Mating Disruption of the Oriental Beetle

Rutgers University research demonstrates the potential of using sex pheromones to disrupt mating.

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The oriental beetle, *Anomala orientalis*, is part of a complex of white grub species (Coleoptera: Scarabaeidae) that damages turfgrass throughout the northeastern United States. It has been erroneously considered a relatively minor pest until recently because the adults largely go unnoticed while the larvae of the Japanese beetle, *Popillia japonica*, and oriental beetle are indistinguishable without magnification.

The oriental beetle has become the most important white grub species in turfgrass in New Jersey, southeastern New York, Connecticut, and Rhode Island. It also is the major white grub species in ornamental nurseries and blueberries, and it causes losses in cranberries, strawberries, raspberries, peaches, and sweet potatoes. An increase in oriental beetle significance may occur in other areas where it is already established, i.e., all of coastal New England and the Middle Atlantic states, as well as Ohio, Virginia, North Carolina, South Carolina, West Virginia, and Tennessee.[6,7]

The oriental beetle has a one-year life cycle similar to that of other important white grub species. At the latitude of New Jersey, oriental beetle flight occurs from early June through early August, with peak flight activity typically in late June/early July. The adult beetles live only for about two weeks and do not cause significant damage. After mating, the females lay eggs among the roots of host plants, and the eggs hatch in two to three weeks. The first and second instar each last around three weeks, so that by mid-September the majority of the larvae are in the third instar.[6,7]

Male oriental beetle screening the air for sex pheromone.

After overwintering below the frost line, the third instars resume feeding until pupation in late spring. The extensive feeding activity of the larger larvae can kill large areas of grass from mid-August to mid-October, especially under warm, dry conditions. In addition, vertebrate predators (i.e., raccoons, opossums, skunks, crows) often damage the turf to feed on the grubs.

ORIENTAL BEETLE MATING BEHAVIOR AND CONTROL

Sex pheromone-mediated mate finding and copulation of oriental beetles occur at or near the soil surface, immediately after female emergence from the soil, close to the emergence site.[3,4,5] Males respond to female-released pheromone by a combination of flying upwind and walking short distances. Both sexes are most active between 6 and 10 pm.

Chemical insecticides are still the primary tools for white grub management. However, the implementation of the Food Quality Protection Act of 1996 (FQPA) resulted in the loss of many insecticides for white grub control. Mating disruption with sex pheromones is widely used as an environmentally safe, non-toxic alternative to broad-spectrum insecticides for several moth species.[1]

The sex pheromones of scarab beetles have been studied intensively and are used for monitoring purposes. But only recently has mating disruption technology been considered as a possibility for management of white grubs.

MATING DISRUPTION FIELD TRIALS

To determine the feasibility of mating disruption technology in turfgrass, we conducted field trials with a sprayable microencapsulated formulation of the oriental beetle sex pheromone. Two methods were used to determine the treatment effects on the mating success or oriental beetles. The first method measured the ability of oriental beetle males to locate a pheromone source similar to a female by determining the number of oriental beetle males captured in traps.

Trapping also was used to monitor oriental beetle male flight and optimize the application timing. The traps were placed in each plot in early June each year, at least 66 feet from the plot's border and any other trap. In 2002, four traps were placed per plot, and septa containing the pheromone were replaced once after four weeks. In 2003 and 2004, three traps were placed per plot, and septa were replaced twice after three weeks of use. Captured males were killed and counted.

The second method estimated oriental beetle larval densities during September, following the applications by taking 30 soil/sod cores (4.25" diam × 4" depth) with a standard golf hole cup cutter in a grid pattern at least 50 feet within the plot's border. Scarab larvae found in the cores were identified to species using the raster pattern. Field plots were situated in turfgrass areas at the Rutgers Research Station in large lawn areas and in golf course rough areas (typically between tee and fairway) in Monmouth County, N.J.

The treatment plots were broadcast sprayed once or twice with microencapsulated oriental beetle sex pheromone using locally available spray equipment. The first spray was applied about 10 days after the first oriental beetle males were captured in traps. Where applicable, a second spray was applied about 14 days after the first spray.

In 2002, one treatment was applied, consisting of two sprays of 20 g ai/acre of a formulation developed by 3M Canada Company (London, Ontario) containing 20% (Z)- and (E)-7-tetradecen-2-one at a 93:7 ratio. In 2003, two treatments were applied, consisting of one spray of 30 g ai/acre or two sprays of 5 g ai/acre of the 3M formulation. Because 3M discontinued the production of its formulation, two

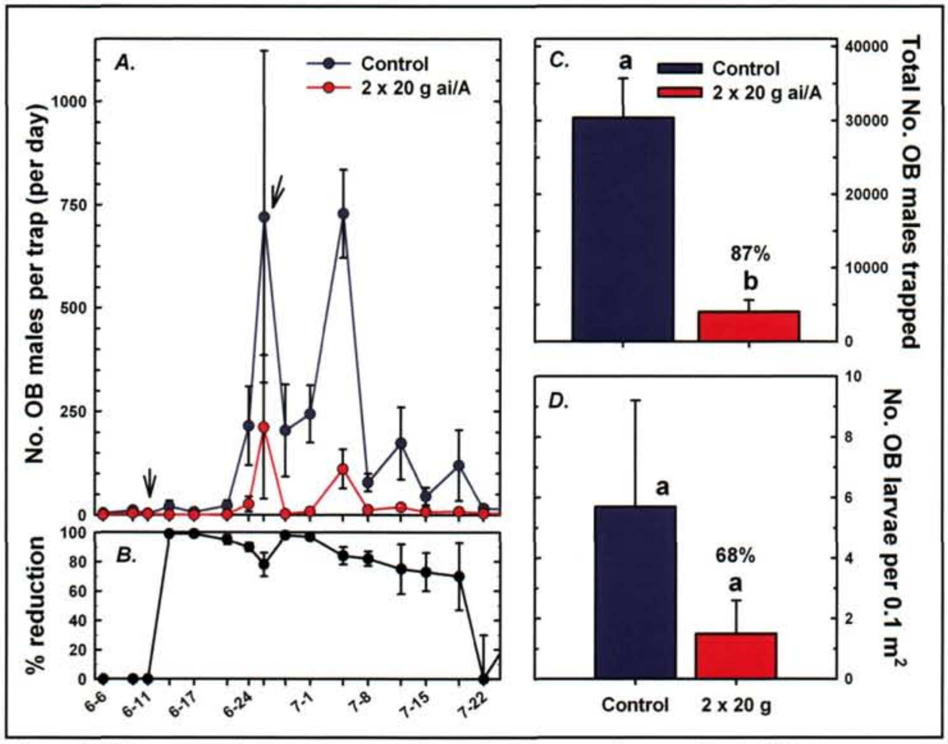

Figure 1: A) Twice-weekly male trap captures (arrows indicate application dates). B) Percentage reduction in twice-weekly trap captures. Arrows indicate pheromone application dates. C) Total seasonal trap captures. D) *A. orientalis* larval densities in September following pheromone application. C, D: means with same letter above bars are not significantly different, and figures above bars indicate percent reduction compared to control.

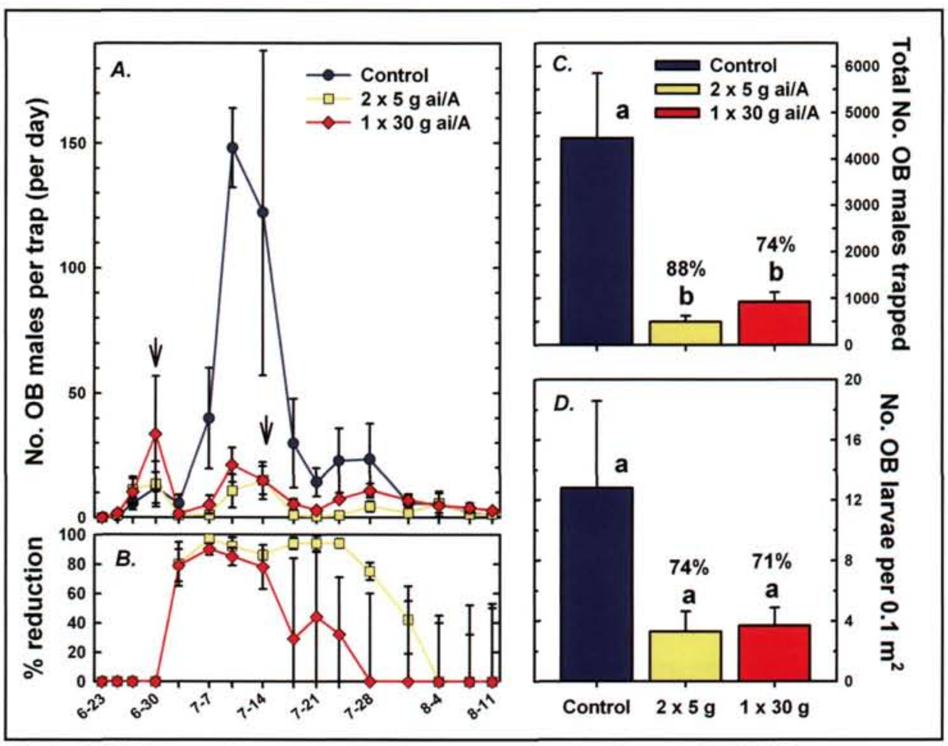

Figure 2: A) Twice-weekly male trap captures (arrows indicate application dates). B) Percentage reduction in twice-weekly trap captures. Arrows indicate pheromone application dates. C) Total seasonal trap captures. D) *A. orientalis* larval densities in September following pheromone application. C, D: means with same letter above bars are not significantly different, and figures above bars indicate percent reduction compared to control.

Suterra LLC (Bend, Ore.) formulations were used in 2004 containing 5.35% (Suterra 03) and 24.11% (Suterra 04), respectively, (Z)-7-tetradecen-2-one, both applied twice at 10 g ai/acre.

RESULTS

Mating Disruption Field Trials

In 2002, oriental beetle male flight started in the first week of June, and trap captures had two distinct peaks on June 25 and around July 5 (Figure 1A). Percent reduction in trap captures (Figure 1B) in the treated plots was 96-100% for the first week after each application, but started to drop during the second week. Total trap captures were 87% lower in the treated plots than in the control plots (Figure 1C). Oriental beetle larval densities in September were 68% lower in the treated plots than in the controls, but due to high variation in the control plots, the reduction was not statistically significant.

In 2003, oriental beetle male flight started in the last week of June after an unusually cool spring (Figure 2A). Percent reduction in trap captures (Figure 2B) in the treated plots was 96-100% for the first week after each application, but started to drop during the second week. Total trap captures were significantly lower in the 1 × 30 g ai/acre treatment (74% reduction) than in the control, and they were significantly lower in the 2 × 5 g ai/acre treatment (88% reduction) than in the 1 × 30 g ai/acre treatment (Figure 2C). Oriental beetle larval densities in September were 71-74% lower in the treated plots than in the controls, but due to high variation in the control plots, the reduction was not statistically significant (Figure 2D).

In 2004, oriental beetle male flight started in the first week of June, had an extended peak between June 17 and July 5, and continued elevated activity until about July 20. Total trap captures were significantly lower for the Suterra 03 (68% reduction) and Suterra 04 formulations (70% reduction) (both applied at 2 × 25 g ai/acre) compared to the untreated control. The effect of the pheromone started to decline in the second week after each application. Due to the high variation in larval densities, there were no significant differences among treatments.

Shoes used to walk through pheromone-treated areas one day after treatment were sufficiently contaminated with pheromone to attract high numbers of oriental beetle males in non-treated areas.

Effect of Post-Application Irrigation on Pheromone Adherence to Grass Blades

After spray application, a significant amount of oriental beetle pheromone may remain on the grass foliage, rather than drip off into the thatch and soil. Removal of grass clippings from mowing could then reduce the efficacy of the pheromone application. To determine whether post-application irrigation is necessary to wash the pheromone off the foliage and into the thatch and upper soil layers, areas were sprayed with 30 g ai/acre of the 3M formulation and overhead-irrigated with 0", ⅛", or ¼" after treatment. The grass was then cut just above the thatch surface, collected, and the pheromone extracted. The amount of pheromone in the clippings extract was determined with gas chromatography-mass spectrometry. In samples taken directly after application, significantly less pheromone was detected in clippings taken from plots watered with ⅛" and ¼" than in the non-watered plots. No pheromone could be detected in samples taken after seven days.

Adsorption of Sex Pheromones to Shoes

Oriental beetle pheromone can adsorb to surfaces with which it comes into contact, such as shoes. These can then attract male oriental beetles over an extended period of time. To test whether shoes can be contaminated with enough oriental beetle pheromone to cause a potential nuisance to golfers, one pair of athletic shoes was walked through each of the areas treated with oriental beetle pheromone, for 30 minutes at one or eight days after treatment. From each pair, one shoe was used for pheromone extraction, the other in a bioassay.

In the bioassay, the shoes were lined up on the surface of a non-pheromone treated turfgrass area in a continuous line of three groups, with each group containing one shoe from each treatment and a non-pheromone exposed shoe. Oriental beetle males were collected from the shoes for 45 minutes. No males were attracted to the control shoes. Significantly fewer males were attracted to shoes walked at eight days after treatment (average 1.8; range 0-10) compared to shoes walked at one day after treatment (average 42.3; range 6-81).

The shoe not used in the bioassay was rinsed with acetone for 10 minutes, and the amount of pheromone in the extract analyzed by gas chromatography. From shoes walked one day after treatment, 62.1 ± 15.3 μg per shoe were detected. No pheromone was detected on the shoes walked eight days after treatment or on the control shoes.

Traps containing sex pheromones are used to monitor the male oriental beetle flight pattern.

CONCLUSIONS

This study demonstrates the feasibility of mating disruption in the turfgrass system. However, the effect of the pheromone spray started to wane after about 10 days, making necessary a second application after 14 days. Due to the inherently high variability of white grub populations within and among turfgrass sites, the larval counts in our experiments, particularly in the non-treated areas, were too variable to allow for the detection of statistically significant differences. Nevertheless, the trend in the 2002 and 2003 field seasons using the 3M formulation was very consistent, with 68-74% lower oriental beetle larval populations in the treated areas.

The efficacy of mating disruption using sprayable formulations could be improved with more frequent applications, probably even with lower pheromone application rates than used in this study. However, the availability of insecticides that are highly effective and require only one seasonal application (i.e., imidacloprid, clothianidin) will limit the acceptance of mating disruption unless a formulation can be developed that is more effective and/or requires only one seasonal application. We don't believe that this goal can be achieved using microencapsulated sprayable formulations. In addition, the potential contamination of shoes and other clothing articles by the sprayable formulation and the ensuing attraction of male beetles to these articles outside of treated areas present a drawback of these formulations.

Dispersible pheromone formulations consisting of numerous broadcast small pheromone sources or fewer larger sources may solve the problems of limited persistence as well as contamination of clothing articles in the turfgrass system. Our ongoing studies with dispersible formulations suggest that mating disruption can be an effective, safe, environmentally and economically sound, easily implemented, durable, and highly IPM-compatible option for oriental beetle management in turfgrass.

LITERATURE CITED

1. Cardé, R. T., and A. K. Minks. 1995. Control of moth pests by mating disruption: successes and constraints. *Ann. Rev. Entomol.* 40:559-585.

2. Facundo, H. T., A. Zhang, P. S. Robbins, S. R. Alm, C. E. Linn, M. G. Villani, and W. L. Roelofs. 1994. Sex pheromone responses of oriental beetle (Coleoptera: Scarabaeidae). *Environ. Entomol.* 23:1508-1515.

3. Facundo, H. T. 1997. The reproductive ecology of the oriental beetle, *Exomala orientalis* (Waterhouse) (Coleoptera: Scarabaeidae). Ph.D. thesis, Cornell University, 223 pp.

4. Facundo, H. T., M. G. Villani, C. E. Linn Jr., and W. L. Roelofs. 1999. Emergence, mating, and post-mating behaviors of the oriental beetle (Coleoptera: Scarabaeidae). *J. Insect Behav.* 12:175-192.

5. Facundo, H. T., M. G. Villani, C. E. Linn Jr., and W. L. Roelofs. 1999. Temporal and spatial distribution of the oriental beetle (Coleoptera: Scarabaeidae) in a golf course environment. *Environ. Entomol.* 28:14-21.

6. Potter, D. A. 1998. Destructive turfgrass insects: biology, diagnosis, and control. Ann Arbor Press, Chelsea, Mich.

7. Vittum, P. J., M. G. Villani, and H. Tashiro. 1999. Turfgrass insects of the United States and Canada, 2nd ed. Cornell University Press, Ithaca, N.Y.

8. Zhang, A., H. T. Facundo, P. S. Robbins, R. Charleton, C. E. Linn, J. S. Hanula, M. G. Villani, and W. L. Roelofs. 1994. Identification and synthesis of the female sex pheromone of the oriental beetle, *Anomala orientalis* (Coleoptera: Scarabaeidae). *J. Chem. Ecol.* 20:2415-2427.

CONNECTING THE DOTS

A Q&A with* Albrecht Koppenhöfer, Ph.D., *associate professor and extension specialist, Rutgers University, on the mating disruption of the oriental beetle.

Q: What other crops have benefited from mating disruption technology of their insect pests? Have producers of those crops readily accepted mating disruption as a primary means of managing insect pests of those crops?

A: Mating disruption has been used for a long time in orchard systems (e.g., apples, pears, peaches) for the control of various moth species (e.g., codling moth, oriental fruit moth), but it is also used in cole crops (diamond back moth), tomatoes (tomato pinworm), and forestry (gypsy moth). Mating disruption is widely used in many of the above systems, sometimes as the primary means of controlling a pest, often as an important component of Integrated Pest Management that does not disrupt biological control and reduces the chances of development of insecticide resistance in pest species.

Q: If mating disruption technology for turf insects proves feasible, are there specific requirements for storing and using insect sex pheromones, or would they be formulated in such a way that storage conditions would not be an issue?

A: Storage of sex pheromone products should be non-problematic with similar minimum requirements as for synthetic insecticides and good shelf life.

Q: As you know, some municipalities in the U.S. and Canada have banned the use of turfgrass pesticides. Do you feel that the use of mating disruption may prove to be an acceptable alternative strategy for control of white grubs in those locations?

A: Mating disruption could certainly be an acceptable alternative to insecticides for white grub management. However, since mating disruption generally is only effective if used over larger areas (at least one acre, better for several acres), its use would have to be coordinated in a more area-wide approach for landscape situations. On golf courses this requirement should not be difficult to meet.

Q: One of the primary considerations that superintendents have in considering pest control strategies is cost, especially on golf courses with limited maintenance budgets. If mating disruption technology proves feasible in turfgrass, how do you think the cost of this strategy would compare with conventional use of insecticides?

A: On a per-acre basis, mating disruption should be cheaper than many of the newer insecticides. If used in a more area-wide approach such as on large areas of a golf course, the cost may become higher. However, it is likely lower, and with that even less expensive rate would be effective if used in larger areas.

Q: Are sex pheromones used for mating disruption federally regulated in ways similar to the ways (e.g., FIFRA, FQPA) that conventional pesticides are regulated? If not, would you expect them to be?

A: Sex pheromones are regulated by FIFRA, but the requirements are less strict than for conventional insecticides.

Q: In your opinion, what would it take for the golf course industry to accept mating disruption as a primary means to control certain insects?

A: Cost and efficacy similar to that of available synthetic insecticides. Lack of safe and/or effective synthetic insecticides would, of course, lower the bar considerably.

Jeff Nus, Ph.D., *manager, Green Section Research.*

Editor's Note: A complete report of this study can be found at *USGA Turfgrass and Environmental Research Online*: http://usgatero.msu.edu/v05/n09.pdf.

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