

The deposition and retention of a microencapsulated oriental fruit moth pheromone applied as an ultra-low volume spray in the canopy of three peach cultivars

Orkun Baris KOVANCI¹, Nimet Sema GENCER¹, Thomas Everett LARSEN²

¹Department of Plant Protection, Uludag University, Gorukle Kampusu, Bursa, Turkey

²Suterra LLC, Bend, OR, USA

Abstract

Microencapsulated oriental fruit moth pheromone (Checkmate OFM-F) was applied using airblast sprayers at a rate of 15 g a.i./ha either in 635 or 40 litres of water/ha for high-volume and ultra-low volume (ULV) application, respectively. Trials were conducted in peach orchards composed of “Dixired”, “Redhaven” and “Glohaven” cultivars in northwestern Turkey in 2006 and 2007. Male moth catches were significantly higher in the insecticide control plots (mean 5.58/week) than those in both high volume (3.38/week) and ULV (1.40/week) pheromone treatments. The ULV application deposited 1.6 times greater number of microcapsules per cm² leaf and fruit than the high-volume application. Significantly more microcapsules per cm² were deposited on peach leaves (0.06 ± 0.003) than fruits (0.03 ± 0.002). “Dixired” leaves and fruits retained significantly more microcapsules per cm² than “Redhaven” and “Glohaven” leaves and fruits. The relatively open canopy of “Dixired” may have allowed the accumulation of more pheromone microcapsules around midrib of curved leaves. The difference in microcapsule density did not significantly differ between upper and lower surfaces of peach leaves but leaves in the upper tree canopy had significantly more microcapsules per cm² than those in the lower canopy. Unlike leaves, neither fruit surface nor canopy height had any significant effect on the microcapsule deposition on fruits of any cultivar.

Key words: *Grapholita molesta*, peach cultivar, mating disruption, sex pheromone, spray method.

Introduction

Oriental fruit moth (OFM), *Grapholita molesta* (Busck), is a major pest of several fruit crops worldwide but peaches, nectarines and quinces are usually the most preferred hosts (Rothschild and Vickers, 1991). Other potential hosts include almonds, apples, apricots, cherries, pears, and plums (Rice and Kirsch, 1990). OFM completes five generations per year in Bursa region of northwestern Turkey, three generations in peaches and nectarines plus two more generations in late-season hosts such as apples, pears and quinces (Kilincer and Kovanci, 1986). Most larvae of the first generation cause peach twig damage while later generation larvae feed in both twigs and fruits.

OFM is conventionally controlled with broad-spectrum organophosphate insecticides (Il'ichev *et al.*, 2006). During the growing season, it is common to apply up to five or six insecticide sprays to reduce OFM damage to peaches, especially for late-maturing varieties. However, with over use, OFM populations have developed resistance to organophosphate insecticides in some parts of the world (Usmani and Shearer, 2001; Kanga *et al.*, 2003). One alternative to chemical control of OFM is mating disruption by using sex pheromones, an important component of integrated pest management programmes in peach orchards (Cravedi and Molinari, 1995). Mating disruption is widely used against OFM in for example, Italy (Molinari and Cravedi, 1990), Australia (Il'ichev *et al.*, 2002) and North America (Kovanci *et al.*, 2005a).

Several controlled-release devices have been developed to release large quantities of OFM sex pheromone

in the field to achieve mating disruption (Carde and Minks, 1995). These pheromone dispensing devices include hand-applied dispensers (Kovanci *et al.*, 2004), microencapsulated sprayables (Trimble *et al.*, 2004; Kovanci *et al.*, 2005b), and aerosol puffers (Stelinski *et al.*, 2007a). Among these, sprayable pheromone formulations have become increasingly popular for OFM management in the USA in recent years owing to the ease and flexibility of application (Knight, 2000). However, the higher cost of sprayable formulations compared with insecticides as well as their short residual activity are still major obstacles to their adoption by fruit growers (Il'ichev *et al.*, 2006; Stelinski *et al.*, 2007b). Currently, Checkmate OFM flowable formulation is sprayed at 10-15 g a.i. per application, which costs about \$ 30-45 per ha. One sprayable pheromone application can be effective up to 3-4 weeks (Kovanci *et al.*, 2005b).

The effectiveness of sprayable pheromone formulations may be increased by targeting a greater percentage of the pheromone ingredient into the tree canopy using concentrated, low volume sprays. When the spray volume was reduced from 1000 to less than 100 l per ha, Knight and Larsen (2004) reported improved control of codling moth due to a sharp increase in the number of codlemone microcapsules deposited on apple leaves. However, no such information is available for application of OFM sprayable formulation, which contains a more stable pheromone than codlemone, in a reduced spray volume.

Many other factors can influence the deposition and retention of pheromone microcapsules in the field. Possible factors include the chemical stability and release

rate of sex pheromone, differences in cultivar characteristics, environmental conditions, and mechanical set-up of the sprayer (Waldstein and Gut, 2003; Knight and Larsen, 2004; Waldstein and Kering, 2006). In this study, the influence of two pheromone application spray volumes on the deposition and retention of pheromone microcapsules for OFM on the leaf and fruit surfaces of various peach cultivars was examined.

Materials and methods

Orchard block layout

Trials were conducted in Bursa region of northwestern Turkey, which is the major peach growing area established by Italian agronomists in the 1900s and accounts for 25% of national peach production. Two experimental orchards located in Gursu (40°21'N - 29°19'E) and in Inegol town (40°2'N - 29°32'E) were used in 2006 while both experimental orchards were selected from Inegol in 2007. Each 9-ha orchard was composed of three peach blocks each approximately 3 ha in size containing the cultivars “Dixired”, “Redhaven” and “Glohaven”. The “Redhaven” and “Glohaven” blocks were 5 to 9-year-old trees grafted on Marianna GF 8-1 rootstocks while 6-year-old “Dixired” trees were grafted on GF 677. Redhaven trees were taller (4-5 m) in height and had more dense foliage compared with the other cultivars (2-3 m). All cultivars were planted at distances of 6 x 6 m and trained in a typical vase shape. Each cultivar block was further split into three 1 ha plots each receiving different treatments.

Treatments

In each year, two pheromone sprays were applied four weeks apart. Treatments were made on 29 May and 26 June in 2006, and on 1 and 29 June in 2007. At each block, each plot was randomly assigned to the following treatments separated by at least 10 m from each other. Treatments were separated from each other to avoid the effects of pheromone drift. The barrier zones between pheromone treatments were treated with conventional insecticides:

High volume application of sprayable pheromone

OFM sprayable pheromone composed of 21.8% Z8-12:Ac, 1.5% E8-12:Ac, 0.3% Z8-12:OH and 76.4% inert ingredients was applied at a rate of 15 g ai/ha or 65 ml of formulation. Plots were sprayed at a rate of 635 l/ha using an airblast sprayer (BT32-1000, Teknik20, Bursa, Turkey). The sprayer was equipped with eight nozzles (Quickjet, Spraying Systems Ltd., Istanbul), which were mounted either 1.3 or 1.6 m, 4 nozzles at each height, from the ground and angled at 45-55° to target the spray into the upper canopy at a height of 2.5 to 3 m. The top half of the “Redhaven” trees at 4-5 m height was not sprayed to provide a uniform sampling height of 2-3 m while the whole “Dixired” and “Glohaven” trees at 2-3 m height were sprayed. Eight nozzles delivered a spray volume of 12.7 l per minute at 400 kilopascals with a travelling speed of 2 km/hr.

ULV application of sprayable pheromone

The same pheromone formulation was applied at the same rate but in a ULV of 40 l/ha. Only two nozzles were turned on and they together delivered a spray volume of 1.6 l per minute at 25 kilopascals with a travelling speed of 4 km/hr.

Insecticide treatment (no-pheromone) as a control

In insecticide-treated plots, Thiacloprid 480 SC (Calypto, Bayer CropScience, Turkey) was applied at a rate of 440 ml/ha on the same days as the sprayable pheromone. Novaluron 10 EC (Rimon, Makhteshim Agan, Israel) application was made at a rate of 700 ml/ha, 14 days after each Thiacloprid application. The water volume was the same high volume rate used in high volume pheromone treatments.

Monitoring

Delta-style pheromone traps (Easiset Delta Trap, AgriSense-BCS Ltd., UK) baited with 100 µg of OFM pheromone containing Z-8-dodecen-1-yl acetate, E-8-dodecen-1-yl acetate, and Z-8-dodecen-1-ol (Biolure OFM, Suterra LLC, Bend, OR) were used to monitor OFM populations (Kovanci *et al.*, 2005a). Male moth catches in the pheromone traps placed in pheromone treated plots were compared with those in insecticide-treated control plots. For each treatment, four traps were deployed in the upper third of the canopy. Traps were placed 50 m apart among plots. Trap bottoms were changed every 4 weeks.

Foliage and fruit sampling

Mature peach leaves were glossy green, lance-shaped, and long pointed. Leaf length and width ranged between 12-16 cm long, and 3-5 cm wide. Leaves were collected < 2 h after sprays were applied, individually bagged and returned to the laboratory.

“Dixired” had medium sized, oval-shaped fruits while the fruits of “Redhaven” and “Glohaven” were larger and more round than “Dixired”. In contrast to the smooth texture of “Redhaven” fruits, the surface of “Dixired” fruits was covered with short, dense trichomes. Glohaven fruits were almost unpubescent. Samples were individually bagged and frozen for later analysis. Fruits were picked by pressing thumb gently into the fruit near the stalk.

In each plot, 10 leaves and 10 fruits per tree from four randomly selected trees were sampled at two canopy heights, lower (< 2 m), and upper (> 2 m up to 3 m), for each cultivar and treatment. Overall, a total of 1440 leaf and fruit samples per orchard per year were analyzed for the presence of microcapsules.

Microcapsule counts

The density of microcapsules per leaf and fruit at each canopy height was compared among different treatments. The dying method of Waldstein and Gut (2003) was used to increase the visibility of the microcapsules under light microscopy. Microcapsules were counted within 48 h of the final treatment with a dissecting mi-

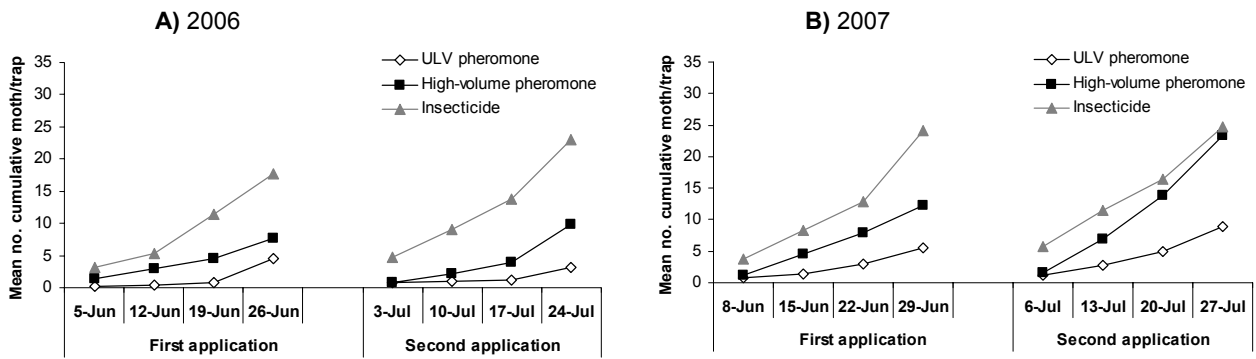


Figure 1. Mean cumulative catches of male OFM on peaches at all treatments during two pheromone application periods in 2006 (A) and 2007 (B) in Bursa, northwestern Turkey.

croscop at 40X magnification. The lower and upper surfaces of the leaves were examined. Because leaf surface area is a variable, a leaf area meter (LI-COR Model LI-3000, Lincoln, Nebraska, USA) was used so that counts could be standardized to a cm^2 surface area. For fruit examination, each peach was cut in half through the middle so that two halves would lie flat on the microscope stage. Then each fruit section was examined for the presence of microcapsules per cm^2 .

Data analysis

Male moth catches in traps after each pheromone application were square root transformed and compared using analysis of variance (ANOVA) (SAS Institute, 2004). Data are presented as back transformations and averaged over two pheromone applications in each year. Matched pair t-tests were conducted to distinguish between moth trap catches at different weeks.

A four-way ANOVA was conducted to analyze the density of microcapsules on apple leaves and fruits with cultivar, spray volume, leaf (lower and upper surfaces) or fruit surface, and canopy height (low and high) as the main effects.

Significant means in all ANOVA's were separated with Fisher's protected least significant difference test at the $p = 0.05$ significance level. LSMEANS statement was used to identify the interaction effects. Two-sample paired t-test analysis for means were performed to compare the mean number of microcapsules per cm^2 deposited on leaves with those on fruit surface.

Results

Moth catch

Seasonal mean cumulative moth catches did not significantly vary between years, with a total of 40.6 and 48.8 moths/trap in conventional insecticide-treated plots in 2006 and 2007, respectively ($F = 1.66$, $p = 0.20$). Figure 1 shows the variation in mean cumulative moth catches among treatments during two pheromone application periods in both years. Despite higher cumulative moth catches at all treatments during the second application period, no significant difference existed between application periods (figure 1).

Male moth catches were significantly higher in the in-

secticide control plots than those in both pheromone treatments ($F = 176.96$, $p < 0.01$). Significant differences were also found in disruption of male capture in pheromone traps between pheromone treatments and there were significantly fewer moths in the ULV-applied pheromone treatment than the high volume pheromone treatment. Pheromone trap catches significantly varied among cultivars ($F = 15.95$, $p < 0.01$) but there was a significant week by cultivar interaction ($F = 3.50$, $p < 0.01$). No significant difference in moth catches was detected among cultivars for the first two weeks. During the third week, moth catches in cv. "Glohaven" blocks were significantly higher than the other cultivars. Significantly fewer moths were caught in cv. "Dixired" blocks compared with the other cultivars both in the third and fourth week.

Microcapsule deposition

Significantly more microcapsules per cm^2 were deposited on peach leaves (0.06 ± 0.003) than fruits (0.03 ± 0.002) averaged across years, locations, treatments and cultivars ($t = 15.07$, $p < 0.01$). No significant difference was detected in microcapsule counts between years ($F = 1.20$; $p = 0.27$ for leaves; $F = 0.34$; $p = 0.80$ for fruits).

The density of microcapsules deposited on peach leaves and fruits significantly differed among treatments ($F = 489.64$; $p < 0.001$ for leaves; $F = 131.50$; $p < 0.01$ for fruits). The highest mean \pm SEM density of microcapsules per cm^2 leaf (0.10 ± 0.008) was found in plots where the sex pheromone was sprayed in ULV application (figure 2). The ULV application of CheckMate® OFM-F deposited 1.6 times more microcapsules per cm^2 on leaves and fruit than the high-volume application.

Cultivar had significant effect on microcapsule deposition on leaves and fruits ($F = 49.30$; $p < 0.01$ for leaves; $F = 66.36$; $p < 0.01$ for fruits). "Dixired" leaves and fruits retained significantly more microcapsules per cm^2 than the "Redhaven" and Glohaven leaves and fruits (figure 3). However, there was a significant cultivar by treatment interaction ($F = 49.30$; $p < 0.01$ for leaves; $F = 47.10$; $p < 0.01$ for fruits). "Dixired" leaves and fruits treated with ULV pheromone application had the highest density of microcapsules compared with other cultivars treated either with ULV or high-volume application (figure 4). The ULV application significantly increased the number of microcapsules deposited on leaves of all cultivars but not on the fruits of "Redhaven" and "Glohaven".

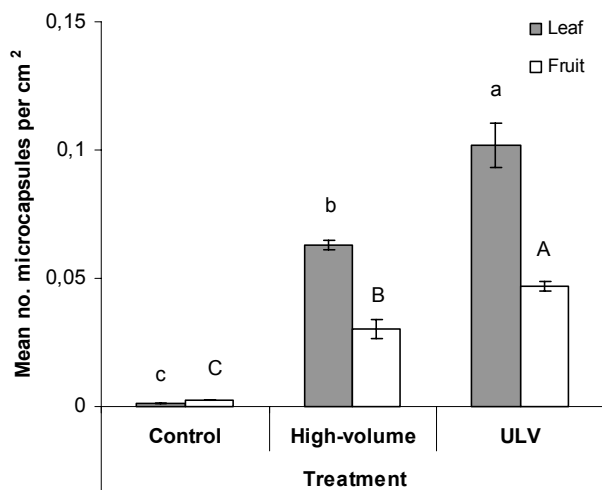


Figure 2. Mean \pm SEM number of pheromone microcapsules deposited on the peach leaves and fruits treated with a sprayable pheromone for OFM either in high-volume or ULV applications using an airblast sprayer. High-volume insecticide treatment served as a negative control. Means followed by the same letter for leaf (small letters) and fruit counts (capital letters) are not significantly different ($p < 0.05$) by Fisher's protected LSD-test.

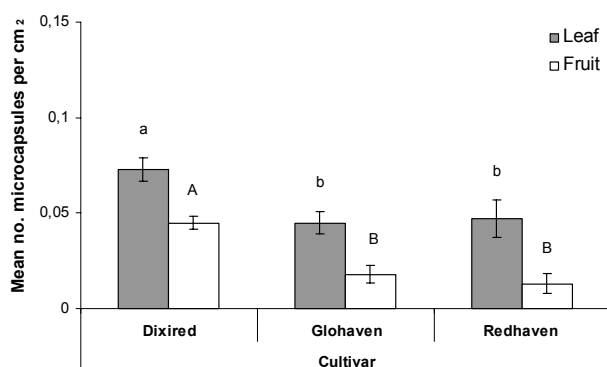


Figure 3. Mean \pm SEM number of pheromone microcapsules deposited on leaves and fruits of cvs. "Dixired", "Redhaven", and "Glohaven" averaged over treatments, locations and years in Bursa, northwestern Turkey. Means followed by the same letter for leaf (small letters) and fruit counts (capital letters) are not significantly different ($p < 0.05$) by Fisher's protected LSD-test.

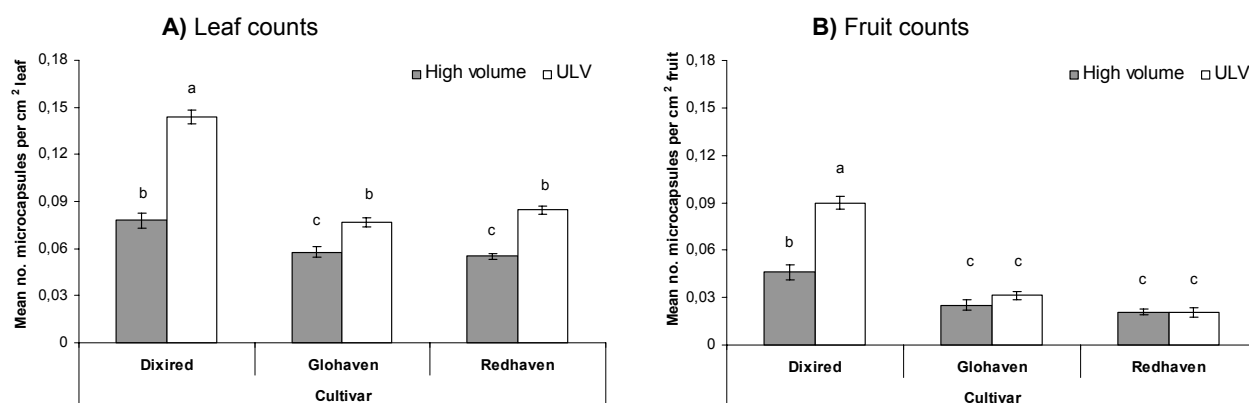


Figure 4. Mean \pm SEM number of pheromone microcapsules deposited on A) leaves and B) fruits of peach cvs. "Dixired", "Redhaven", and "Glohaven" treated with sprayable pheromone either in high-volume or ULV applications averaged over locations and years in Bursa, northwestern Turkey.

Microcapsule density did not significantly differ between upper and lower surfaces of peach leaves ($F = 3.31$; $p = 0.07$). On the other hand, leaves located in the upper tree canopy had significantly greater number of microcapsules per cm^2 than those located in the lower canopy ($F = 8.39$; $p < 0.01$). However, the mean density of microcapsules deposited in the lower and upper tree canopy varied with pheromone treatment and cultivar (figure 5) ($F = 17.81$; $p < 0.01$ for treatment by canopy height; $F = 7.05$; $p < 0.01$ for cultivar by canopy height). ULV-pheromone applied leaves contained significantly more microcapsules per cm^2 both in the upper and lower canopy than the leaves subjected to high-volume pheromone treatment. For cultivars, "Dixired" leaves retained the highest number of microcapsules per cm^2 at each canopy height while the number of microcapsules on the upper and lower surfaces of "Glohaven" and "Redhaven" leaves was not statistically different. Unlike leaves, neither fruit surface nor canopy height had any significant effect on the microcapsule deposition on fruits of any cultivar ($F = 0.43$; $p = 0.62$ for leaf surface; $F = 2.33$; $p = 0.13$ for canopy height).

Discussion

Field studies showed that pheromone microcapsule deposits on leaves and fruits could be improved by using ULV sprays compared with the standard high volume treatment. Overall, significantly fewer moths were captured in the ULV pheromone-treated blocks than those in the high-volume. The difference in moth capture efficacy between spray application methods could be associated with significant differences in microcapsule deposition.

Turning off some spray nozzles of a conventional airblast sprayer to achieve an ULV spray appeared to be an effective and convenient approach. Reducing various spray parameters, including spray volume and pressure, increased the deposition of microcapsules. This finding is in agreement with the results of Knight and Larsen (2004) who reported improved deposition rates of codling moth sprayable pheromone on apple leaves using a low volume sprayer. However, our findings suggest that spray volume can be further reduced to ULV levels, which could provide significantly more attractive point sources than low- and high-volume sprays.

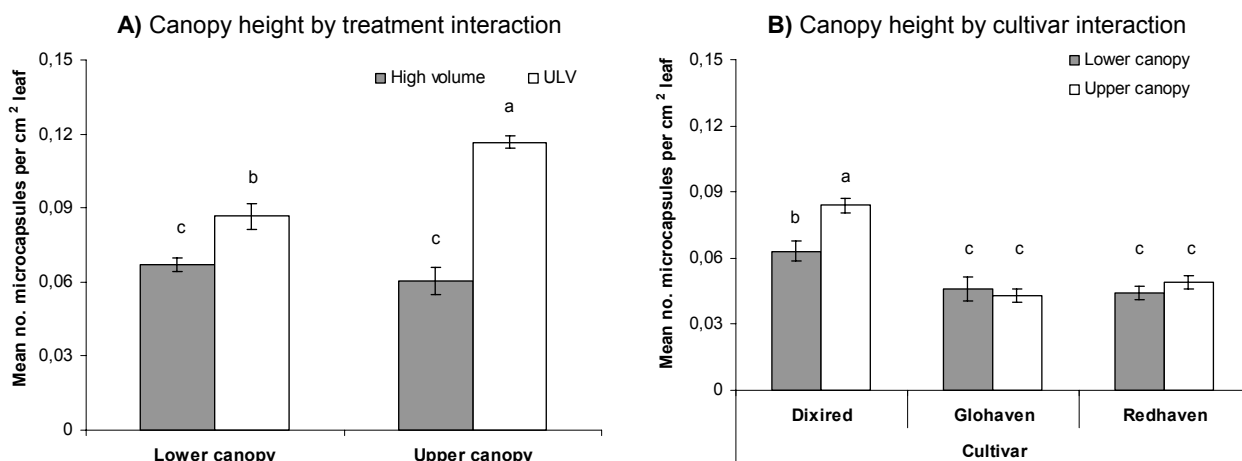


Figure 5. Mean \pm SEM number of pheromone microcapsules deposited in the upper and lower canopy of peach trees according to (A) the pheromone treatment made either in low or high-volume applications and B) cultivar, “Dixired”, “Redhaven” and “Glohaven”, averaged over locations and years in Bursa, northwestern Turkey.

The ULV treatment deposited concentrated droplets containing many clumps of microcapsules. The number of microcapsule clumps on leaves and fruits was considerably higher in the ULV treatment than the high-volume although the overall distribution of microcapsules is nonuniform. Some leaves had clumps of up to 100-250 microcapsules per leaf while others had no or few microcapsules. As suggested by Knight *et al.* (2008) for codling moth, leaves with clumps of OFM microcapsules may become attractive as individual point sources over time and aid in mating disruption by causing false trail following.

Another factor that may affect the microcapsule retention by cultivars is leaf shape (Waldstein and Gut, 2003). “Dixired” trees had lanceolate, acutely pointed leaves curved along midrib whereas the leaves of “Redhaven” and “Glohaven” trees were comparatively large and straight. Pheromone microcapsules tended to accumulate around midrib of curved “Dixired” leaves.

Microcapsule retention can also be influenced by the physicochemical and structural characteristics of the peach leaf surface such as microroughness, trichome abundance and the composition of the cuticle (Bukovac *et al.*, 1979). Waldstein and Kering (2006) attributed the difference in microcapsule abundance on “Redhaven” and “Encore” peach leaves treated with high-volume application of OFM pheromone to varying trichome abundance and cuticle structure among cultivars. These varying characteristics may cause differences in the degree of surface wetting of leaves of different peach cultivars (Boynton, 1954), which could explain the presence of higher number of microcapsules on “Dixired” leaves than the “Redhaven” and “Glohaven” leaves in this study.

Peach leaves are difficult to wet, especially on the lower (abaxial) surface, mainly due to their surface roughness (Holloway, 1969). In addition, upper (adaxial) cuticles of peach leaves are thinner and lighter (less wax) than their lower cuticles (Leece, 1976). Therefore, it is predicted that the microcapsule density would be greater on the upper surface of peach leaves. However, both surfaces of the sampled peach leaves were rather smooth and no significant differences were

found in microcapsule density between upper and lower surfaces of peach leaves. This finding is further supported by previous research that reported no significant difference between the number of microcapsules/cm² on upper and lower leaf surfaces of “Golden Delicious” apples treated with the same pheromone formulation for OFM (Waldstein and Gut, 2003).

As the mean number of microcapsules per cm² deposited on peach leaves was significantly greater than those on fruit surface, peach fruit appeared to be a more difficult target for sprayable pheromone adhesion than peach foliage. Among peach cultivars, “Dixired” fruits, which have short and dense trichomes, had significantly more microcapsules per cm² than other cultivars. No significant difference was found between “Glohaven” fruits, which are almost fuzzless, and “Redhaven” fruits with a smooth texture. Microcapsule retention of fruits seemed to be lessened as their trichome density decreased.

With the use of ULV application, sprayable pheromones can be effectively combined with insecticides and hand applied dispensers for the management of OFM on early-, mid-, and late-season peach cultivars. However, this study revealed that mixed planting of different cultivars influences the use of sprayable pheromones for mating disruption.

Conclusions

In summary, the study highlighted deficiencies in current spray application technology for sprayable pheromones. Refining spray application volumes reduced OFM catches on peaches. The ULV spray increased the mean number of microcapsules deposited, especially on leaves located in the upper canopy. Not only upper but also lower and inner canopies were more effectively targeted by the ULV application of pheromone with an airblast sprayer compared with conventional high volume sprays. However, an improved microcapsule deposition does not necessarily mean a better mating disruption and differences of microcapsule retention among cultivars should be considered in commercial peach plantings that contain a two- to three-

cultivar mixture. Further studies are needed to optimize spray parameters for ULV airblast applications of pheromone to manage OFM populations in different cultivars of other tree fruit species such as apples and pears.

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References

- BOYNTON D., 1954.- Nutrition by foliar application.- *Annual Review of Plant Physiology*, 5: 31-54.
- BUKOVAC M. J., FLORE J. A., BAKER E. A., 1979.- Peach leaf surfaces: Changes in wettability, retention, cuticular permeability, and epicuticular wax chemistry during expansion with special reference to spray application.- *Journal of the American Society of Horticultural Science*, 104: 611-617.
- CARDE R. T., MINKS A. K., 1995.- Control of moth pests by mating disruption: Successes and constraints.- *Annual Review of Entomology*, 40: 559-585.
- CRAVEDI P., MOLINARI F., 1995.- Feromoni degli insetti nella protezione dei pescheti.- *Informatore Agrario*, 51 (8): 115-121.
- HOLLOWAY P. J., 1969.- The effects of superficial wax on leaf wettability.- *Annals of Applied Biology*, 63: 145-153.
- IL'ICHEV A. L., GUT L. J., WILLIAMS D. G., HOSSAIN M. S., JERIE P. H., 2002.- Area-wide approach for improved control of oriental fruit moth *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae) by mating disruption.- *General and Applied Entomology*, 3: 7-15.
- IL'ICHEV A. L., STELINSKI L. L., WILLIAMS D. G., GUT L. J., 2006.- Sprayable microencapsulated sex pheromone formulation for mating disruption of oriental fruit moth (Lepidoptera: Tortricidae) in Australian peach and pear orchards.- *Journal of Economic Entomology*, 99: 2048-2054.
- KANGA L. H. B., PREE D. J., PLAPP JR. F. W., VAN LIER J. L., 2001.- Sex-linked altered acetylcholinesterase resistance to carbamate insecticides in adults of the oriental fruit moth, *Grapholita molesta* (Lepidoptera: Tortricidae).- *Pesticide Biochemistry and Physiology*, 71: 29-39.
- KILINCER N., KOVANCI B., 1986.- *Recherches sur la possibilité d'emploi des pheromones sexuelles dans la lutte du Carpocapse des pomes et des poires (Cydia pomonella L.), de la tordeuse Orientale du pêcher (Cydia molesta Busck), et de la teigne de pêcher (Anarsia lineatella Zeller) dans la Province de Bursa.*- Turkish Scientific and Technical Research Council, Ankara, Turkey. (In Turkish)
- KNIGHT A. L., 2000.- Applying sex pheromones - from puffers to air-blast sprayers.- *Proceedings of the Washington Horticultural Association*, 96: 161-163.
- KNIGHT A. L., LARSEN T. E., 2004.- Improved deposition and performance of a microencapsulated sex pheromone formulation for codling moth (Lepidoptera: Tortricidae) with a low volume application.- *Journal of the Entomological Society of British Columbia*, 101: 79-86.
- KNIGHT A. L., LARSON T. L., KETNER K., HILTON R., HAWKINS L., 2008.- Field evaluations of concentrated spray applications of microencapsulated sex pheromone for codling moth (Lepidoptera: Tortricidae).- *Environmental Entomology*, 37 (4): 980-989.
- KOVANCI O. B., WALGENBACH J. F., KENNEDY G. G., 2004.- Evaluation of extended-season mating disruption of the Oriental Fruit Moth *Grapholita molesta* (Busck) (Lep., Tortricidae) in apples.- *Journal of Applied Entomology*, 128: 664-669.
- KOVANCI O. B., SCHAL C., WALGENBACH J. F., KENNEDY G. G., 2005a.- Comparison of mating disruption with pesticides for management of oriental fruit moth (Lepidoptera Tortricidae) in North Carolina apple orchards.- *Journal of Economic Entomology*, 98: 248-258.
- KOVANCI O. B., WALGENBACH J. F., KENNEDY G. G., SCHAL C., 2005b.- Effects of application rate and interval on the efficacy of sprayable pheromone for mating disruption of the oriental fruit moth.- *Phytoparasitica*, 33: 334-342.
- LEECE D. R., 1976.- Composition and ultrastructure of leaf cuticles from fruit trees, relative to differential foliar absorption.- *Australian Journal of Plant Physiology*, 3: 833-847.
- MOLINARI F., CRAVEDI P., 1990.- Il metodo della confusione nella difesa contro *Cydia molesta* (Busck) e *Anarsia lineatella* Zell.- *Informatore Fitopatologico*, 40 (3): 31-36.
- RICE R. E., KIRSCH P., 1990.- Mating disruption of the oriental fruit moth in the United States, pp. 193-211. In: *Behavior-modifying chemicals for pest management: applications of pheromones and other attractants* (RIDGWAY R. L., SILVERSTEIN R. M., INSCOE M. N., Eds).- Marcel-Dekker, NY, USA.
- ROTHSCHILD G. H. L., VICKERS R. A., 1991.- The biology, ecology and control of Oriental fruit moth, pp. 389-412. In: *World crop pests. Tortricid pests: Their biology, natural enemies and control* (VAN DER GEEST L. P. S., EVENHUIS H. H., Eds).- Elsevier, Amsterdam, the Netherlands.
- SAS INSTITUTE, 2004.- *SAS/STAT 9.1 User's Guide*.- Version 8. Cary, NC, USA.
- STELINSKI L. L., GUT L., HAAS J. M., MCGHEE P., EPSTEIN D., 2007a.- Evaluation of aerosol devices for simultaneous disruption of sex pheromone communication in *Cydia pomonella* and *Grapholita molesta* (Lepidoptera: Tortricidae).- *Journal of Pest Science*, 80 (4): 225-233.
- STELINSKI L. L., MCGHEE P., HAAS M., IL'ICHEV A. L., GUT L. J., 2007b.- Sprayable microencapsulated sex pheromone formulations for mating disruption of four tortricid species: effects of application height, rate, frequency, and sticker adjuvant.- *Journal of Economic Entomology*, 100: 1360-1369.
- TRIMBLE R. M., PREE D. J., BARSZCZ E. S., CARTER N. J., 2004.- Comparison of a sprayable pheromone formulation and two hand-applied pheromone dispensers for use in the integrated control of Oriental fruit moth (Lepidoptera: Tortricidae).- *Journal of Economic Entomology*, 97: 482-489.
- USMANI K. A., SHEARER P. W., 2001.- Topical pheromone trap assays for monitoring susceptibility of male oriental fruit moth (Lepidoptera: Tortricidae) populations to azinphosmethyl in New Jersey.- *Journal of Economic Entomology*, 94: 233-239.
- WALDSTEIN D. E., GUT L. J., 2003.- Comparison of microcapsule density with various apple tissues and formulations of oriental fruit moth (Lepidoptera: Tortricidae) sprayable pheromone.- *Journal of Economic Entomology*, 96: 58-63.
- WALDSTEIN D. E., KERING M. K., 2006.- Pheromone microcapsules using various tree fruit species, cultivars, and application methods.- *Journal of Agricultural and Urban Entomology*, 23: 7-16.

Authors' addresses: Orkun Baris KOVANCI (corresponding author: baris@uludag.edu.tr), Nimet Sema GENCER, Uludag University, Department of Plant Protection, Gorukle Kampusu 16059, Bursa, Turkey; Thomas Everett LARSEN, Suterra LLC, 213 SW Columbia Street, Bend, OR 97702 USA.

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