarb treatment in both years and followed by lamda-cyhalothrin treatment. No significant differences were determined among *B. thuringiensis* and spinosad treatments. The effects of all four treatments were

Table 3. Efficacy of different treaments on Mediterranean fruit fly (*Ceratitis capitata*).

Treatments	4 years old pomegranate orchard			5 years old pomegranate orchard		
	Total # of fruits	# of damaged fruits	% of damaged fruits	Total # of fruits	# of damaged fruits	% of damaged fruits
Cypermethrin	1845±310[a]	46±6[c]	2.50[c]	2781±222[a]	67±2[c]	2.41[c]
Thiamethoxam	1885±238[a]	76±11[b]	4.05[b]	2995±130[a]	114±12[b]	3.81[b]
Spinosad	1820±254[a]	82±7[b]	4.51[b]	3068±315[a]	127±5[b]	4.16[b]
Traps (60 units ha^{-1})	1921±219[a]	25±3[d]	1.34[d]	2863±76[a]	24±5[d]	0.85[d]
Traps (30 units ha^{-1})	1814±201[a]	26±5[d]	1.46[d]	2750±185[a]	23±3[d]	0.82[d]
Traps (15 units ha^{-1})	1865±94[a]	77±5[b]	4.15[b]	2964±92[a]	115±7[b]	3.89[b]
Untreated control	1889±116[a]	158±30[a]	8.41[a]	2721±175[a]	250±16[a]	9.21[a]

Values followed by the same letter or letters are not significantly different at 1% level (Duncan's multiple range test); #, number.

Table 4. Efficacy of different treaments on pomegranate butterfly (*Deudorix livia*).

Treatments	4 years old pomegranate orchard			5 years old pomegranate orchard		
	Total # of fruits	# of damaged fruits	% of damaged fruits	Total # of fruits	# of damaged fruits	% of damaged fruits
Indoxacarb	1891±244[a]	38±3[d]	2.00[d]	2866±493[a]	40±7[d]	1.46[d]
Lamda-cyhalothrin	1959±286[a]	87±13[c]	4.43[c]	3098±242[a]	115±2[c]	3.72[c]
Bacillus thuringiensis	2097±295[a]	119±31[b]	5.60[bc]	2918±318[a]	137±10[b]	4.72[b]
Spinosad	1812±342[a]	105±11[b]	5.87[b]	2783±175[a]	136±18[b]	4.87[b]
Untreated control	1889±116[a]	276±21[a]	14.63[a]	2721±175[a]	425±72[a]	15.57[a]

Values followed by the same letter or letters are not significantly different at 1% level (Duncan's multiple range test); #, number.

higher in 2012 than 2011 although the damage in untreated control was higher in 2012.

DISCUSSION

All three tested chemical treatments cause significant reduction in the number of damaged fruits for *P. citri*. However, none of the chemical treatments reduced the *P. citri* infestation as much as in fruit thinning. The success of fruit thinning is attributed to the elimination of favourable habitats for *P. citri*. Ahmed and Abd-Rabou (2010) reported that *P. citri* is found to infest 65 plant species belonging to 36 families in Egypt and pomegranate is one of these species. Su and Wang (1988) highlighted that *P. citri* prefer to host clusters of fruit and inner canopy fruits. On the other hand, after development, *P. citri* has protective wax secretions, adding to reasons why chemical control of this pest is often an inefficient management strategy, especially as a contact pesticides. Similar findings for the inefficiency of chemical treatments have been reported (Tandon and Lal, 1980; Ishaq et al., 2004). Spirotetramat is a systematic pesticide and it is not surprising to have higher effects than the cypermethrin and chlorpyrifos-ethyl. Kerns et al. (2004) reported that chlorpyrifos-ethyl is commonly used for control of *P. citri* in Arizona, but they also reported that it is a contact pesticide and thorough coverage is need for chlorpyrifos to be most effective. This can be a possible reason why, this pesticide become least effective in present study. The effect of chlorpyrifos-ethyl may be increased with alternative control methods such as fruit thinning. Cypermethrin is a synthetic pyrethroid, stomach and contact pesticide. It is fast-acting and especially effective against chewing insects and absorbed by the insect pest when it walks over the dry residue, and can attribute to cypermethrin being more effective than chlorpyrifos-ethyl.

According to the results, all treatments had at least 50% reduction in the number of damaged fruits by *C. capitata* when comparing to untreated control. Although, all treatments were found to be effective, least effective treatment was the spinosad application. Several studies reported that spinosad bait treatments under laboratory conditions are effective in causing high mortality of *C. capitata* (Raga and Sato, 2005; Chueca et al., 2007; Manrakhan et al., 2013). Both studies were conducted by combining spinosad with protein hydrolysate and were conducted in laboratory conditions. The present study was conducted in orchards and this could be the reason for low efficiency of spinosad. Another important finding during the present study was that the attract-and-kill traps are very effective against *C. capitata*. Navarro-Llopis et al. (2011) reported that fruit flies are an economically important pests for crops; and attractants and pheromones are generally used in integrated pest management programs for monitoring in order to prepare insecticidal treatment programs. They also indicated that the most important consideration for using traps is the cost and the number of required traps. The present study indicated that 30 units ha^{-1} of traps are effective to control *C. capitata* in pomegranate orchards, with a maximum 1.46% damaged fruits in 2011 and 0.82% in 2012. Similarly Navarro-Llopis et al. (2013) reported that attract-and-kill type devices were effective control tools against *C. capitata*.

D. livia is among the most important and destructive pests of pomegranate. Morton (1987) reported that the moth lays eggs on the flower-buds and the calyx of developing fruits and they may cause loss of an entire crop unless the flowers are sprayed 2 times 30 days apart. *D. livia* was determined as the highest damaging pest in the present study, where it caused 14.63% damage in 2011 and 15.57% damage in 2012 in the untreated control treatments. Ksentini et al. (2011) reported that the damage caused by *D. livia* in Tunisia pomegranate varieties was between 5.2 and 52%. Findings of the present study are among these limits, as all treatments reduced the damages below to 5%. Blumenfeld et al. (2000) reported that *D. livia* lays its eggs into the crown of the fruit and damages occur towards ripening or in storage with *B. thuringiensis* the best way of control. Within this study, *B. thuringiensis* reduced the damage from 15% to below 5% but the highest effect was obtained from the indoxacarb treatment. The biological insecticide, spinosad, also gave similar effect with the *B. thuringiensis*. Similarly Singh and Singh (2000) reported that *B. thuringiensis* is an effective control agent for the *D. livia*. The effects of spinosad and *B. thuringiensis* can be increased by increasing the number of applications. Among the treatments, indoxacarb was found to be most effective control tool against *D. livia* with only 1.46% damage in 2012. Obeidat and Mazen (2002) studied the effect of four pesticides on the *D. livia* and they reported that lamda-cyhalothrin gave 97% clean fruits. This result is similar with our findings where the per cent fruit damaged by *D. livia* was 3.72%.

Results of the experiments suggest that chemical treatments, especially with systematic insecticides, reduce damages of *P. citri*. Spirotetramat, which is a systematic insecticide can reduce damages of *P. citri* below to 5%. However, for a better control of *P. citri*, it is important to eliminate favourable habitats for this insects, which can be achieved by fruit thinning to one fruit per spur. Fruit thinning in combination with spirotetramat can reduce damages caused by *P. citri* to a level of 0.15%. Recently, alternative control strategies are becoming important for the producers with inceasing concerns of consumers and health organizations about the pesticide residues. For this reason, attract-and-kill traps are becoming an important tool for producers. Results of present study confirm the effectiveness of traps against *C. capitata* by providing information about the adequate number of traps for pomegranate orchards. This two years study suggests that 30 units ha^{-1} of traps are sufficient for the control of *C. capitata*. Results also indicate that *D. livia* is among the most important pests of pomegranates causing around 15% damages to fruits. Indoxacarb insecticide was found to be effective in controlling this pest but at least two applications were necessary. Results also suggest that *B. thuringiensis* and spinosad are effective biological control agents for the *D. livia* and can be used in organic farming systems and/or in integrated pest management practices.

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