Disruption of Sex Pheromone Communication in the Blackheaded Fireworm in Wisconsin Cranberry Marshes by Using MSTRS™ Devices[1]

Thomas C. Baker, Timothy Dittl,[2] and Agenor Mafra-Neto[3]

Department of Entomology
Iowa State University
Ames, Iowa 50011 USA

J. Agric. Entomol. 14(4): 449–457 (October, 1997)

ABSTRACT The results of experiments in Wisconsin cranberry marshes by using a novel, controlled release system called the Metered Semiochemical Timed Release System, or MSTRS™, for disrupting pheromone-source location by males of the blackheaded fireworm, *Rhopobota naevana* (Hübner), are described. During the first flight, disruption (trap catch reduction) of males' ability to locate synthetic sex pheromone lures containing 10 µg of the *R. naevana* pheromone blend averaged 95.7% in the first grower location and 99.6% in a second grower location, regardless of the MSTRS deployment pattern. However, disruption averaged only 81.7%, 80.7%, and 56.4% for a 12 MSTRS-per-ha cross pattern, a 5 MSTRS-per-ha perimeter pattern, and a 12 MSTRS-per-ha perimeter pattern, respectively, in the third grower site. During the second flight, in which the night-only emission of pheromone was tried, disruption of trap catch averaged 86.7% in the first location overall for all MSTRS configurations, 85.4% in the second location, and 53.8% in the third and poorest disruption location. Significant levels of disruption were achieved season-long regardless of the MSTRS array, but there was no significant difference in disruption efficacy among the three arrays. No significant effect on larval infestation following the first flight was observed in the MSTRS-treated plots, but there was high sampling variability and very low infestation in the check plots, making it difficult to discern effects of MSTRS on larval populations.

KEY WORDS Sex pheromone, *Rhopobota naevana*, blackheaded fireworm, Tortricidae, mating disruption, controlled release dispensers, *Vaccinium macrocarpon*

There has been much progress over the past 10 yr or so in improving the release-rate characteristics of some of the most commercially successful pheromone mating disruption formulations. However, none of the existing controlled-release technologies allow the user to actively alter the release rate. The existing systems are

[1]Accepted for publication 18 September 1997.
[2]Ocean Spray Cranberries, Inc., P. O. Box 155, Babcock, Wisconsin 54413.
[3]Current address: Department of Entomology, Univ. of California, Riverside, California 92521.

all passive systems that emit pheromone continuously according to ambient wind and temperature conditions.

We recently described a new system called Metered Semiochemical Timed Release System, or MSTRS™ (Mafra-Neto & Baker 1996), in which an aerosol canister containing pheromone is placed in a machine and an aerosol sprayburst is emitted onto a large pad on a timed basis (e.g., every 15 min). Pheromone is then emitted from the pad at extremely high rates, ca. 20 times higher than most existing dispensers. Fewer dispensers are therefore needed for effective disruption, and pheromone is not wasted by being passively emitted from the reservoir during periods of the day when the insects are inactive. In addition, the pheromone is protected from oxidation and UV degradation because it is housed in pressurized canisters.

Significant work on mating disruption of the blackheaded fireworm, *Rhopobota naevana* (Hübner), a serious pest of cranberries (*Vaccinium macrocarpon* Aiton), has been undertaken by Fitzpatrick et al. (1995). Her work has shown much promise for using this technique for control of blackheaded fireworm by using either Shin-Etsu ropes (Pacific Biocontrol, Ltd.) or Ecogen Spirals (Scentry/Ecogen, Billings, Montana) with a total application rate of ca. 70 g of pheromone per acre. One problem with these dispensers, however, is that they must be retrieved at the end of the season due to the potential for the buildup of environmentally unacceptable levels of plastic in the cranberry marshes. The placement and retrieval of a high number of point sources on the cranberry beds also would result in unacceptably high foot traffic that would damage the delicate, slow-growing plants.

We hypothesized that a relatively few MSTRS stationed mostly around the perimeter of marshes, using the same total amount of pheromone per hectare as existing formulations tested by Fitzpatrick et al. (1995), might provide effective levels of disruption of pheromone source location that could reduce damage by the blackheaded fireworm and suppress populations of this species. We sought to begin our investigation in 1997 by first determining whether different arrays of MSTRS machines are effective in reducing captures of males in traps baited with the synthetic pheromone blend of this species to the same degree achieved by Fitzpatrick et al. (1995). We also sought to achieve levels of disruption comparable to those achieved by Fitzpatrick and colleagues during 1996 who were conducting concurrent experiments in neighboring cranberry marshes in Wisconsin (Fitzpatrick 1997).

Materials and Methods

We used MSTRS devices and affixed them to wooden stakes at a height of 20 cm above the cranberry plant canopy. The canisters contained *R. naevana* pheromone, a blend of (*Z*)-11-tetradecenyl acetate, (*Z*)-11-tetradecen-1-ol, and (*Z*)-9-dodecenyl acetate in a ratio of 9:3:1 (McDonough et al. 1987, Slessor et al. 1987). These components were purchased from Bedoukian Research, Inc., Connecticut, diluted in reagent ethanol to a weight of 40 g of solution, and formulated with propellant in the canisters for a total weight of 160 g inside each canister.

There were three MSTRS treatments (deployment patterns) plus a check in each of three grower locations within 50 km of each other near Babcock, Wisconsin. Two of the treatments used MSTRS containing 8 g of pheromone in the canisters (8-g canisters) and the third treatment used MSTRS outfitted with canisters containing 20 g of pheromone (20-g canisters). At each location, treatments were clustered such that the three plots containing MSTRS arrays occupied adjacent beds, whereas check plots that were not treated with pheromone disruptant were located at least 100 m from the MSTRS-treated beds. We hypothesized that any of the three MSTRS arrays would significantly reduce trap capture of males (pheromone source location) compared with the check plots. We also hypothesized that none of the arrays of MSTRS would be better than the others in disrupting pheromone source location.

At grower location 1, the check plot consisted of two beds having an area of 0.8 ha each for a total area of 1.6 ha. At locations 2 and 3 the check plots consisted of one bed of 1.4 ha and 1 bed of 1.7 ha, respectively. In the first MSTRS treatment, 8-g canisters were deployed at a density of 12 MSTRS per ha around the perimeter of two 0.6-ha beds at location 1, one 1.7-ha bed at location 2, and six 0.2-ha beds at location 3. The second MSTRS treatment again used 8-gm canisters and 12 MSTRS per ha, but with three of the devices transecting the center of the plot and the rest placed around the perimeter. For this treatment, at location 1 a single 0.8-ha bed was used, at location 2 a single 1.6-ha bed was used, and three 0.6-ha beds were used at location 3. The final MSTRS contained 20-g canisters and these were deployed around the perimeters of one bed of 0.8 ha at location 1, one bed of 1.5 ha at location 2, and six beds of 0.2 ha at location 3 at a density of 5 MSTRS per ha at each location.

Disruption was assessed by counting the number of males captured in wing traps (IPM Technologies, Inc., Portland, Oregon) baited with 10 µg of the pheromone blend on a rubber septum, a lure considered to be comparable in attractancy to females (Fitzpatrick 1997). The wing traps were placed, three per plot, in the interiors of the beds, and not closer than 30 m from the nearest machine. The number of males captured was assessed weekly, the males removed, and trap bottoms replaced as needed. At the end of the season, mean weekly male trap catch for each plot was calculated, and then these means were used to calculate a first-flight and second-flight mean trap catch per treatment. These means were subjected to a two-way ANOVA with three locations (complete blocks) as replicates. Means were compared using Tukey's HSD test. (Sokal & Rohlf 1981) Percent disruption in treatment plots also was calculated at each location by first dividing mean weekly male trap catch from treatment plots by mean weekly male trap catch from the check plot at the same location. This trap capture proportion relative to the check was then subtracted from 1 and multiplied by 100 to obtain the percentage reduction (disruption) of trap catch caused by the MSTRS.

Sweep samples were taken for several weeks after the first flight. Every week, a scout walked two randomly chosen straight-line transects within a given bed in each plot (one in the interior and the other near the edge) and made 100 sweeps per transect of the vegetation (one sweep per step) with a standard insect sweep net. The net was examined for blackheaded fireworm larvae that were then counted. Each week, mean larval counts per 100 sweeps

for each plot were analyzed using a two-way ANOVA with three locations (complete blocks) as replicates.

Both the check plots and the disruption plots were subject to standard grower practices of spray irrigation and applications of pesticides, including insecticides. When any of the three growers did apply pesticides, they treated both the check and the disruption plots with the same materials at the same time. The growers each made three applications of insecticide during the 1996 season. During the first flight of moths, the MSTRS were programmed to discharge every 15 min, 24 h per day. At the end of the first flight, the machines were switched off and the canisters were then all replaced because their contents were nearly depleted. In the week before the beginning of the second flight, the MSTRS were switched on again and programmed to discharge in the night-only mode, in which a light-sensor triggers them to begin discharging every 15 min only around sunset and to stop at sunrise. Discharging in this mode gave the MSTRS canisters a longevity of >75 d.

Results and Discussion

During both the first and second flights, all three MSTRS arrays caused significant disruption of pheromone source location (Table 1). However, none of the three MSTRS arrays were significantly better at disrupting pheromone source location season-long than the others (Table 1).

During the first flight, disruption averaged 95.7% in the first grower location, and 99.6% in the second grower location (Fig. 1) regardless of the MSTRS deployment pattern. However, disruption averaged only 81.7%, 80.7%, and 56.4% for the 12- dispenser-per-ha cross pattern (low cross), the 5 dispenser-per-ha perimeter pattern (high perimeter), and the 12 dispenser-per-ha perimeter pattern (low perimeter), respectively, in the third grower site (Fig. 1), which had a history of very high populations of fireworm and low yields compared with the industry average in the region.

Thus, the overall levels of disruption, averaging ca. 90% during the first flight across all three locations and all MSTRS treatments combined (Table 1), were affected by the poor disruption at the third grower location. At this third site, captures in the check plot averaged 98.9 males per trap per week over the 5-wk period from 27 June to 25 July, and 18.1 (± 11.2 SD; $n = 5$), 19.1 (± 12.8 SD; $n = 5$), and 43.1 (± 35.5 SD; $n = 5$) males per trap per week in the low-cross, high-perimeter, and low-perimeter patterns, respectively. The MSTRS at the other two grower locations during this 5-wk period resulted in high and similar levels of disruption compared with the third location. Captures in the check plots averaged 102.5 (± 68.4 SD; $n = 3$) and 52.1 (± 48.4 SD; $n = 3$) males per trap per week in location 1 and 2, respectively, whereas captures in the disruptant-treated plots (all MSTRS deployment patterns combined) in these locations averaged 4.4 (± 6.8 SD; $n = 15$) and 0.2 (± 0.3 SD; $n = 15$) males per trap per week, respectively.

For the first, second, and third grower locations the larval infestation rates were not significantly different in the MSTRS-treated plots than in the check plots following the first flight (Table 2). The check plot sweep samples were at

Table 1. Mean number (± SD) of blackheaded fireworm males captured during the first and second flights in the different MSTRS-treated and check plots from the same locations over the 1996 season in Wisconsin cranberry marshes. Data were square-root-transformed and a two-way ANOVA was conducted. Asterisks indicate significant *F* values. Means from the same flight having no letters in common are significantly different according to Tukey's HSD test ($P < 0.05$, df = 64; Sokal & Rohlf 1981).

	Mean no. of males per trap (± SD)
1st flight (13 June - 1 Aug.)	
Control	50.7 ± 58.0a
MSTRS™ low, perimeter	9.7 ± 23.1b
MSTRS™ low, cross	5.0 ± 9.2b
MSTRS™ high, perimeter	5.1 ± 10.1b
F statistics	15.3*
2nd flight (8 Aug. - 25 Sept.)	
Control	42.7 ± 45.8a
MSTRS™ low, perimeter	13.3 ± 20.6b
MSTRS™ low, cross	11.1 ± 14.3b
MSTRS™ high, perimeter	12.4 ± 17.4b
F statistics	7.9*

or near zero in most cases, and so it would be difficult to reveal any effect of the disruptant on larval density during this particular year in these beds. The apparent lack of reduction in larval populations may be due to the high variability inherent in this sampling technique due to the highly aggregated nature of the larval infestations (Fitzgerald 1997). Another factor may be the unknown level of migration of gravid females from one cranberry bed to another. An alternative way to get a more direct assessment of the efficacy of MSTRS-based disruption than using pheromone trap catch reduction would be to treat a wider area to reduce the effect of gravid female migration, and to examine freely flying females captured in disruption plots versus check plots for the presence of spermatophores. Collection of *R. naevana* females without undue foot-traffic on the beds is difficult, however.

During the second flight, in which the night-only emission of pheromone was tried, disruption was not as good as during the first flight in most plots but still

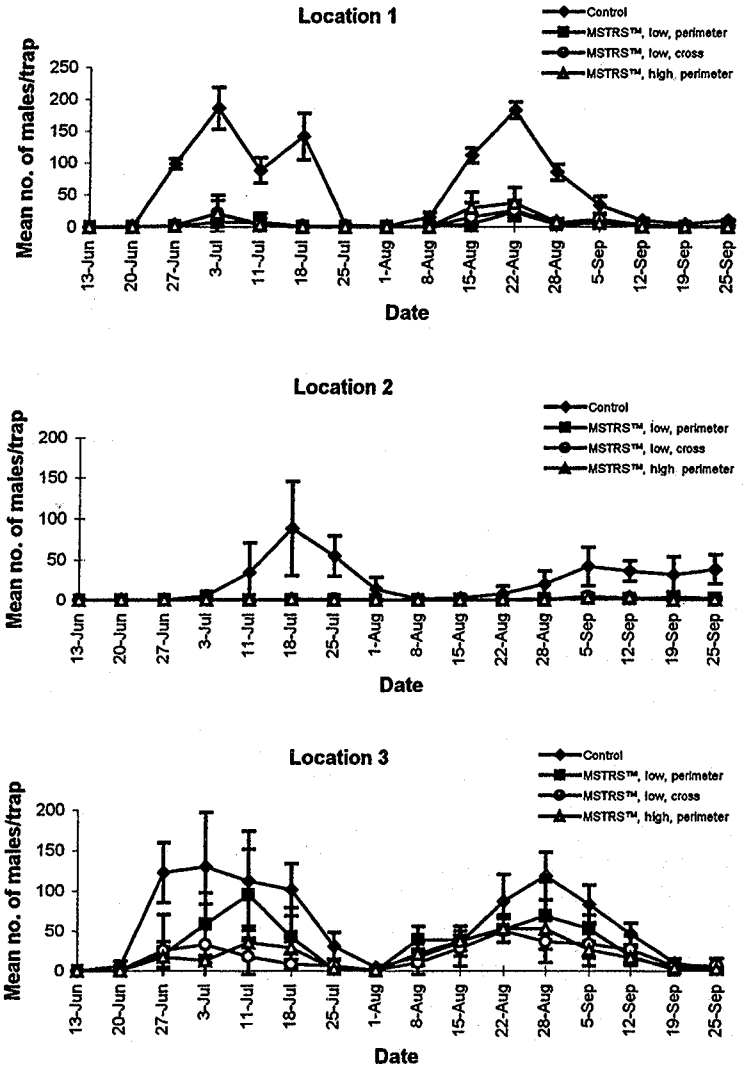

Fig. 1. Mean capture per trap (n = 3) of male blackheaded fireworm in wing traps containing 10 µg of synthetic pheromone at three locations at which either 5 (high perimeter) or 12 (low perimeter and low cross pattern) MSTRS™ devices per hectare were deployed in cranberry beds. The devices were activated before the first flight began and continued to release pheromone throughout the season (ending 25 September) from either 20-g canisters (high perimeter) or 8-g canisters (low perimenter and low cross). During the second flight, the MSTRS were programmed to release pheromone onto the pads only at night. Bars above and below the means (n = 3) indicate standard deviations.

Table 2. Mean number of blackheaded fireworm larvae (± S.D) sampled per 100 sweeps in cranberry beds following the first flight in three grower locations. These locations were the same grower locations that were used in asssessing the disruption of trap catch (Fig. 1; Table 1). There were no differences among means (insignificant *F* value for treatment mean square) following a two-way ANOVA ($F = 0.45$, df 16, $P = 0.71$). No sample was available at grower location 2 on 5 Aug. ($n = 2$).

	Date			
Treatment	15–18 July	22–25 July	29–31 July	5 Aug.
Control	2.10 ± 2.83	2.67 ± 4.02	0.0 ± 0.0	0.0 ± 0.0
MSTRS™ Low Perimeter	2.50 ± 2.78	3.10 ± 5.11	0.67 ± 1.16	0.85 ± 1.20
MSTRS™ High Perimeter	2.27 ± 2.37	3.83 ± 3.75	0.00 ± 0.00	0.0 ± 0.0
MSTRS™ Low Cross	0.60 ± 0.53	2.40 ± 2.35	0.67 ± 1.16	1.25 ±1.77

averaged 86.7% in the first location overall for all MSTRS configurations, 85.4% in the second location, and 53.8% in the third, poorest disruption location (Fig. 1). As during the first flight, capture levels in the MSTRS-treated disruption plots were significantly lower during the second flight than in the check plots (Table 1), but no MSTRS treatment produced significantly lower captures than another. The poor disruption at the third grower site (Fig. 1) was the main contributer to the relatively poor (ca. 75%) disruption averaged across all MSTRS arrays and all three sites during this flight (Table 1).

Our measurements of the emission rates from the pads during the daytime when they are not being recharged showed that after 14 d of night-only emission, the pads from the MSTRS containing canisters with 8 g of pheromone released Z11-14:Ac at 8 μg/min during the first 3 h of daylight, and then by nightfall this rate diminished to 2.5 μg/min. *Rhopobota naevana* appear to have a broad mating periodicity during daylight hours, commencing in late morning and extending to dusk (Sheila Fitzpatrick, Agriculture Canada, Agassiz, British Columbia, unpublished data). Thus, it is possible that the night-only discharge and slow diminution of emission rate from the pads during the day during the second flight may have caused the somewhat lower disruption efficacy compared with the 24-h discharge used during the first flight.

Nevertheless, our results are encouraging in this first attempt at using MSTRS on this species, in that they show that a relatively few MSTRS per hectare can, in some locations, effectively disrupt pheromone source location by *R. naevana* at levels of 95%–99% disruption for an entire flight period on ca. 1.2-ha plots consisting of several cranberry beds. The machines proved to be highly durable, and examinations of the batteries and the ability of the machines to produce sprays during the entire season showed that all but one of the machines and batteries were unimpaired and functioning perfectly all season long. This level of durability was encouraging because most of the beds were spray-irrigated and the irrigation regularly drenched the machines and pads. In addition, thunderstorms with high winds occurred in the area several times over the course of the summer and buffeted the MSTRS devices.

In all three locations, the MSTRS devices were deployed at the same time that a sprayable formulation of pheromone (microencapsulated, called MEC; Scentry/Ecogen) was applied directly to neighboring cranberry beds. Monitoring traps and lures used in the MEC plots were identical to those used in the MSTRS plots. Disruption levels achieved were 85%–93% during the first flight in MEC plots and 78%–91% during the second flight (Fitzpatrick 1997). Thus, the MSTRS gave levels of disruption of pheromone source location comparable to the sprayable formulation, and comparable to those achieved with other low-emission sources placed on the beds at ca. 1,000/ha (Fitzpatrick et al. 1995).

The geometry of deployment of such a low number of MSTRS devices per hectare is important, and it must be considered that the smaller the plot, the greater the amount of edge there is to protect relative to the interior area of crop. In principle, the MSTRS technology should work better over a very large, regularly shaped area where there will be fewer pheromone-plume-free holes along the edges. Experiments with high-emission-rate aerosol devices similar to MSTRS in California over very large areas of orchards or fields (16–256 ha) against various tortricid and noctuid species demonstrated that this type of device does indeed work very effectively over large areas (Shorey & Gerber 1996a, b; Shorey et al. 1996). A 256-ha block of tomatoes was effectively protected by a density of only one aerosol device per 13.5 ha (Shorey & Gerber 1996b). Thus, in the future, against the blackheaded fireworm on these relatively small blocks of cranberries comprising a much higher edge-to-area ratio, a slightly greater number of MSTRS should be used to fill holes that will occur along the edges of the beds, especially on the upwind side. Also, aerial transport of the pheromone plumes over multiple beds will probably be aided by deploying the devices higher up on the grassy banks of the dikes rather than lower, on the edges of the beds themselves, as was done in this study.

Finally, it must be considered that the efficacy of widely spaced dispensers such as described herein, whose plumes need to sweep for tens, and perhaps hundreds of meters horizontally over the crop canopy to both attract and habituate males sufficiently so that they are prevented from mating, will likely be more dependent upon ambient meteorological conditions than will be numerous lower-emission-rate point sources spaced only meters apart throughout the crop. This vulnerability may be accentuated for species that mate during the daytime, when adiabatic lapse rates are highest, and unstable,

rising air can potentially carry plumes from disruptant dispensers up and away from the crop canopy.

Acknowledgment

This work was supported by grants from the Wisconsin Cranberry Board, Inc., and from Ocean Spray Cranberries, Inc. (both to TCB). We thank Sheila Fitzpatrick for the use of her unpublished observations and her collaboration in setting up and conducting these field studies; Julie Todd, Allard Cossé, Simeon Wright, and Jenny Remmers for their assistance with the fireworm experiments; Henry Fadamiro and Allard Cossé for conducting the statistical analysis of the data; and Allard Cossé for assisting in the measuring of release rates from the pads and for preparing the figure and tables. Journal Paper No. J-17646 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, Project No. 3240, and supported by Hatch Act and State of Iowa funds.

References Cited

Fitzpatrick, S. M. 1997. Mating disruption: what is it and how does it work? Proc. 1997 Wisc. Cranberry Sch. 8: 1–12.

Fitzpatrick, S. M., J. T. Troubridge, C. Maurice & J. White. 1995. Initial studies of mating disruption of the blackheaded fireworm of cranberries (Lepidoptera: Tortricidae). J. Econ. Entomol. 88: 1017–1020.

Mafra-Neto, A. & T. C. Baker. 1996. Timed, metered sprays of pheromone disrupt mating of *Cadra cautella* (Lepidoptera: Pyralidae). J. Agric. Entomol. 13: 149–168.

McDonough, L. M., H. G. Davis & S. Voerman. 1987. Blackheaded fireworm: laboratory and field studies of its sex pheromone. J. Chem. Ecol. 13: 1235–1242.

Shorey, H. H. & R.G. Gerber. 1996a. Use of puffers for disruption of sex pheromone communication of codling moths (Lepidoptera: Tortricidae) in walnut orchards. Environ. Entomol. 25: 1398–1400.

———. 1996b. Disruption of pheromone communication through the use of puffers for control of beet armyworm (Lepidoptera: Noctuidae) in tomatoes. Environ. Entomol. 25: 1401–1405.

Shorey, H. H., C. B. Sisk & R. G. Gerber. 1996. Widely separated pheromone release sites for disruption of sex pheromone communication in two species of Lepidoptera. Environ. Entomol. 25: 446–451.

Slessor, K. N., J. Raine, G.G.S. King, S. J. Clements & S. A. Allan. 1987. Sex pheromone of the blackheaded fireworm, *Rhopobota naevana* (Lepidoptera: Tortricidae), a pest of cranberry. J. Chem. Ecol. 13: 1163–1170.

Sokal, R. R. & F. J. Rohlf. 1981. Biometry. W. H. Freeman & Company, San Francisco, 859 pp.