Final report

LNE97-85

Integration of behavioral, biological, and reduced-risk chemical approaches into a sustainable insect management program for cranberries

Coordinator

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Ocean Spray Cranberries Inc.
3M Canada Company
Pine Island Cranberry Co., Inc.

SARE grant

$133,179

Match

$210,000

Duration

1998 to 2001

Summary

This project proposes to develop a biorational integrated pest management program comprising disruption of mating with sex pheromones for *Sparganothis* fruitworm management, biological control of spotted fireworm, with *Trichogramma* egg parasitoids, and control of lepidopteran larvae with a reduced-risk insecticide, tebufenozide. The feasibility and cost-effectiveness of an integrated program of insect pest management involving this suite of soft insect suppression tactics have been evaluated on grower fields in New Jersey and Massachusetts. Work completed so far under this project has directly contributed towards the registration of a *Sparganothis* fruitworm mating disruption product and tebufenozide for lepidopterous pest management in cranberries.

Objectives

To develop microencapsulated formulation of E11-tetradecenyl acetate for disrupting mating in *Sparganothis* fruitworm.

To evaluate the potential of the egg parasitoid, *Trichogramma minutum*, in managing the populations of spotted fireworm.

To assess the effects of application method, rate, and pest development stage on toxicity of tebufenozide.

To compare the efficacy and cost-effectiveness of new and traditional insect management methods.

Methods

Objective 1: During the 2000 season, we initiated large-scale field trials in Massachusetts to demonstrate the feasibility of managing *Sparganothis* fruitworm with applications of microencapsulated formulation of the major sex pheromone component (*E*11-14:Ac). Eight paired field sites were set up with 16 participating growers and over 200 treated acres. The sites, averaging 26.7 acres, were paired and assigned either the treatment (pheromone) or the control (no pheromone). When *Sparganothis* moth catch began, pheromone was applied by chemigation at 25 g a.i./acre. For each treated or control bog, berry samples from 2 sq ft were removed from each treatment area and inspected for *Sparganothis* damage.

Objective 2: Work under this objective has been completed during 1998 and 1999 field seasons. No new work has been undertaken during the 2000 field season.

Objective 3: This season, we compared the residual toxicity of Confirm 2F applied with and without Latron B-1956 and Bond (sticker) against neonate larvae of *Sparganothis* fruitworm. All treatments were applied with a CO_2 pressurized tractor-drawn R&D boom sprayer. Foliage was collected from each treatment/replicate on 0, 3, 6, and 10 days following treatment application for a laboratory bioassay. Mortality was recorded 14 days after initiation of bioassay.

Objective 4: The cost-effectiveness and efficacy of mating disruption and mating disruption with Confirm 2F application was compared with a standard program of applying Lorsban 4E for the management of fruitworm pests in New Jersey. Three pairs of plots (replicates), each between 28 acres and 39 acres in size, were either treated with pheromone or with Lorsban 4E. A subset of plots (10–12 acres) that were treated with pheromone was also treated twice with Confirm 2F, on June 30 and July 8. Formulated pheromone was applied by air at 15 g a.i./acre/application on June 12 and June 30.

Results

Objective 1: Of the eight paired sites, fruit damage was lower in six pheromone-treated bogs compared with untreated bogs. At the remaining two sites, fruit damage was greater in the pheromone treated bogs. The Middle France treated area, which experienced higher damage than the untreated area, was adjacent to an untreated bog of 10 acres. This may have contributed to influx of mated females from the adjacent untreated bog, accounting for the lack of reduction in

Sparganothis damage at this site. Treated areas realized an average reduction of 4.7% (1.4% compared to 6.1%) in *Sparganothis* damage, or about $149.07/acre with current prices of $16/barrel (100 lbs of cranberries).

Objective 2: Work under this objective has been completed during 1998 and 1999 field seasons. No new work has been undertaken during the 2000 field season.

Objective 3: Addition of adjuvants, Latron B-1956, and Bond did not increase mortality of *Sparganothis* fruitworm or residual toxicity over time compared with the application of Confirm 2F alone. Larval mortality among the treatments was not significantly different at 0, 3, and 6 DAT. However, the mortality on 10 DAT was significantly lower compared with mortality on 0 DAT. The waxy nature of cranberry leaves may enhance the adsorption of the formulation, precluding the need for spreader/stickers.

Objective 4: Fruit damage was higher in bogs treated with pheromone alone. Mating disruption with Confirm 2F treatment provided nearly the same level of protection as the OP treatment. However, the cost of mating disruption with Confirm 2F treatment is expected to be $50–$60 higher per acre than OP treatments. These data suggest that *Sparganothis* fruitworm can be managed effectively with nonorganophosphate strategies. The recent decline in cranberry prices has severely constrained the adoption of more expensive alternatives.

Reported March 2001

Appendices

Change in plan of work

Initially, we planned on evaluating an IPM program that will include mating disruption for fruitworm, *Trichogramma* for spotted fireworm management, and tebufenozide for other caterpillar pest management with a standard program of using organophosphate insecticides. Because of the difficulty in deploying *Trichogramma* parasitoids in large acres and the high cost involved, we decided not to include the parasitoids in the IPM program and just go with mating disruption and tebufenozide (Confirm 2F) applications. We are currently collaborating with a company to develop an aerial application strategy for *Trichogramma* eggs in cranberries. Once we establish the feasibility of aerial applications of *Trichogramma,* we will initiate further research and development towards commercializing egg parasitoids for use in cranberries.

Resources

A completed resource form is attached for inclusion in the *SARE Resources Directory.*

Events

S. Polavarapu, 2000. "Novel, selective insect management strategies for cranberries." Cranberry Twilight meeting, May 2000, Browns Mills, NJ. About 45 attendees.

S. Polavarapu, 2000. "Confirm 2F: A novel selective insecticide for fruitworm control." Cranberry Twilight meeting series, June 2000, Chatsworth, NJ. About 45 attendees.

S. Polavarapu and D. Weber, 2000. "Evaluation of novel, selective insecticides for the management of bloom-time pests." American Cranberry Growers' Association annual summer meeting, August 2000, Chatsworth, NJ. About 60 attendees.

S. Polavarapu, 2001. "Management of cranberry insects under depressed market conditions." American Cranberry Growers' Association annual winter meeting, January 2001, Chatsworth, NJ. About 60 attendees.

S. Polavarapu, 2001. "Management of spotted fireworm with bloomtime applications of Confirm 2F. " New Jersey Ocean Spray Cranberry Growers' Workshop, March 2001. About 35 attendees.

D. Weber, 2000. "Managing *Sparganothis* in Massachusetts: Lessons from 1999"; "Fruitworm management: How do old and new tools perform?" Massachusetts Cranberry Growers' Workshops, January and March 2000. Total about 120 attendees.

D. Weber, 2000. "Managing *Sparganothis*: Lessons from 1999." New Jersey Cranberry Growers' Workshop, March 2000. About 35 attendees.

D. Weber, 2000. "Managing direct fruit pests." Wisconsin Cranberry Growers' Workshop, March 2000. About 90 attendees.

Publicity

G. W. Oliver, 1999. Mating disruption: A paradigm shift. Cranberries Magazine, May 1999, pages 6–7.
D. C. Weber, 1999. *Sparganothis*: New management options for a difficult cranberry pest. Cranberries Magazine, May 1999, pages 9–13.
D. C. Weber, 1999. Confirm: A breakthrough in caterpillar control. Cranberries Magazine, June 1999, page 15.

Potential for Mating Disruption of *Sparganothis sulfureana* (Lepidoptera: Tortricidae) in Cranberries

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ABSTRACT The feasibility of disrupting mating of *Sparganothis* fruitworm with a sprayable microencapsulated formulation of (*E*)-11-tetradecenyl acetate (*E*11–14:Ac), the major pheromone component, was evaluated in New Jersey during 1996 and 1997 seasons. In both years, application of encapsulated *E*11–14:Ac, at 25–187.5 g (AI)/ha, reduced the incidence of mating of virgin females placed in treated plots relative to those placed in control plots. Pheromone trap catches were lower in pheromone treated plots, indicating that fewer male moths were able to locate the traps in treated plots. Larval density and fruit damage were significantly lower in plots treated with 62.5, 125, or 187.5 g (AI)/ha of pheromone than in the untreated control. Air and foliage samples were collected to determine the air titers and foliage residuals of *E*11–14:Ac throughout the adult flight during 1996 and 1997. *E*11–14:Ac levels in air and foliage samples, declined sharply one wk after the pheromone application. However, detectable levels of *E*11–14:Ac were present in both air and foliage samples throughout the 3- to 4-wk period after the pheromone application. Multiple applications of pheromone at lower rates may be more effective in maintaining pheromone levels than a single dose at higher rates. These results suggest that mating disruption is a promising strategy to manage *Sparganothis* fruitworm in cranberries.

KEY WORDS *Sparganothis* fruitworm, cranberries, *Vaccinium macrocarpon*, (*E*)-11-tetradecenyl acetate

Sparganothis FRUITWORM, *Sparganothis sulfureana* (Clemens), is regarded as a major frugivorous pest of cranberries in Massachusetts, Wisconsin, and New Jersey, which together account for >90% of cranberry production in United States (Averill and Sylvia 1998, DeSmet 1998). In New Jersey, *S. sulfureana* is the most important insect pest of cranberries and is the primary target for the majority of insecticide sprays. *Sparganothis* fruitworm has two generations per year (Marucci 1953). First instars emerge from overwintering sites from early May onward in New Jersey, feed on new foliage by webbing several uprights, and develop into adults by late May–early June (Cockfield et al. 1994). The first flight period lasts 4–5 wk. Larvae of the second-generation bore into fruit and consume three to five berries during development (Beckwith 1938). The second flight begins in the first week of August, and continues for 8–10 wk. In addition to cranberries, *Sparganothis* fruitworm also feeds on blueberries, apples, and several common weed species that occur in and around cranberry bogs such as loosestrife and sweetfern (Marucci 1953, Averill and Sylvia 1998).

More than 90% of insecticide treatments in cranberries involve the use of nonselective organophosphates and carbamates (see Rice-Mahr and Moffitt 1994). The continued availability of these insecticides for use in cranberries is under a serious threat from the Food Quality Protection Act (FQPA). In addition, to the regulatory concerns from FQPA, there are several other constraints in using these insecticides in cranberries which include the following: environmental, food, and worker safety concerns; effects on nontargets such as natural enemies, pollinators, and wildlife; incompatible use patterns especially during flowering; and regulatory restrictions on residues for export to Canada and Europe. Moreover, the recent outbreaks of *Sparganothis* fruitworm populations in Massachusetts and New Jersey have been generally attributed to the gradual loss of efficacy of organophosphate insecticides as a result of over reliance on a few insecticides or the concomitant destruction of natural enemies (Beckwith 1942, Marucci and Moulter 1992, Averill and Sylvia 1998). For these reasons, it is imperative that new alternatives to the organophosphate and carbamate insecticides be developed to ensure the availability of commercially acceptable controls to manage *Sparganothis* fruitworm and other cranberry pests.

Mating disruption with sex pheromones is being developed as an environmentally safe, nontoxic alternative to broad-spectrum insecticides for several insects (see Cardé and Minks 1995), including blackheaded fireworm on cranberries (Fitzpatrick et al. 1995). Mating disruption is especially suitable for cranberries considering the high value of crop, environmental risk of current pest management methods,

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flat topography of cranberry beds, and high level of adoption of integrated pest management practice in cranberries.

In this study we evaluated the feasibility of disrupting mating of *Sparganothis* fruitworm by permeating cranberry bogs with a microencapsulated formulation of (*E*)-11-tetradecenyl acetate (*E*11–14:Ac), the major sex pheromone component (Roelofs and Comeau 1970; G.L. and S.P., unpublished data) of *Sparganothis* fruitworm. Reductions in male moth captures in pheromone or virgin female-baited traps, mating status of virgin females, fruit damage, and larval density were used to assess the potential of mating disruption to manage *Sparganothis* fruitworm in cranberries. In addition, we also monitored levels of *E*11–14:Ac in air and on foliage samples collected over a 3- to 4-wk period after the pheromone application to determine the persistence of formulated *E*11–14:Ac.

Materials and Methods

Mating Disruption Assessment Methods. Experiments were conducted during the first- and second-generation flights in 1996 and 1997 on a 500-ha cranberry farm, near Chatsworth, Burlington County, NJ. Experimental bogs were either surrounded by other cranberry bogs or adjacent to native pinelands. In all experimental plots throughout this study, mating disruption was assessed by monitoring moth captures in pheromone-baited or virgin female-baited traps and determining the incidence of mating of virgin females enclosed in cylindrical polyvinylchloride (PVC) cages (20 by 7.5 cm diameter). These PVC cages are similar in design to cone traps previously used by Steck and Bailey (1978) for monitoring, and Fitzpatrick and Troubridge (1993) for assessing mating status of enclosed virgin females. Each PVC cage had a wire-mesh cone with an opening (10 mm diameter) on each end of the cage to allow moth entry. Previous experiments determined that 10 mm diameter hole reduced the escape of *S. Sulfureana* female moths while not deterring the entry of male moths. A small plastic vial (3 by 0.5 cm diameter) was glued horizontally in the PVC cage to provide 8% sucrose solution. A Pherocon 1C trap top served as a roof over each cage. A single virgin female (two to three scotophases old) was enclosed in each cage, retrieved after three scotophases in the field and dissected to determine the mating status. The entire process was repeated 5–10 times over a 3- to 5-wk period after the pheromone application during the first- and second-generation flights of 1996 and 1997. Up to 18 PVC cages were placed in each treatment bog in two circles, 12 cages in an outer circle of 40 m diameter, and six cages in an inner circle 20 m diameter. Cages were arranged along the circumference of the circle ≈10 m apart in each circle. In each bog, four or six Pherocon 1C traps (Trécé, Salinas, CA) baited with commercially available red rubber septa (Trécé) loaded with 10 mg of *E*11–14:Ac and other proprietary pheromonal components were deployed during the first- and second-generation flights of 1996 and only during the first-generation flight in 1997 for assessing reduction in male moth captures in pheromone treated bogs relative to untreated bogs (trap shutdown). During the second-generation flight of 1997, virgin-female baited-traps were used. Traps in all experiments were checked at 3- to 4-d intervals during each flight period.

Mating Disruption Trials, 1996. Three cranberry bogs were selected for conducting this study during the first- and second-generation flights. Bogs were assigned to one of the following three treatments: (1) (*E*)-11-tetradecenyl acetate (*E*11–14:Ac) at 187.5 g (AI)/ha, (2) *E*11–14:Ac and (*E*)-11-tetradecenol (*E*11–14:OH) each at 187.5 g (AI)/ha (1:1 blend), and (3) an untreated control. *E*11–14:OH is not a sex pheromone component of *Sparganothis* fruitworm, but it is the primary sex pheromone component of the fireworm *Choristoneura parallela* (Robinson), a major cranberry pest in New Jersey (Polavarapu and Lonergan 1998). We evaluated the potential of mating disruption in both of these tortricid species with a 1:1 blend containing *E*11–14:Ac and *E*11–14:OH. However, only data on *Sparganothis* fruitworm are presented here. Treatments were separated from each other by at least 300 m. Each pheromone treatment was formulated as a sprayable microencapsulated formulation (3 M Canada, London, Ontario) by a proprietary process ("Phase I" formulation) containing 20% (AI) by weight. Treatments were applied at the beginning of adult flight by fixed-wing aircraft in 94.6 liters of water per hectare on 10 June during the first-generation flight and on 6 August during the second-generation. The three treatments were repeated during the second-generation flight in the same plots. The size of the cranberry bogs for *E*11–14:Ac, *E*11–14:Ac+ *E*11–14:OH, and the untreated control treatments were 0.8, 1.2, and 1.0 ha, respectively.

Mating Disruption Trials, 1997. During the first-generation flight, *E*11–14:Ac applications at 62.5, 125, and 187.5 g (AI)/ha and an untreated control were evaluated on four cranberry bogs each measuring 1.1, 1.1, 1.2, and 1.0 ha, respectively. Bogs were separated from each other by at least 500 m. The treatments were applied by air on 15 June in 94.6 liters/ha. *E*11–14:Ac in 1997 was formulated in the same manner as in 1996. In addition to assessing trap shutdown and reduction in mating of virgin females, in each treatment we also measured fruit damage and larval density by sampling fruit from randomly selected 15 by 15-cm areas (n = 120, 30 samples from each quadrant). A prepollination treatment with an organophosphate was made targeting spotted fireworm and *Sparganothis* fruitworm during the second week of May on all treatment bogs before the pheromone application. None of the bogs received an insecticide treatment after the pheromone application. However, fertilizers and fungicides were applied to all experimental bogs in the same manner, as part of regular crop management program.

During the second-generation flight in 1997, we evaluated *E*11–14:Ac applications at 25, 62.5, and 187.5 g (AI)/ha. A lower pheromone rate (25 g [AI]) was evaluated to further optimize the rate at which mating can be disrupted. Formulated *E*11–14:Ac was applied

Table 1. Pheromone trap catches (mean ± SE) and percentage of mated females of *Sparganothis* fruitworm moths enclosed in PVC cages during the first- and second-generation flights, 1996

Generation	Treatment	Male moths/trap	DI	% mating[a]	n
First	E11-14:Ac	4.2 ± 1.1	83.2	0.0b	38
	E11-14:Ac + E11-14:OH	4.5 ± 0.5	81.9	3.9b	51
	Untreated	24.8 ± 2.6	—	87.8a	41
Second	E11-14:Ac	8.8 ± 2.6	82.1	24.5c	147
	E11-14:Ac + E11-14:OH	11.3 ± 1.8	76.9	14.0b	143
	Untreated	48.8 ± 9.5	—	74.8a	151

DI, disruption index, calculated using (C-T/C)*100, where C = mean trap catches in control, T = mean trap catches in treatment.
[a] Chi-square contingency table analysis; numbers within a column and generation followed by different letters are significantly different ($P < 0.05$).

by air on 30 August in 94.6 liters/ha, approximately 3 wk after the onset of the adult flight. All treatments were replicated twice. The size of the cranberry bogs for 25, 62.5, 187.5 g (AI)/ha, and untreated control were 0.8 and 1.1, 1.6 and 1.1, 1.0 and 2.1, and 1.3 and 1.6 ha for each of the two replications, respectively. Different bogs than the ones used in the first-generation were treated in the second-generation with the exception of the 1.0-ha bog that was used as control during the first-generation. Larval density or fruit damage was not assessed because the first instars after the adult flight in this generation enter diapause and are difficult to sample.

Monitoring *E*11–14:Ac Levels in Air and on Foliage Samples. Air and foliage samples were collected during the first- and second-generation flights of 1996 and the first-generation flight of 1997. In the case of air sampling, a rotary vane vacuum pump (Cole Parmer, Vernon Hills, IL) was calibrated to draw 2 m^3 of air through a glass-column (3 by 20 cm) containing 25 g of Supelpak 2B adsorbent (Supelco, Belefonte, PA). Samples were collected over a 2-h period between 1900 and 2200 hours, close to the period of peak female calling and mating (S.P. and G.L., unpublished data). From each pheromone-treated plot, two to four air samples were collected per sampling date. Samples from all plots were collected over the same 2-h period at foliage level and were at least 20 m apart within the same plot. Foliage samples were collected from two, 6-point transects through each plot at 5- to 7-d intervals. Approximately 10 g of foliage (leaves and stems from 8–9 cm long uprights) was collected at each sampling location. Air and foliage samples were stored at −10°C until sample analysis.

The Supelpac 2B adsorbent used for air collections was extracted three times with 30 ml of dichloromethane (HPLC grade), the combined washes concentrated first under vacuum and then under N_2 to 1 ml. One gram of cranberry foliage was removed from each sample of vines and air dried for 1 h to remove excess moisture. The leaves were extracted twice with 5 ml of dichloromethane, and the combined washes concentrated under N_2 to 1 ml. Samples were dried with sodium sulfate and some samples further purified by silica gel clean-up before analysis.

The air and foliage samples were analyzed by GC-FID when levels of active ingredient were sufficiently high (ppm) or by GC-EAD for low level (ppb) detection. The GC-FID analysis was conducted on a Hewlett–Packard 5890 gas chromatograph, with a 30 m, 0.53 i.d capillary column (Supelcowax 10). The GC-EAD analysis was conducted on a Varian 6000 GC with a 30 m, 0.53 i.d capillary column (Supelcowax 10) with the effluent split and delivered equally and simultaneously to the FID and EAD detectors. Each antenna detector was subjected to a 3-point standard calibration (usually 0.1, 0.01, and 0.001 ppm standards of *E*11–14:Ac) with occasional single standard recalibration over the life of the antenna (2–3 h). The pheromone quantification of the individual samples was estimated by reference to the standard calibration.

Data Analyses. Data on mating status of virgin females were subjected to chi-square contingency table analyses. To assess reduction in trap captures, a disruption index (DI) was calculated using DI = (C-T/C)*100, where C = average moth capture per trap in control plot, and T = average moth capture per trap in treatment plot. Analysis of variance (ANOVA) procedures were conducted on trap catches (when treatments were replicated), larval density and fruit damage (SAS Institute 1990). Data were transformed before analysis using either square root (trap captures and larval density) or arcsine (percentage fruit damage) transformations. Means were separated using Duncan's multiple range or least significant means (LSMEANS) tests.

Results

Mating Disruption Trials, 1996. Overall, trap captures in pheromone-baited traps in the two bogs treated with *E*11–14:Ac and *E*11–14:Ac+*E*11–14:OH were 76.9–83.2% lower than those in the untreated bog (Table 1) during the first- and second-generation flights. Over the 4-wk duration of the experiments in each of the two generations, trap captures remained consistently lower in the pheromone-treated plots than in the untreated bog (Fig. 1 A and C). Trap captures were nearly twofold higher in the second-generation than in the first-generation. During the first-generation flight, mating status of females enclosed in PVC cages differed among treatments ($\chi^2 = 99.5$, df = 2, $P < 0.001$) with significantly fewer females mated after 3-d exposure in the treated bogs than in untreated control bog (Table 1). The differences in

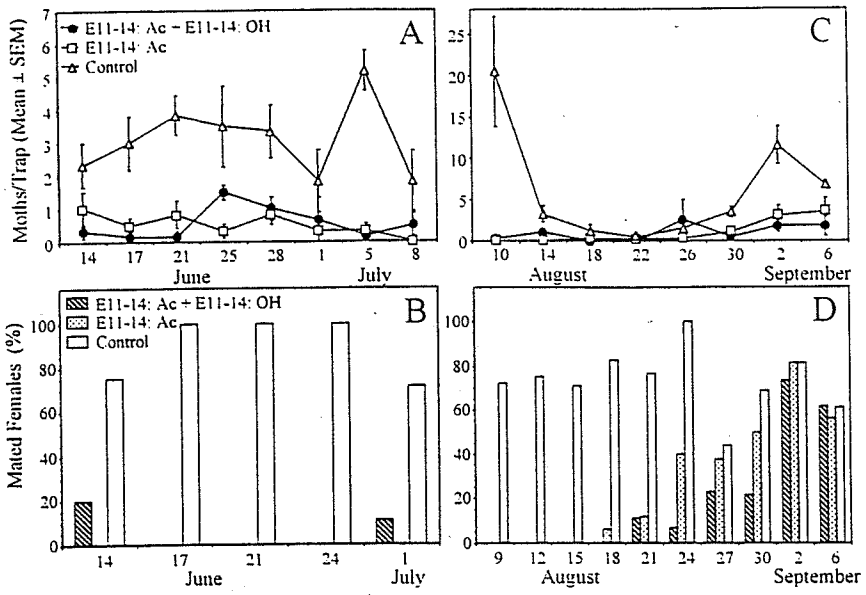

Fig. 1. Male moth catches (mean ± SE) in pheromone traps and percentage of mated females enclosed in PVC cages during the first-generation (A and B), and second-generation flights of 1996, respectively (C and D), in bogs treated with (*E*)-11-tetradecenyl acetate or a mixture of (*E*)-11-tetradecenyl acetate + (*E*)-11-tetradecenol, and an untreated control.

the number of mated females were not significant between the bog treated with *E*11–14:Ac alone compared with the bog treated with a 1:1 mixture of *E*11–14:Ac+*E*11–14:OH. More than 70% of the females were found mated in the untreated bog compared to <20% mated females in the two pheromone treated bogs on each of the five sampling periods during the first-generation (Fig. 1B). Mating status of females enclosed in PVC cages also differed among bogs during the second-generation ($\chi^2 = 132.9$, df = 2, $P < 0.001$) with significantly fewer females mated in the two pheromone-treated bogs than in untreated bog (Table 1). However, significantly higher ($\chi^2 = 5.1$, df = 1, $P = 0.023$) number of moths were found mated in the bog treated with *E*11–14:Ac+*E*11–14:OH compared with the bog treated with *E*11–14:Ac alone (Table 1). The effect of pheromone application on mating disruption appeared to decrease toward the end of the third week after the pheromone application (Fig. 1 C and D).

Mating Disruption Trials, 1997. During the first-generation flight, male moth counts in pheromone-baited traps in the bogs treated with *E*11–14:Ac at 62.5, 125, and 187.5 g (AI)/ha were 91.5–98.9% lower than T2 in the untreated control bog (Table 2). The reduction in trap captures was not dose-dependent. Numbers of females found mated in PVC cages also differed among treatments ($\chi^2 = 142.6$, df = 3, $P < 0.001$) with significantly less mating in the three treated bogs relative to the control bog (Table 2). Trap captures and female mating appeared to be affected for the entire 4-wk test period irrespective of the pheromone rate applied F2 (Fig. 2). The numbers of mated females were not significantly different among the three pheromone rates ($P = 0.31$).

Fruit damage and larval density were significantly different among the treatments (fruit damage, $F = 32.0$; df = 3, 470; $P < 0.0001$; larval density, $F = 41.1$; df = 3, 470; $P < 0.0001$) with significantly greater fruit damage and larval density in the untreated bog than in the three bogs treated with 62.5, 125, or 187.5 g (AI)/ha (Fig. 3). Fruit damage and larval density were F3 higher in the 125-g treatment than in either the 62.5- or 187.5-g treatment, paralleling the slightly higher trap catches and mating observed in this treatment compared with the other two treatments (Table 2).

During the second-generation of 1997, moth catches in virgin female-baited traps differed among treatments ($F = 140.82$; df = 3, 24; $P < 0.0001$) and were 79.7–99.5% lower in pheromone-treated bogs than in the untreated control bogs (Table 3). The T3 differences in trap counts between the two replicates were not significant ($F = 0.39$; df = 1, 24; $P = 0.5360$).

Table 2. Male moth catches (mean ± SE) in pheromone-baited traps and percentage of mated females enclosed in PVC cages during the first-generation flight, 1997

*E*11-14:Ac (g[AI]/ha)	Male moths/trap	DI	% mating[a]	*n*
62.5	1.0 ± 0.4	98.9	4.3a	69
125.0	8.0 ± 2.7	91.5	10.6a	66
187.5	1.8 ± 0.6	98.1	5.6a	71
Untreated	93.8 ± 12.5	—	78.3b	69

DI, disruption index, calculated as in Table 1.

[a] Chi-square contingency table analyses; numbers within a column followed by different letters are significantly different ($P < 0.001$).

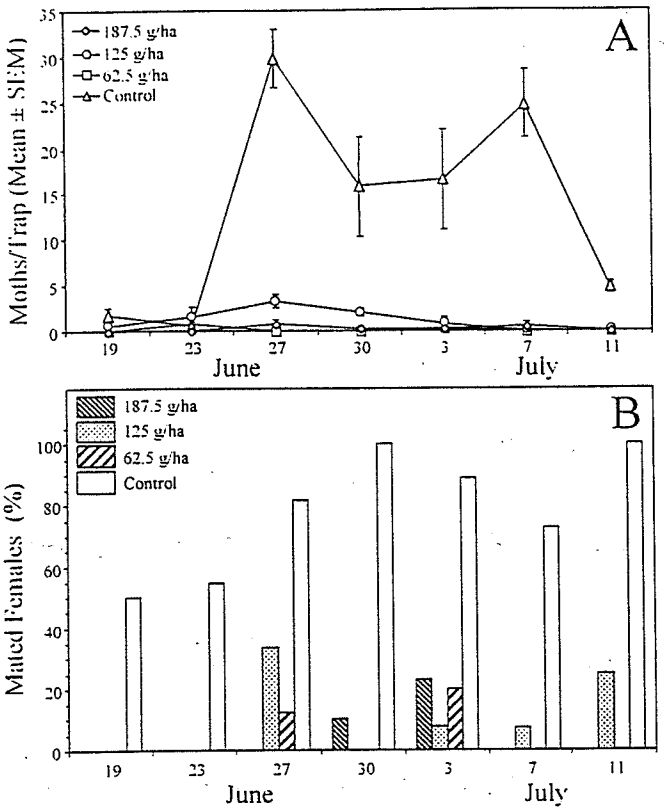

Fig. 2. Male moth catches (mean ± SE) (A), and percentage of mated females enclosed in PVC cages (B) during the first-generation flight, 1997, in bogs treated with (*E*)-11-tetradecenyl acetate at 62.5, 125, and 187. 5 g (AI)/ha.

The interaction between treatment and replicate was also not significant ($F = 2.19$; df = 3, 24; $P = 0.1155$). Again, the number of females mating in PVC cages differed among treatments (replicate 1, $\chi^2 = 157.4$; df = 3; $P < 0.001$; and replicate 2, $\chi^2 = 102.5$; df = 3; $P < 0.001$) with fewer mated in the treated bogs than

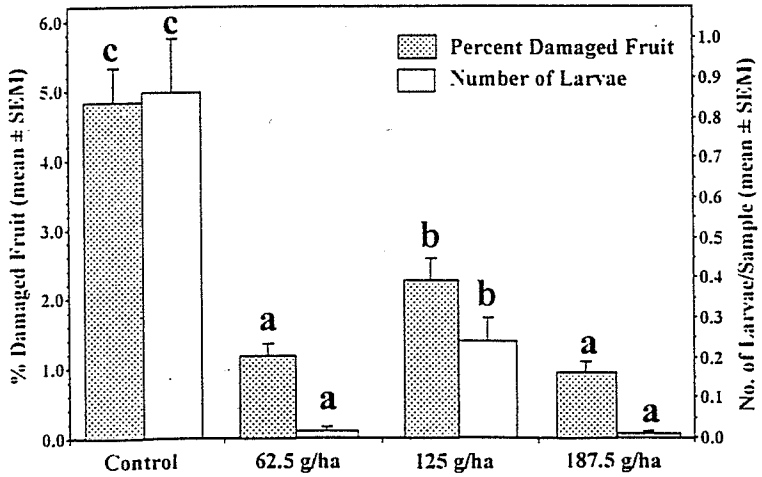

Fig. 3. Number of larvae and percentage damaged berries (mean ± SE) in a 15 by 15-cm area, in bogs treated with (*E*)-11-tetradecenyl acetate at 62.5, 125, and 187. 5 g (AI)/ha, and an untreated control, 1997. Bars within a category with similar letters are not significantly different at the $P = 0.05$ level based on ANOVA and LSMEANS tests.

Table 3. Male moth catches (mean ± SE) in virgin female-baited traps, and % of mated females enclosed in PVC cages during the second-generation flight of 1997

Replicate	*E*11-14:Ac (g[AI]/ha)	Male moths/trap	DI	% mating[a]	*n*
1	25	0.5 ± 0.3b	99.5	3.1a	65
	62.5	8.5 ± 2.7c	91.9	22.5b	71
	187.5	2.8 ± 0.5b	97.4	4.7a	64
	Untreated	105.5 ± 8.2a	—	88.7c	71
2	25	2.0 ± 0.7b	97.8	7.6a	66
	62.5	18.5 ± 4.9c	79.7	23.1b	65
	187.5	2.0 ± 1.1b	97.8	2.6a	77
	Untreated	91.3 ± 18.6a	—	70.3c	64

Means for the same replicate within a column followed by different letters are significantly different (Duncan's multiple range test, $P = 0.05$). DI, Disruption Index calculated as in Table 1.

[a] Chi-square contingency table analysis; numbers within a column for the same replicate followed by different letters are significantly different ($P < 0.05$).

in the respective untreated bog (Table 3). Regardless of the pheromone rate applied, trap captures and female mating indicated higher levels of mating disruption during the first 2 wk (1–14 September) after the pheromone application (Fig. 4) than in the later 2 wk (15–26 September). Trap captures and percent female mating in both the 62.5-g replicates were significantly greater than either in the 25-g or the 187.5-g replicates; reasons for this anomaly are not clear.

*E*11–14:Ac Levels in Air and on Foliage Samples. Detectable levels of *E*11–14:Ac were present in all air samples collected over the 3- to 4-wk period after the pheromone application in both treated plots during the first- and second-generation flights in 1996 (Fig. 5). *E*11–14:Ac levels were generally higher in the second-generation than in the first-generation. *E*11–14:Ac levels declined very sharply in the first 7–10 d after the pheromone application.

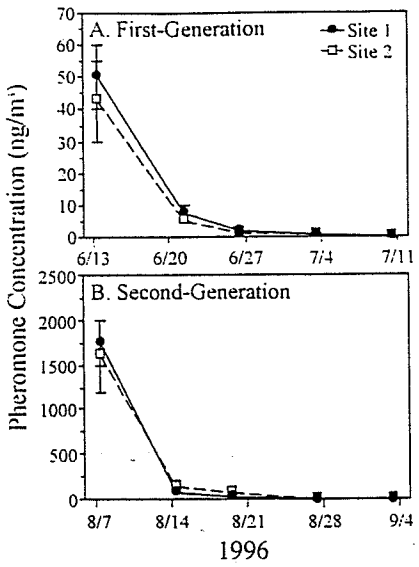

Fig. 5. (*E*)-11-tetradecenyl acetate levels in air samples collected from bogs treated with (*E*)-11-tetradecenyl acetate alone at 187.5 g (AI)/ha (site 1) or a 1:1 mixture of (*E*)-11-tetradecenyl acetate + (*E*)-11-tetradecenol (site 2) each at 187.5 g (AI)/ha, during the first- (A) and second-generation flights (B) in 1996.

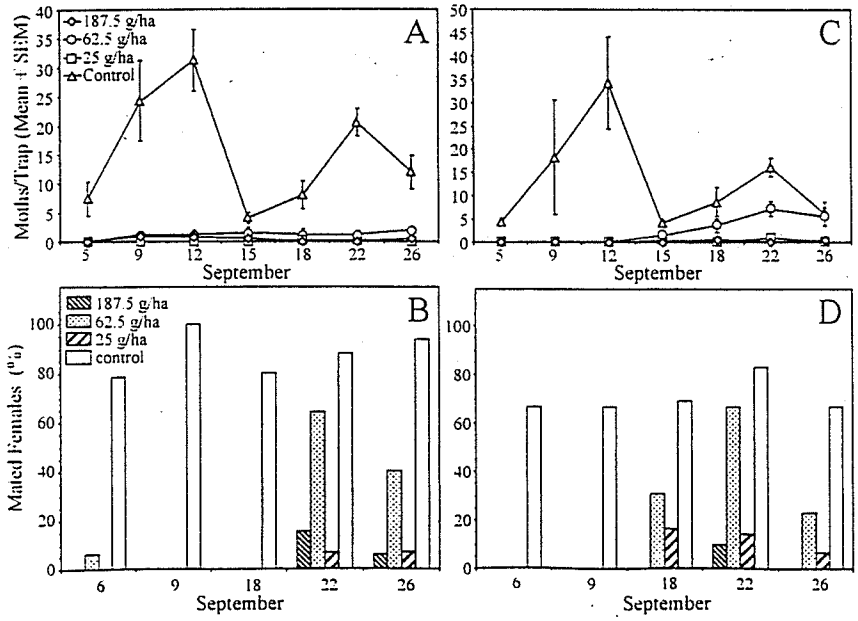

Fig. 4. Male moth catches (mean ± SE) and percentage of mated females enclosed in PVC cages among bogs treated with (*E*)-11-tetradecenyl acetate at 25, 62.5, and 187.5 g (AI)/ha, during the second-generation flight, 1997. Data for replicate 1 (A and B) and 2 (C and D) are presented separately.

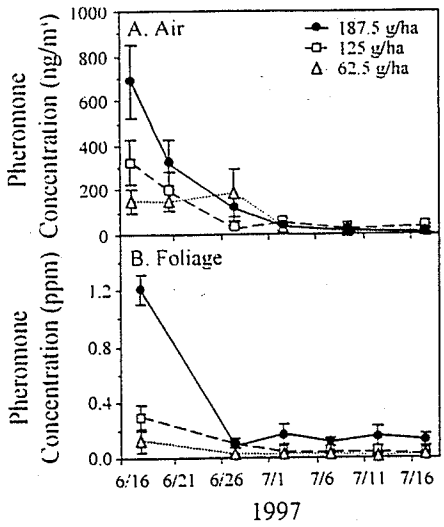

Fig. 6. (*E*)-11-tetradecenyl acetate levels in air and foliage samples collected from bogs treated with (*E*)-11-tetradecenyl acetate at 62.5, 125, and 187. 5 g (AI)/ha, during the first-generation flight of 1997.

During the first-generation flight of 1997, air titers of *E*11–14:Ac were relatively high (100–400 ng/m^3) in the first week after the pheromone application at 62.5, 125, and 187.5 g (AI)/ha rates (Fig. 6A). Detectable levels were present over the entire experimental period (≈4 wk) but at much diminished levels toward the end of the 4-wk period. Foliar levels of pheromone in all treatments decreased by at least a factor of 10 over the 4-wk monitoring period (Fig. 6B). The greatest pheromone losses occurred during the first week after the pheromone application, however, measurable amounts were still present in most of the foliage samples at the end of the fourth week.

Discussion

Application of microencapsulated *E*11–14:Ac at 25–187.5 g (AI)/ha appears to have a strong effect in disrupting communication between male and female *Sparganothis* fruitworm moths. During both years of study, male moth catches in pheromone- or virgin female-baited traps and the numbers of mated females in all pheromone treated plots were significantly lower than in the control bogs. These data indicate that mating disruption for managing *Sparganothis* fruitworm is technically feasible with the application of just the major pheromone component, *E*11–14:Ac alone.

The addition of *E*11–14:OH did not appear to affect the efficacy of *E*11–14:Ac. This is hardly surprising considering that *E*11–14:OH is not a pheromonal component of *Sparganothis* fruitworm. Therefore, it may be feasible to disrupt mating of both the fireworm *C. parallela* and the *Sparganothis* fruitworm with a 1:1 blend containing *E*11–14:OH and *E*11–14:Ac, the respective major pheromone components of both these species.

Pheromone applications at the lower rates were found to be as effective as treatments applied at 3–7.5 times higher during the first- and second-generation flights of 1997. No clear dose-dependent response was observed. This unusual result may be because of differences in relative population densities among these bogs. Although every effort was made to select bogs with similar population densities for these experiments, it is often difficult to find bogs that have identical population densities. It is also possible that the steep decline in pheromone (see below) levels observed during the first 7–10 d after the pheromone application, regardless of the application rate, may preclude any dose-dependent response.

Our data suggest that there was a 100-fold difference in air pheromone levels at the start of the tests relative to those at the completion. Whether the subsequent reductions are due only to lower pheromone release from the microcapsules or in addition to loss of formulation from the foliage is not clear. Laboratory studies have indicated that 30–40% of the formulation can be washed off the foliage under simulated heavy rain conditions (G.L., unpublished data). It is possible that microcapsules washed off the foliage are subjected to quicker degradation by lower pH of cranberry soils or microbial degradation. This may, in part, account for the sharp reduction in *E*11–14:Ac levels in air and foliage samples 1 wk after the pheromone application.

The fruit damage sustained in the mating disruption plots was around 1–2%, which is comparable to the currently available alternatives. This level of protection provided by mating disruption is commercially acceptable. However, the cost of the formulated pheromone even at the lowest rate tested may be two to three times higher than most of the organophosphate options. Formulation improvements targeted to improve pheromone release rate characteristics can reduce the amount of active ingredients required to sustain mating disruption and further improve the cost effectiveness of this technology.

Regardless of the application rate evaluated, single application of *E*11–14:Ac appears to disrupt mating for at least 2 wk after the application, and in some instances mating disruption appears to breakdown beginning the third week after spray. This is particularly evident, during the second-generation flights of 1996 and 1997. Virgin female moths enclosed in PVC cages did not mate during most of the first 2 wk after pheromone application (Figs. 1D and 4 B and D). However, mating increased in all treatments beginning the third week after the pheromone application, suggesting a reduction in mating disruption efficacy.

These results suggest that a single application of *E*11–14:Ac at 25–187.5 g (AI)/ha can significantly disrupt communication in *Sparganothis* fruitworm at least over a 2-wk period. Considering the rapid decrease in pheromone levels in air and foliage samples, multiple applications of the encapsulated formulation at 2-wk intervals at low rates (15–20 g (AI)/ha) may be an

effective strategy to maintain high levels of pheromone titer throughout the adult flight period. However, it is important to note that the relatively low pheromone levels in the third and fourth week after pheromone application were still sufficient in some cases for having a behavioral impact. Further research is required to determine the effect of application method (aerial versus ground) and application strategy (number and frequency of applications) on the efficacy of mating disruption.

Acknowledgments

Technical assistance of Elizabeth Bender and Rob Holdcraft in rearing moths for this project is gratefully acknowledged. Our sincere thanks to Richard Trout and Robert Berk for assistance with statistical analyses. Special thanks to Robin Stuart for reviewing an earlier version of the manuscript. We thank USDA-Northeast SARE program, Ocean Spray Cranberries, Inc., 3 M Canada Company, IR-4 biopesticide program, New Jersey Blueberry and Cranberry Research Council, Wisconsin Cranberry Board, and the Cranberry Institute for partially funding these studies.

References Cited

Averill, A. L., and M. M. Sylvia. 1998. Cranberry insects of the northeast. University of Massachusetts Extension, Amherst, MA.

Beckwith, C. S. 1938. Sparganothis sulfureana Clem., a cranberry pest in New Jersey. J. Econ. Entomol. 31: 253–256.

Beckwith, C. S. 1942. The false yellowhead fireworm, pp. 23–25. Proceedings, 72nd American Cranberry Growers' Association, January.

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

Cockfield, S. D., S. L. Butkewich, K. S. Samoil, and D. L. Mahr. 1994. Forecasting the flight activity of *Sparganothis sulfureana* (Lepidoptera: Tortricidae) in cranberries. J. Econ. Entomol. 87: 193–196.

DeSmet, R. 1998. Cranberry statistics. New Jersey Agricultural Statistics Service, Trenton, NJ.

Fitzpatrick, S. M., and J. T. Troubridge. 1993. A modified live-trap for assessing mating disruption of Microlepidoptera. Can. Entomol. 125: 1135–1136.

Fitzpatrick, S. M., J. T. Troubridge, C. Maurice, and J. White. 1995. Initial studies of mating disruption of the blackheaded fireworm of cranberries (Lepidoptera: Tortricidae). J. Econ. Entomol. 88: 1017–1023.

Marucci, P. E. 1953. The sparganothis fruitworm in New Jersey, pp. 6–13. Proceedings, 83rd American Cranberry Growers' Association Meeting, January.

Marucci, P. E., and H. J. Moulter. 1992. Biological control of *Sparganothis* fruitworm on cranberries in New Jersey: Part I. Cranberries Mag. 56: 14–15.

Polavarapu, S., and G. C. Lonergan. 1998. Sex pheromone of *Choristoneura parallela* (Lepidoptera: Tortricidae): components and development of a pheromone lure for population monitoring. Environ. Entomol. 27: 1242–1249.

Rice-Mahr, S. E., and L. J. Moffitt. 1994. Biologic and economic assessment of pesticide usage on cranberry. USDA Nat. Agric. Pestic. Impact Assessment Prog. Rep. 2-CA-94.

Roelofs, W. L., and A. Comeau. 1970. Lepidopterous sex attractants discovered by field screening tests. J. Econ. Entomol. 63: 969–970.

SAS Institute. 1990. SAS/STAT user's guide for personal computers. SAS Institute, Cary, NC.

Steck, W., and B. K. Bailey. 1978. Pheromone traps for moths: evaluation of cone trap designs and design parameters. Environ. Entomol. 7: 449–455.

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CONFIRM:
A Breakthrough in Caterpillar Control

by Donald C. Weber
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The first new regular US cranberry insecticide registration in ten years has been granted by the US federal EPA to tebufenozide (Confirm®2F), a selective insect growth regulator with broad activity against lepidopteran pests. The compound is a reduced-risk biorational safe for bees, birds, and fish, as well as handlers. The registrant, Rohm & Haas, will be issuing a label for rapid registration in the various cranberry-growing states.

This new registration represents the fruit of the cranberry industry's pursuit of reduced-risk registration, and a real off-the-shelf technology for growers to use in 1999, at only slightly higher cost per acre than conventional insecticides. Partners in this effort include growers associations, Ocean Spray, the Cranberry Institute, Rutgers University, Washington State University, University of Massachusetts, Rohm & Haas, and the IR4 project.

Analytic work as well as field trials for the Pacific Northwest region were performed in Canada, in support of both US and Canadian registrations of Confirm. Registration is now pending in Canadian cranberries with an URMULE (User-Requested Minor-use Label Extension) request submitted by the Pacific Agricultural Research Centre of Agriculture and Agri-Food Canada in Agassiz, British Columbia, to the Pest Management Regulatory Agency (PMRA) in Ottawa. At a recent meeting in Ottawa, Minor Use Coordinator Douglas Rothwell expressed optimism that the URMULE would receive rapid review.

Tebufenozide, the active ingredient of Confirm®2F, mimics the action of the natural insect hormone 20-hydroxyecdysone, the physiological inducer of the molting and metamorphosis process in insects. Tebufenozide is an IGR – insect growth regulator – because it regulates the molting process. More specifically, it is a MAC – molt accelerating compound. Tebufenozide controls lepidopterous larvae through a novel mode-of-action by the induction of a premature lethal molt which initiates within hours of ingestion of treated crop surfaces.

The activity is primarily through ingestion, so that toxicity is dependent on the feeding behavior of the target pest, and thorough coverage of the treated plants. Unlike some Bt's, which are also stomach poisons, tebufenozide is more persistent on foliage, as long as it is allowed to dry on before rain or irrigation. When caterpillars ingest tebufenozide, actual death will take several days to occur although feeding by the insects generally ceases within 24 hours of ingestion.

Tebufenozide is highly active against most lepidopterous larvae while having practically no activity at typical use-rates against other orders of insects. This selectivity allows for the conservation of beneficial and predatory insects which is a key element in suppression of most cranberry pests.

Confirm performance has been excellent in several field trials against blackheaded fireworm. *Sparganothis* larvae are also very sensitive, although in the post-bloom fruit-feeding generation, growers and researchers are planning trials to determine optimum timing.

The cutworm picture is promising, too. New Jersey aerial field trials against blossomworm and false armyworm, by Dan Schiffhauer of Ocean Spray and Sridhar Polavarapu of Rutgers, showed a drastic post-treatment decrease in both species. The material is effective on at least some spanworms, but more work is needed here. Gypsy moth is very susceptible, as shown by years of work in forestry.

Confirm may or may not turn out to be a useful tool to manage cranberry fruitworm, because of the lack of contact activity. Except with blackheaded fireworm, more experience is needed with Confirm chemigation applications to define the efficacy of this application method.

Despite some gaps in the efficacy picture, the proven efficacy of Confirm against several key lepidoptera should give it an important role in cranberry insect management in all regions. Growers are eager to put this breakthrough material to work, while researchers continue to test additional reduced-risk tactics.

Mating Disruption: A Paradigm Shift

by Grant W. Oliver

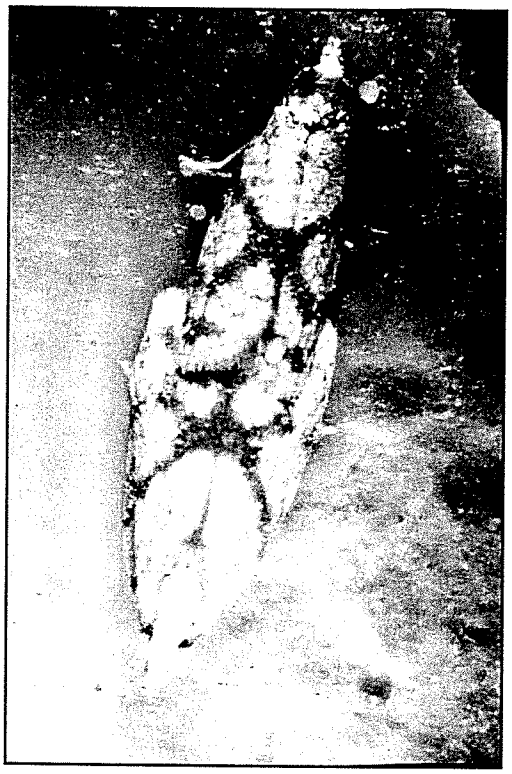
Did you ever think you could manage insect populations by confusing them about sex? Sound far-fetched? Well, it isn't! Not with pheromone mediated "mating disruption". Mating disruption is a novel tool in integrated pest management methodology that has been employed successfully for a number of years in a variety of crops including cotton, tomatoes, apples, pears, and grapes. In Egypt, at least 600,000 acres of cotton have been treated with mating disruption technology for each of the last four years. In North America the largest usage currently is in the Pacific Northwest where mating disruption has become an integral part of codling moth management in apple and pear orchards. In Washington State approximately 40,000 acres of pome fruits were treated in 1998.

Female calling

To understand the concept of mating disruption one must first understand how the sexes find each other for the purposes of "propagating the species". This is accomplished during the adult moth stage of the insect's life cycle and involves the female emitting a plume of her pheromone or sex attractant to attract males. This is termed "female calling". The pheromone plume is only detectable by male moths of the same species and thus mating disruption is a species specific process. When the male moth detects a pheromone plume with his antennae, he flies up-wind in and out of the plume towards the source, and if he is lucky, he will be directed right into wings of a willing female moth. We all know what happens then . . . !

Mating disruption technology attempts to prevent this "sexual rendezvous" from happening. If successful, there will be many females "calling" but no males answering the call! The result is reduced numbers of fertilized eggs being laid, thereby reducing larval populations and the potential for crop damage.

The mechanisms at work in "mating disruption" involve the masking of the female plume so that it becomes invisible to the male's antennae. This occurs when a synthetic copy of the female's pheromone is broadcast over an area where male and female moths are found. Currently this is accomplished by using "devices" that have been loaded with synthetic pheromone attached by hand to the crop that is being protected. These "devices" generally come in the form of PVC tubes, spirals, twist ties, ropes, etc. Because of the difficulties and the problems in application and retrieval these devices do not lend themselves very well to the cranberry crop environment.



Sparganothis *adults mating.*

Microencapsulation

The 3M Company, in the mid 1970s developed a technology called microencapsulation. In the mid 1990s, 3M Canada Company began experimenting with this technology to determine how this process might be used to make a user-friendly sprayable mating disruption product. Microencapsulation involves the mixing of the synthetic pheromone with certain polymers and then through a number of carefully controlled processes, producing the microcapsules. These capsules range in size from approximately 20 to 40 microns. For perspective, a human red blood cell is about 10 microns in size. These microcapsules are suspended in a water based solution and remain inactive until sprayed and dried. The pheromone inside each capsule is then released into the environment by a process of diffusion through the capsule wall. This creates a controlled "timed-released" product. The capsule wall also protects the environmentally sensitive pheromone from the effects of oxidation and UV degradation.

There are many obvious advantages to sprayable pheromones over hand-applied dispensers for mating disruption control of cranberry pests. The major benefit to the cranberry grower, however, is the ease and speed of application. 3M Sprayable Pheromones for Mating Disruption of Blackheaded Fireworm and Sparganothis Fruitworm can be applied using any of the application methods currently employed by the cranberry industry, including chemigation. Work has also been done to show that 3M Sprayable Pheromones can be tank mixed with most of the commonly used pesticides and fungicides.

Mating disruption as a "population management tool" against these two major cranberry pests will be most effective on farms with low to moderate pest pressures. This is not to imply that mating disruption will not be of benefit in high pest populations but in those situations the grower will unable to reduce mating to the same extent as in lower population areas. This is because of the "bump into" factor in heavily populated areas. You will still see some benefit, however with a reduction in larvae hatch counts.

Mating disruption also works best if the treated areas are isolated from non-treated areas or if an "area-wide" program involving all the farms in a region is initiated. This will reduce the incidence of mated female moths from flying from other farms into pheromone-treated areas and laying fertile eggs.

Monitoring with IPM traps

Monitoring of pest activity in a "mating disruption" environment is critical to ensure that mating disruption is being effective. The use of standard IPM traps to accomplish this is recommended. In addition you may want to consider the use of a few "decoy-female" pheromone traps in a representative number of fields. "Decoy-female" lures are loaded with .01 mg of pheromone as opposed to the 1 mg loaded lures in standard pheromone traps. These traps can be purchased from Phero Tech, Inc. in British Columbia or any other pheromones lure supplier by requesting grey lures loaded with .01 mg of pheromone. "Decoy-female" traps should be placed at least 50 feet in distance from standard traps. Research conducted on Blackheaded Fireworm in Wisconsin has shown that these lures more closely approximate the pheromones release from female moths and thus may be a better indicator of the male's ability to find a female. The overall objective is to monitor how well disruption is working while at the same time keeping costs for lures and labor to install them at a minimum.

Since mating disruption does not kill your target pests, it also does not harm beneficial insects in the environment. The reduction in pest population using mating disruption is a "process" that may involve several adult moth flight periods. During this process you should be able to begin to reduce your usage of traditional insecticides and/or the new biopesticides. In time, reductions in the amount of pheromone required to effect good mating dirsuption may also be possible. Since mating disruption is "pest specific" it is important to continue to monitor and treat for other pests as required that may exist on your farm.

"Mating disruption" should not be considered a stand-alone pest management tool. Used in conjunction with other conventional methods it will add significant benefit by helping to suppress and reduce insect populations. with the possible loss of many of our conventional insecticides due to FQPA, mating disruption is an environmentally friendly and effective tool when used properly in an IPM program.

Now when you are thinking about pest management issues remember . . . *"less sex is best!!!"*

ABOUT THE AUTHOR: Grant W. Oliver is business development manager, 3M Canada Company.

(Editor's Note: Related article starts on page 9.)

SPARGANOTHIS: New Management Options for a Difficult Cranberry Pest

by Donald C. Weber
Ocean Spray Cranberries Agricultural Science Group

Sparganothis sulfureana, a moth in the tortricid family, was in Henry Franklin's 1948 masterwork "Cranberry insects in Massachusetts," a mere figure and a caption:

> "This moth is common on dry bogs in July. The larva has a yellow head and works as a fireworm but never does much harm on bogs except in New Jersey and there locally. It also attacks grape, strawberry, clover, and many other plants."

The *Sparganothis* problem

In the past 50 years many aspects of cranberry culture have changed. And something about these changes has brought increased populations of *Sparganothis*. Compared to 50 years ago, the vast majority of cranberry pest insects are now easier to control. But *Sparganothis* is a serious exception.

Sparganothis numbers have, in the past four years or so, increased dramatically in certain areas of Massachusetts, including but not limited to Middleboro. Also, in New Jersey and Wisconsin, *Sparganothis* ("spag") has gained in importance relative to other pests.

From a June 1997 cranberry grower survey, growers consider *Sparganothis* a worse pest in Massachusetts than in either New Jersey or Wisconsin (Figure 1). Of those growers considering *Sparganothis* a pest, Lorsban (chlorpyrifos) was by far the most-cited primary control in Massachusetts. In New Jersey, Guthion (azinphosmethyl) and other unspecified insecticides were grower-reported primary controls, whereas Wisconsin growers used a variety of organophosphates.

Together these responses indicate a serious pest problem with a narrow base of effective management tactics, especially in Massachusetts. Even so, a significant number of Massachusetts growers (41% of respondents) still do not have what they consider a serious *Sparganothis* problem, at least not serious enough to rate in their top five insect pests. So the problem appears to be somewhat localized, even in the most affected region.

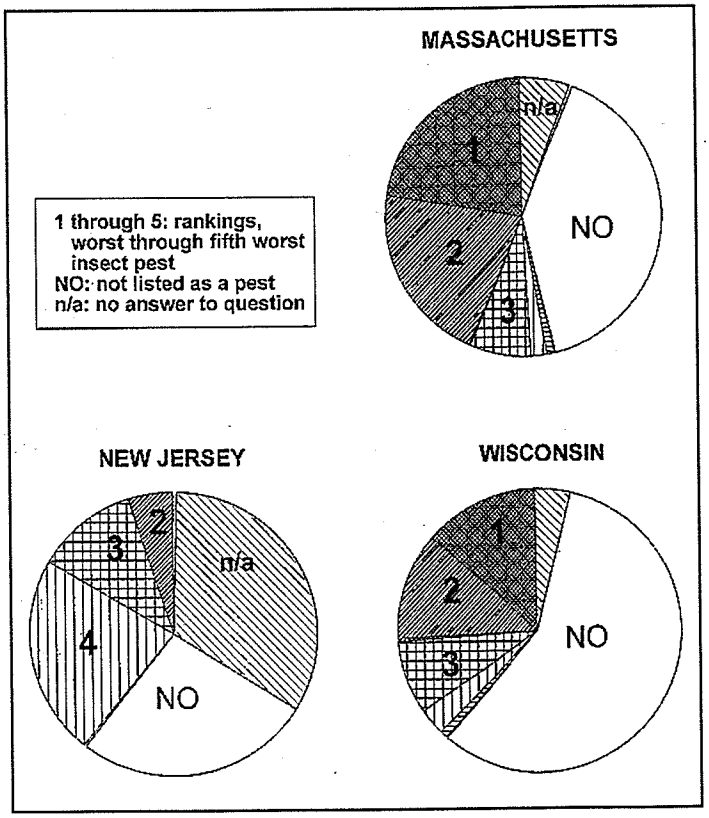


Figure 1. Cranberry grower ratings of* Sparganothis *as an insect pest, 1997. Number responding is 170 in Massachusetts, 18 in New Jersey and 93 in Wisconsin, representing over 50% of cranberry acreage in each state.

Why wasn't *Sparganothis* a pest species in the past?

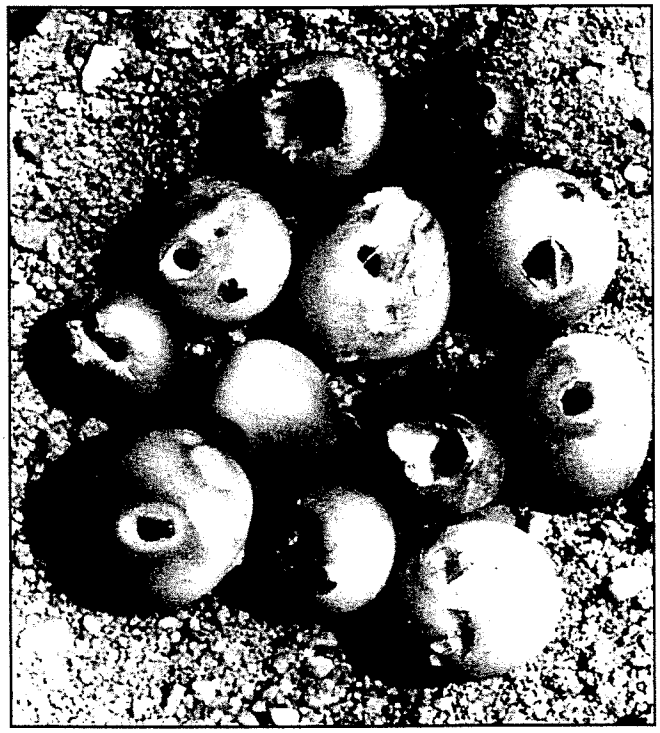
This is a difficult question to answer, because there are many insects which are not pests, and many reasons for them not reaching pest status. Among the reasons are limitations of food quality, physical factors, and natural enemies. *Sparganothis* could have been limited by plant food quality (nutrients, antinutrients) in the past: historically, cranberry foliage was probably less palatable due to lower fertilization, and fruit was less abundant. In Franklin's day, average yields were around 30 barrels per acre, and growers strove for one fruit per upright. *Sparganothis* may also have been limited by physical factors: flooding instead of sprinklers for frost protection in the past, as well as a generally cooler climate. *Sparganothis* appears to be effectively limited by natural enemies in the absence of insecticides. Marucci & Moulter (1992) described biological control of *Sparganothis* by natural enemies in New Jersey, and advocated an integration of biological and chemical control as a long-term management strategy to avoid damaging outbreaks.

Why is *Sparganothis* now a problem? There are practices which seem to encourage or discourage outbreaks, but we have only anecdotal evidence on this. Pre-bloom sprays with organophosphate insecticides (OPs) seem to encourage outbreaks. Weed presence (which species is not clear, possibly whorled loosestrife) may discourage outbreaks. These two observations may share a common link. *Sparganothis* natural enemies are conserved by avoidance of pre-bloom sprays, and they also may build up on *Sparganothis* and other hosts in the weed refuges. These trends are definitely not the last word in reasons for *Sparganothis* outbreaks. Dr. Anne Averill's lab at University of Massachusetts is continuing investigation of the importance of native natural enemies in *Sparganothis* population dynamics.

What *existing* control tactics still work?

In Wisconsin and New Jersey, most registered insecticides still appear to be effective. In Massachusetts, generally only two organophosphates (OPs), chlorpyrifos (Lorsban) and acephate (Orthene) still work against *Sparganothis* larvae (Sylvia 1998). Some Massachusetts growers think the pest may even have developed resistance to these materials as well. It is important to use them judiciously and precisely to avoid wasting applications and encouraging resistance.

In Massachusetts, Lorsban is also the only reliable control for cranberry weevil, sometimes posing a dilemma for growers with both weevil and *Sparganothis* problems, since only two applications per year are allowed. Many growers in this situation avoid Lorsban for *Sparganothis* before bloom, since it is the most effective material for post-bloom applications. Orthene is another option, and through 24c registration in several states, Orthene is allowed for two applications, one of which may be post-bloom, with a 75-day pre-harvest interval. Observe pollinator cautions and remember that Orthene has a common mode of action with Lorsban: Therefore it is likely that using one will select for pest resistance to both chemicals.



Fruit damaged by* Sparganothis *in New Jersey.
(Photo by Walter Z. Fort.)

Insecticide mixtures are not recommended against *Sparganothis*. They do not show added efficacy, and are likely to be particularly toxic to *Sparganothis* natural enemies. On the other hand, BTs including Dipel, Mattch, Xentari, Crymax, and Agree (strains of *Bacillus thuringiensis*) could be useful with good coverage for early-instar first generation.

Researchers serve up alternatives.

The increasing pest status of *Sparganothis*, and the decreasing usefulness of conventional chemicals, has prompted a concerted effort on the part of Ocean Spray, Rutgers University and University of Massachusetts. As a result of this effort, new tactics will be available for grower use in 1999. Use of the *Sparganothis* pheromone for mating disruption, new and selective larvicides, and possibly short mid-summer floods, all offer environmentally-friendly alternatives to conventional insecticides, and together will be key to the development of a field strategy in areas with particularly high *Sparganothis* populations.

Mating's a wreck when you use MEC.

Sparganothis microencapsulated (MEC) pheromone (USA regular registration by 3M Canada) offers a completely new tactic by disrupting mating of adult *Sparganothis* moths (see article by Grant Oliver in this issue, and Gary Deziel 1998). Field tests by Dr. Sridhar Polavarapu at the Rutgers University with Ocean Spray cooperators in New Jersey have established the efficacy of this technique both for shutting down mating of adults, and in reducing larval damage. The controlled-release pheromone formulation appears to provide mating suppression over approximately four weeks. A typical

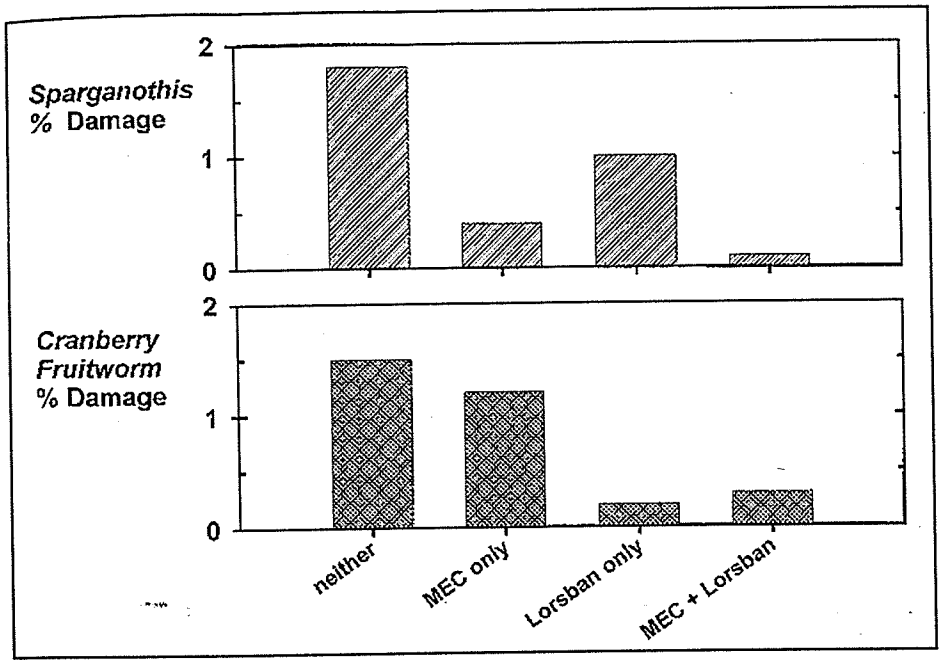


Figure 2.* Sparganothis *and cranberry fruitworm damage at harvest: effect of* Sparganothis *MEC pheromone and Lorsban treatment, Massachusetts 1998. Lorsban chemigated twice at full rate, timed for cranberry fruitworm suppression by out-of-bloom counts. Pheromone chemigated at 25 g active ingredient per acre, timed by trap captures. Pseudoreplicated trial (only one 30-acre bog each pheromone-treated and untreated) shows significant ($p<0.05$) effect of MEC only for* Sparganothis *damage, and Lorsban only for cranberry fruitworm damage.

Trap captures indicated a strong effect of the pheromone treatments. Before treatments, male captures were 1.3 times higher on the non-treated bog: within the same magnitude for *Sparganothis* numbers. But by the end of the second flight, and after two pheromone treatments on the treated bog, captures on the untreated bog were over 28 times the numbers on the pheromone-treated bog.

Sparganothis damage data are consistent with this. They indicate that both pheromone and the OP treatments suppressed damage at harvest. However, only the pheromone treatment had a stronger, statistically-significant effect (Figure 2). This suppression represents the effect of only one application of pheromone, since the offspring of the second flight adults, which was also treated, are the overwintering generation which will not be damaging the crop until early 1999. Not surprisingly, cranberry fruitworm damage was not affected by pheromone applications, since *Sparganothis* MEC pheromone is specific to this species. OP applications had a significant suppressive effect on cranberry fruitworm damage at harvest.

program, determined by pheromone trap catches, would involve one application for each flight. It is an environmentally safe complement to larval control tactics. The MEC pheromone may be chemigated; in fact, this appears to be the best means of application! As always, see the label for all the details.

An initial trial in Massachusetts in 1998, by Ocean Spray in cooperation with Dr. Polavarapu, was also quite promising. The 1998 *Sparganothis* MEC pheromone trial in Massachusetts involved about 30 acres treated twice with the pheromone through chemigation, and a comparable bog nearby which was not treated. Each bog was treated for fruitworm and *Sparganothis* with two post-bloom Lorsban chemigation treatments. To test the effect of the pheromone alone, on each bog an area was reserved which was not insecticide-treated. Ten pheromone traps were maintained on each bog throughout the season. Using a harvest and evaluation of 1,000 berries per treatment, we were able to compare the effects of treating or not treating with pheromone, and treating or not treating with organophosphate (OP) insecticide, on the damage attributed to cranberry fruitworm and *Sparganothis*.

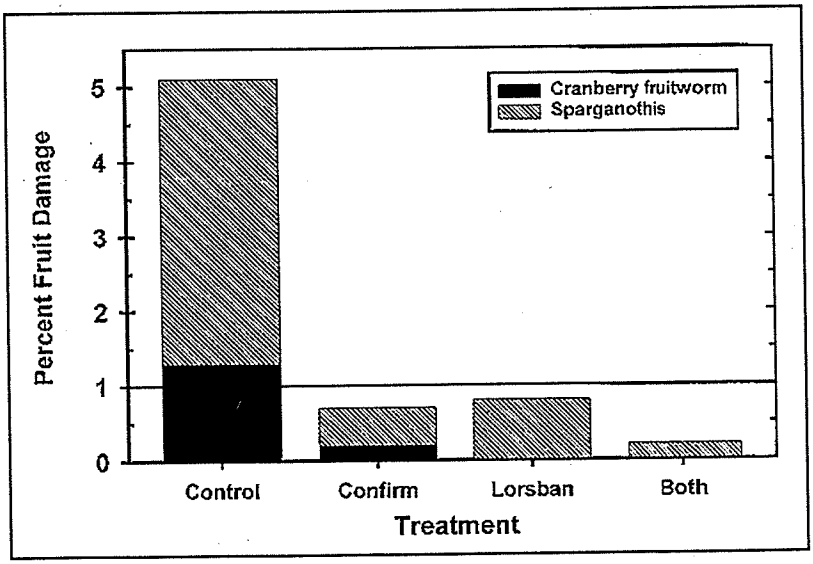


Figure 3. Effect of Confirm and Lorsban chemigation on* Sparganothis *and cranberry fruitworm damage at harvest, Massachusetts 1998. Two treatments of each insecticide were timed with* Sparganothis *trap captures. All three treatments showed a significant ($p<0.05$) reduction to below 1% in both species' damage, compared to untreated control, but no significant differences among one another.

Coming to terms with the worms.

Pheromones are expected to be very useful but must be coupled with an effective larval control program. Confirm (tebufenozide) is a new larvicide, an insect growth regulator (IGR) which fatally accelerates the molt of caterpillars eating treated foliage. Results from the 1998 emergency (Section 18) registration of this material in Massachusetts, New Jersey and Washington indicate it controls a number of lepidoptera (worms). The favorable efficacy data from the US is being used to support an URMULE (User-requested Minor Use Label Extension) in Canada, where it is already registered in forestry and for some food uses.

Confirm is particularly effective against blackheaded fireworm, also against cutworms, and in Massachusetts, our field trials show it can be effective in *Sparganothis* control for the second (fruit-eating) generation, if coverage and timing are good (Figure 3). However these results are limited and may depend very critically on optimum timing and application. Our best guess is that Confirm will be most effective for control of early-season (first-generation) *Sparganothis* larvae, since these feed on foliage, which allows adequate treatment of the worms' food. Also, since Confirm is safe against natural enemies, it will allow biological controls to help suppress pest populations (not just *Sparganothis*) in the early season and through the pollination period.

Confirm is about 25 to 50% more expensive per acre than Lorsban or Orthene, respectively, at the labeled rates. The material costs only are approximately $22 per acre, as compared to $15 to 18 for the OPs. Sparganothis MEC pheromone will cost from $29 to $67 per acre depending on application rate; a typical application of 15 g pheromone (2.5 oz. formulated per acre) would cost about $42 per acre.

Several other selective and environmentally-friendly larvicides are on the horizon for *Sparganothis* management (see Deziel 1999). One of these may be registered under a 1999 Section 18 request submitted by Dr. Averill of University of Massachusetts, for use on second-generation *Sparganothis* in Massachusetts.

Pushing the flash flood button!

Since 1996, several Massachusetts growers have encountered *Sparganothis* populations in outbreak with well over 10% fruit damage. A promising rescue option for this situation, one which still must be considered risky, is to flood for about 30 hours when a cloudy day is assured. Monika Weldon of Clean Sweep Cranberry Consulting first tried this technique in August 1998 (during Tropical Storm Bonnie). The flood started in the late afternoon, continued through one rainy day, and was pulled the following morning. This was been successful in arresting all feeding and killing all larvae, even those in the fruit (see Figure 4). Clearly, great loss of fruit is possible and this is an experimental tactic at this time. However, we are optimistic that, like similar floods for cranberry girdler in the Pacific Northwest and Wisconsin, this technique will prove a valuable tactic. Ocean Spray and Clean Sweep are looking for Massachusetts grower cooperators to test "flash flood" against high populations of *Sparganothis* in 1999.

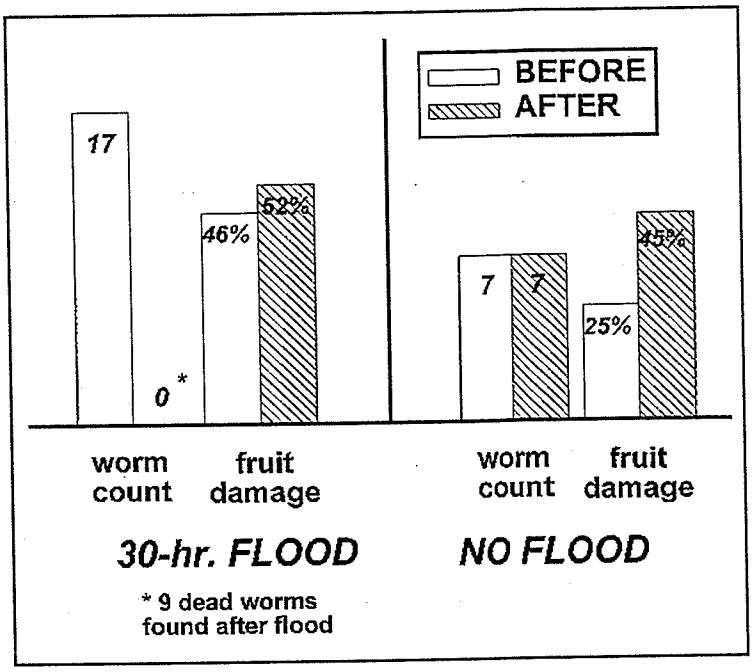


Figure 4. Effect of a 30-hour August flood on* Sparganothis *larval abundance and fruit damage, Massachusetts 1998, Monika S. Weldon, Clean Sweep Cranberry Consulting. The flood eliminated all live worms, and arrested the increasing damage. The unflooded control had the same worm count before and after, as fruit damage continued to increase.

Low-risk registrations on fast track in USA; get push in Canada

Confirm (tebufenozide) has just been granted a food tolerance of 1.0 ppm for cranberries, as a result of the commodity-supported IR4 petition to the US EPA. This is the most important step in a national registration, and a federal label has been submitted by Rohm & Haas.

However, with early May initiation of lepidoptera management fast approaching, it was unclear whether all states in which the product is needed, will grant state registrations in time to allow early treatments.

Sparganothis Sprayable Pheromone, a 3M Canada product, was granted a regular US registration several months ago, due to the tolerance-exempt and low-risk nature of both the pheromone and the polymer microcapsules. It joins the Blackheaded Fireworm Sprayable Pheromone as the second 3M Canada product in US cranberries.

(Please turn to page 26.)

What more is needed to outsmart "spag"?

Clearly, more information is needed to effectively manage *Sparganothis*. We need better knowledge of the exact phenology (seasonal timing) of life stages and their behavior, particularly in regard to feeding site of the second generation, which attacks the berries. In particular, improved use of pheromone trap captures, and applying this to all tactics new and old, is important. Also important is natural enemy identification, abundance, impact on *Sparganothis* population, and what helps or hurts these beneficials in the bog habitat.

Researchers are concentrating efforts for *Sparganothis* control on novel tactics which make up a sustainable and economic strategy for managing all cranberry insects. These include biological, cultural, behavioral, and low-risk chemical controls – all new tools to add to the depleted grower toolbox. *Sparganothis* may have growers and researchers outnumbered, but not outsmarted.

References

Deziel, Gary. 1998. The lure of pheromones. *Cranberries* 62 (11): 16-19.

Deziel, Gary. 1999. The advent of biorational pesticides. *Cranberries* 63 (1): 4-5, 18-19.

Franklin, Henry. 1948. Cranberry insects in Massachusetts. Univ. of Mass. Bulletin 445, Plate 1.

Marucci, Philip E., and Harry J. Moulter, 1992. Biological control of Sparganothis fruitworm on cranberries in New Jersey. *Cranberries* 56 (4):14-15, 56 (5):11-15.

Sylvia, Martha M. (ed.). 1998. Cranberry 1998 Chart Book. Univ. of Mass. Cranberry Station.

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