Pheromone-Based Communication Disruption of *Adoxophyes orana* on Peach Using the New RAK 3+4 Dispensers and Their Effect on Development of Fruit Rot Diseases

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The effectiveness of the pheromone-based communication disruption method was examined against the summerfruit tortrix, *Adoxophyes orana* F.v.R. (Lepidoptera: Tortricidae), a pest of peach trees, using the new RAK 3+4 dispenser (BASF). No *A. orana* males were captured in pheromone traps inside the experimental orchards, which were saturated with the RAK 3+4 dispensers. The percent of damaged leaves was practically zero, while the level of damaged fruits was 0–6% in pheromone-treated orchards. The percentage of fruit rot caused by *Monilinia laxa* was lower in pheromone-based communication disruption orchards than in the control. It was concluded that the RAK 3+4 dispenser could be used against *A. orana* as an economical and environmentally friendly method.
KEY WORDS: *Adoxophyes orana*; pheromone-based communication disruption; peach; pheromone trap; summerfruit tortrix.

INTRODUCTION

Adoxophyes orana (Fischer von Rösslerstamm) (Lepidoptera: Tortricidae) is one of the most damaging pests of peach trees in northern Greece. The summerfruit tortrix damages mainly annual shoots, leaves and fruits (3). The pest has three generations per year in northern Greece (7). So far, the only effective method applied against *A. orana* is the use of synthetic insecticides such as azinphos-methyl + demeton-S-methyl sulphon, chlorpyriphos, permethrin and methidathion, but most of these are expensive with a high probability of residues. Use of the bioagent *Bacillus thuringiensis* against many pests has been reported (2,8,13,17), but its effectiveness is doubtful. Mating disruption is considered as a cornerstone of Integrated Pest Management in orchards (9). The method has been tested against many Lepidoptera such as *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae), *Anarsia lineatella* Zeller (Lepidoptera: Gelechiidae), *Lobesia botrana* (Denis & Schiffermüller) (Lepidoptera: Tortricidae) with promising results (4-6,10-12,16,18).

The aim of this study was to investigate the pheromone-based communication disruption method using RAK 3+4 dispensers, a new product of BASF, against the summerfruit tortrix *A. orana* on peach, and their effect on development of fruit rot diseases.

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MATERIALS AND METHODS

The dispensers (double ampules of 160 mg (*Z*)-11-tetradecenyl acetate) of pheromone RAK 3+4 were applied in the experimental orchards of the Pomology Institute in Naoussa (prefecture of Imathia). According to data provided by the manufacturer, BASF Hellas Company, Thessaloniki, Greece, this kind of dispenser is more effective than the *Z*9-14Ac one used previously against *A. orana*. The experimental orchard, 132 m above sea level and approx. 100 km from the sea, was 3 ha in size and contained 41 different peach cultivars in the full growth stage. The distance between trees was 3×6 m and tree height was 3–3.5 m. There were 550 dispensers per ha and one dispenser per tree. Orchards without dispensers or insecticide treatment against *A. oranae*, 400 m and 1000 m outside of the experimental orchard, were used as controls.

In the same prefecture, another experimental peach orchard (at Agia Marina) was established 15 km away from the first one. 10 ha, This orchard was divided into two plots of 5 ha each, and contained five cultivars. The distances between trees were 5× 5 m and tree height was 3–3.5 m. In the first plot, one dispenser per tree was placed in the middle of each tree canopy. In the second plot (∼50 m away from the first), two dispensers per tree were placed at the orchard borders (diametrically opposite each other) and one dispenser per tree in the center of the orchard. With this method of installation, 450 dispensers per ha were added in the first plot and 520 dispensers per ha in the second plot. Each plot included the same number of trees for each of the five cultivars used. The dispensers were placed in orchards on 12.IV.2002 in the first year and on 16.IV.2003 in the second year. No insecticide was applied in the experimental orchards or the surrounding orchards throughout the experiments. At harvest time, the percent infestation was determined for leaves (100) and fruits (100) collected from each tree (samples were taken from ten trees of each cultivar). An orchard without dispensers and without receiving any insecticide against *A. oranae*, 1000 m away from the experimental orchard, was used as control.

Pherocon traps with 1 mg pheromone were used for monitoring of insect flight inside and outside of pheromone-based communication disruption orchards. Pheromone and the sticky bottoms were changed every 20 days throughout the experimental period. Every 2 days the traps (four traps for each recording area at a distance of 20 m from each other; inside 400 m, 1000 m outside) were checked and the number of males captured was recorded and the males were removed from the traps.

The development of rot diseases was also evaluated. Fifty randomly selected fruits per tree for each treatment were collected (at maturing period) around the tree canopy and the number of rotted fruits was recorded. Isolation of pathogens was made by placing pieces from the borders of rotted tissues on potato dextrose agar.

Experiments were conducted during two consecutive years (2002, 2003). The experimental design was completely randomized. Data were analyzed using Analysis of Variance (ANOVA). To combine data, Bartlett's test of homogeneity was used; treatment means were separated by Duncan's Multiple Range Test ($P>0.05$).

RESULTS AND DISCUSSION

Pheromone-based mating is an environmentally friendly method of pest control. In this study, experiments were conducted to evaluate the effectiveness of the new RAK 3+4 dispenser formulation developed by BASF containing the main pheromone component of

A. orana. No males were captured in pheromone traps inside the experimental orchards which were treated with the RAK 3+4 dispensers. The number of captured males gradually increased with distance from the treated orchards (Table 1). In both experimental orchards (Pomology Institute and Agia Marina – in all three plots), the percent damage on leaves was practically zero for all cultivars used, while fruit damage was 0–6% in both years (Table 2). In contrast, leaf damage was ∼10% and 17–19% in the two control orchards, respectively. Fruit damage was approx. 20–22% and 24–26% in the two control fields. The distribution of dispensers in the experimental field did not affect the effectiveness of the RAK 3+4 dispenser. Similar results regarding the effectiveness of the pheromone-based communication disruption method against this pest were found in the past (15). Minks and Deventer (11,12), using a 'twin dispense' formulation developed by BASF, reduced the numbers of *A. orana*, *Cydia pomonella*, *Archips podamus* and *Pandemis heparana* (Lepidoptera: Tortricidae) males captured in the pheromone-baited traps, decreased the numbers of larvae and pupae collected in apple orchards, and improved the quality of fruit at harvest. They found that, at a density of 300 and 500 dispensers/ha, the population of the target pest was reduced by 50% and 85%, respectively. In this study, a density of 450 and 550 dispensers/ha, with a release rate of pheromone of 0.52 g per day per ha for each dispenser, resulted in no captures of *A. orana* males on pherocon traps, no leaf damage, and reduced the amounts of damaged fruits by 85.7% and 87.7%, respectively.

TABLE 1. Male captures (mean values) of *Adoxophyes orana* in four pheromone traps placed inside and outside of pheromone-based communication disruption orchards (Naoussa and Agia Marina)

Date	Naoussa 2002[z]		2003		Date	Agia Marina[w] 2002
	Meters outside of exp. area[y]					Meters outside of exp. area
	400	1000	400	1000		1000
10.V	0 d[x]	25 a	0 j	0 j	5.V	0 g
20.V	13 b	11.5 b	5 hj	25 e	15.V	13.25 a
30.V	0 d	12 b	5.75 hj	6.25 hj	25.V	9.25 bc
9.VI	0 d	5.25 c	0 j	0.5 j	5.VI	0.75 g
19.VI	0 d	2.5 cd	0 j	0 j	15.VI	1.75 g
29.VI	0 d	0 d	0 j	0 j	25.VI	1 g
9.VII	12 b	12 b	6.25 hj	37.5 cd	5.VII	6.75 cd
19.VII	5 c	12.5 b	1 j	2.5 j	15.VII	11.75 ab
29.VII	3 cd	6.25 c	2.5 j	30 de	25.VII	4 def
8.VIII	0 d	2.75 cd	3.75 j	70 b	5.VIII	3 efg
18.VIII	0 d	4 c	13.5 f	80 a	15.VIII	1 fg
28.VIII	3 cd	2 cd	10 fh	42.5 c	25.VIII	5.25 de

[z]Results differed between the 2 years in the Naoussa experimental orchards according to Bartlett's test of homogeneity of variance; therefore, data were not combined.
[y]Captures inside the experimental orchard were zero.
[x]In the same year and site, values followed by a common letter do not differ significantly according to Duncan's Multiple Range Test (P=0.05).
[w]There are no data for 2003.

According to Neumann *et al.* (14), the mating disruption method against many Lepidoptera, including *A. orana*, has been shown to be effective, but success can be achieved only when the following parameters are observed: uniform distribution of the dispensers; adequate treatment of border areas; sufficient dose levels; steady release of the

TABLE 2. Influence of the RAK 3+4 dispenser on the damage to leaves and fruits of peach trees caused by *Adoxophyes orana*

Plot no.[z]	Damaged leaves (%)	Damaged fruits (%)
1	0 a[y]	2.80 a
2	0 a	3.18 a
3	0 a	3.27 a
Control	13.78 b	22.77 b

[z] 1, Naoussa experimental orchard; 2, Agia Marina experimental orchard with 450 dispensers/ha; 3, Agia Marina experimental orchard with 520 dispensers/ha.

[y] Within columns, values followed by the same letter do not differ significantly (P=0.05) according to Duncan's Multiple Range Test. (Values are means of 2 years of combined data, since results were similar according to Bartlett's test of homogeneity of variance.)

pheromone; a reduction of populations where necessary; and extending the area treated by coordinating the efforts of as many fruit growers as possible. The best control is achieved where physical conditions allow for uniform distribution of pheromone within the orchard. Thus, sites that are relatively calm and flat are better candidates for mating disruption than sites that experience frequent winds or have steep slopes, as was the case with the experimental orchards of this study. Orchards with large numbers of missing trees or uneven canopies are considered poor candidates for mating disruption. Because the borders of mating-disrupted orchards are especially vulnerable to pests, the best choice is the one with the least amount of border exposed to open areas. Besides, a key factor in determining the efficacy of mating disruption is the initial density of the target pest within or adjacent to an orchard being considered a candidate for mating disruption. Controlling the target pest by mating disruption alone becomes more difficult as the pest pressure increases. The choice of the appropriate dispenser is crucial, as it is related to the characteristics of pheromone such as the release rate of pheromone (different pests require different amounts of released pheromone) and its longevity (better the season-long product, applied one time at the beginning of the first flight).

The pathogen *Monilinia laxa* was the only one isolated from the rotted fruits. In most cases, infections started from wounds and then extended throughout the fruit. This is in good agreement with Agrios (1), who reported wounds as the main entrance site for fungi. In this study, the percentage of rotted fruits was much lower inside the pheromone-based communication disruption orchards (0.4%) than outside (2.9%). The fewer damaged fruits from the insects in the pheromone-based communication disruption area may be a good explanation for this.

It was concluded that the RAK 3+4 dispensers at 450 dispensers per ha is effective against *A. orana* on peach trees, since no males were captured in the pheromone traps in either experimental orchard. The percentage of infestation on leaves and fruits was very low and no further control measures were needed. Although pheromone-based communication disruption by release of pheromone components of target lepidopterous pest occurs for various species and has considerable practical application in crop protection, relatively little is known about the basic mechanisms involved. Possibly, the male antennae were polluted by the extra pheromone exposure and they could not locate females. Basic investigations of pheromone-based communication disruption offer a challenge to researchers, with the results having potential practical value in the more efficient application of the technique.

REFERENCES

1. Agrios, G. (1988) Plant Pathology. 3rd ed. Academic Press, San Diego, CA, USA. p. 47.
2. Alberola, T.M., Aptosoglou, S., Arsenakis, M., Bel, Y., Delrio, G., Ellar, D.J. *et al.* (1999) Insecticidal activity of strains of *Bacillus thuringiensis* on larvae and adults of *Bactrocera oleae* Gmelin (Dipt. Tephritidae). *J. Invert. Pathol.* 74:127-136.
3. Alford, D.V. (1992) Colour Atlas of Fruit Pests: Their Recognition, Biology and Control. Wolfe Publ. Ltd., London, UK.
4. Arpaia, S. and Fiore, M. (2001) Insect pest control in peach orchard with the sexual confusion technique [*Prunus persica* L. Batsch-Basilicata]. *Italus Hortus* 8:76-77.
5. Audemard, H., Leblon, C., Neumann, U. and Marboutie, G. (1989) Evaluation of a seven year control experiment on the Oriental fruit moth *Cydia molesta* Busck (Lep., Tortricidae) by the mating disruption technique. *J. Appl. Entomol.* 108:191-207.
6. Balduque, R., Crespo, J., Perdiguer, A., Campillo, R. and Rubies, F. (1988) Mating disruption for control of the Oriental fruit moth (*Grapholita molesta*) and the peach twig borer (*Anarsia lineatella*) in peach tree orchards of Ebre Valley. OILB/SROP. Working group - Integrated protection in fruit orchards: Peach orchards. Valence, France. pp. 36-38.
7. Charmillot, P. and Brunner, J. (1989) Summerfruit tortrix, *Adoxophyes orana*: Life cycle, warning system and control. *Entomol. Hell.* 7:17-26.
8. Charmillot, P., Pasquier, D., Antonin, P. and Mittaz, C. (1992) Control of the grape moth and the vine moth with *Bacillus thuringiensis* (BT): Results for 1991. *Rev. Suisse Vitic. Arboric. Hortic.* 24:109-116.
9. Ilichev, A., Hossain, M. and Jerie, P. (1999) Migration of Oriental fruit moth *Grapholita molesta* Busck (Lepidoptera: Tortricidae) under wide area mating disruption in Victoria, Australia. OILB et Integrée Contre les Animaux et les Plantes Nuisibles, Dijon, France. p. 139.
10. Louis, F. and Schirra, K. (2001) Mating disruption of *Lobesia botrana* (Lepidoptera: Tortricidae) in vineyards with very high population densities. *Bull. OILB SROP* 24:75-79.
11. Minks, A. and Deveneter, P. (1992) Mating disruption utilizing lepidopterous sex pheromones: successful tests in orchards and a need for more fundamental research. *Entomologie* 8:229-233.
12. Minks, A. and Deveneter, P. (1992) Mating disruption of Codling moth and fruit tree leafrollers in Dutch apple orchards: testing of commercial products. *Bull. OILB SROP* 15:72-75.
13. Navrozidis, E.I., Vasara, E., Karamanlidou, G., Salpiggidis, G.K. and Koliais, S.I. (2000) Biological control of *Bactocera oleae* (Diptera: Tephritidae) using a Greek *Bacillus thuringiensis* isolate. *J. Econ. Entomol.* 93:1657-1661.
14. Neumann, U., Jilderda, K., Minks, K., Deventer, P. and Waldner, K. (1993) Mating disruption, a promising new technique in apples, pears and peaches. *Novenyvedelem* 29:137-142.
15. Oku, T. (1993) Suppression of lepidopterous pest populations in apple (*Malus pumila*) orchards through mating disruption with synthetic sex pheromones. *JARQ (Jpn. Agric. Res. Q.)* 26:271-276.
16. Pfeiffer, D., Killian, J., Rajotte, E., Huii, L. and Snow, J. (1991) Mating disruption for reduction of damage by lesser peach tree borer (Lepidoptera: Sesiidae) in Virginia and Pennsylvania peach orchards. *J. Econ. Entomol.* 84:218-223.
17. Savopoulou-Soultani, M., Hatzivassiliadis, A., Vlug, H., Minks, A. and Tzanakakis, M. (1985) First records of the summerfruit tortricid, *Adoxophyes orana* F.v.R. in Greece. *Entomol. Hell.* 10:5-10.
18. Suess, L. (1995) Knowledge and application prospects of the integrated control on pomaceous and drupaceous fruit trees. *Inf. Fitopatol.* 45:9-12.