Pest Phenology and Evaluation of Traps and Pheromone Lures for Monitoring Flight Activity of Obliquebanded Leafroller (Lepidoptera: Tortricidae) in Minnesota Apple Orchards

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ABSTRACT The efficacy of two trap designs (Pherocon 1C "wing" trap versus Pherocon VI "delta" trap) and two pheromone blends for monitoring obliquebanded leafroller, *Choristoneura rosaceana* (Harris), was evaluated in Minnesota apple orchards during the 2001 and 2002 field seasons. Two distinct flight periods of *C. rosaceana* were recorded yearly in Minnesota. Overwintered *C. rosaceana* larvae resumed activity in the spring at ≈60 degree-days (DD) base 10°C, whereas adult emergence began ≈275 DD base 10°C. To determine the optimal pheromone blend for monitoring *C. rosaceana* in Minnesota, traps were baited with either a three-component pheromone blend (Z11–14:Ac, E11–14:Ac, and Z11–14:OH) produced by females in eastern North America, or a four-component blend (Z11–14:Ac, E11–14:Ac, Z11–14:OH, and Z11–14:Al) commonly produced by females in western North America. Of the four pheromone-baited traps evaluated, delta traps baited with the four-component western pheromone lure captured the highest number of *C. rosaceana* males, followed by wing traps baited with western lure. Male *C. rosaceana* were less attracted to traps containing the three-component eastern lure, and both lure types seemed to be considerably selective against sympatric redbanded leafroller, *Argyrotaenia velutinana* (Walker). These results suggest that the pheromonal response of the predominant endemic population of *C. rosaceana* in Minnesota is similar to the response of the pest in many parts of western North America. The delta trap baited with western pheromone lure of *C. rosaceana* is recommended for monitoring the pest in Minnesota, and the results are discussed in relation to the development of effective management strategies against this important pest of apple.

KEY WORDS *Choristoneura rosaceana*, obliquebanded leafroller, flight behavior, pest monitoring, sex pheromone

MANY MOTH PESTS OF AGRICULTURAL importance are commonly monitored using pheromone traps (Durant et al. 1986, Delisle 1992), although other monitoring techniques such as blacklight traps are also used. Pheromone traps have found great use in most integrated pest management (IPM) systems. Data collected from pheromone traps are routinely used to observe seasonal changes in the abundance of adult pest populations and to determine when to implement pest management practices against a target pest species. Various commercial traps and lures are currently available with different degree of efficacy. As more growers begin to adopt IPM, it is imperative that they use the most effective and precise monitoring systems to determine pest action thresholds.

The obliquebanded leafroller, *Choristoneura rosaceana* (Harris), is a widely distributed pest of apples in North America. Although primarily a foliage feeder like most other leafrollers, *C. rosaceana* is also known to attack fruit (Chapman and Lienk 1971, Reissig 1978). In the past, commercial apple growers in North America have rarely monitored for *C. rosaceana* because it was considered a minor orchard pest in most areas and was generally controlled by conventional insecticide sprays targeted against codling moth, *Cydia pomonella* (L.), and other key apple pests (Chapman et al. 1968). However, recent outbreaks probably due to secondary pest resurgence and resistance, as well as recent changes in pesticide regulations have now raised the status of this pest in many locations (Reissig 1978, Lawson et al. 1996, Waldstein and Reissig 2001). The result is that *C. rosaceana* is now being monitored in many fruit growing regions in North America. This trend is likely to continue as growers reduce the use of broad-spectrum insecticides and time applications more accurately for codling moth and other internal fruit feeders.

Fruit damage by *C. rosaceana* has been observed in many apple orchards in Minnesota, and many growers in the state consider *C. rosaceana* a pest of apple

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(Fadamiro and Howse 2002). However, little is known about the seasonal phenology and bionomics of *C. rosaceana* in Minnesota. Many apple growers in the state are interested in monitoring the activity of *C. rosaceana* in their orchards. With the availability of several types of commercial traps and lures, apple growers face the challenge of selecting the most effective trap and lure for their target pest populations. Most of the published studies on monitoring systems for *C. rosaceana* have been performed in the major apple production regions of North America (Knodel and Agnello 1990, Delisle 1992, Agnello et al. 1996). The performance of commercially available traps and lures has not been evaluated under Minnesota conditions, and without a proper evaluation of trap efficacy locally it is difficult to recommend specific traps and lures to Minnesota growers.

Two different geographical pheromonal strains of *C. rosaceana* have been reported in North America (Weatherston et al. 1976; Hill and Roelofs 1979; Vakenti et al. 1988; Thomson et al. 1991; Delisle 1992; El-Sayed et al. 2001, 2003). *C. rosaceana* females from populations in New York, Quebec, and many other parts of eastern United States and Canada produce a three-component pheromone blend consisting of (*Z*)-11-tetradecenyl acetate (Z11–14:Ac), (*E*)-11-tetradecenyl acetate (E11–14:Ac), and (*Z*)-11-tetradecenol (Z11–14:OH) in the approximate ratio of 20: 1:1 (Hill and Roelofs 1979, Thomson et al. 1991). This three-component blend has been found to be optimally attractive to conspecific males from the same geographical locations. Weatherston et al. (1976) studied the pheromone-mediated behavior of different geographical populations of *C. rosaceana* and reported that the addition of (*Z*)-11-tetradecanal (Z11–14:Al) to the major pheromone component, Z11–14:Ac did not improve attraction in New York and Quebec, but it did significantly increased attraction of males in Ontario. Vakenti et al. (1988) later isolated a fourth component, Z11–14:Al, from *C. rosaceana* females from Okanagan Valley, British Columbia. The authors further demonstrated that the addition of Z11–14:Al to the three-component eastern lure increased trap capture of conspecific males in British Columbia, while reducing trap capture of sympatric European leafroller, *Archip rosanus* (L.). Thomson et al. (1991) also reported similar results in which the addition of Z11–14:Al to the three-component blend significantly increased trap capture of *C. rosaceana* males in British Columbia, but not in Quebec. However, two recent reports have suggested the possibility of occurrence of Z11–14:Al also in the pheromone blends of eastern populations of *C. rosaceana* (El-Sayed et al. 2001, 2003). Despite this interesting discovery of geographical differences in the pheromone blend composition of *C. rosaceana,* little has been done to identify the predominant pheromonal strain of populations of the pest in other parts of North America, in particular in upper midwestern United States. As *C. rosaceana* continues to assume pest status in various parts of North America, growers interested in IPM will have to face the challenge of monitoring this pest. The first step toward the development of an effective monitoring system for *C. rosaceana* is the identification of the predominant pheromonal strain in the region.

A major objective of this study was to identify the predominant pheromonal strain of *C. rosaceana* in Minnesota. Two different pheromone-based approaches can be used to identify the strain of an endemic population of *C. rosaceana.* The first method involves the collection, analysis, and identification of the pheromone components produced by females from a known feral population. A second, less direct approach involves field evaluation of synthetic lures that mimic the pheromone blends produced by different strains of the insect. Collection, analysis, and identification of pheromone blends require regular access to analytical equipment and facilities. In the current study, I identified the pheromone blend most attractive to *C. rosaceana* in Minnesota by field evaluation of traps baited with the two known synthetic pheromone blends. Additional objectives of this study were to evaluate two commercially available traps for monitoring *C. rosaceana* and to determine its seasonal phenology in Minnesota orchards. Results of this study will be used to develop *C. rosaceana* monitoring recommendations and guidelines for apple growers in Minnesota and other parts of upper midwestern United States.

Materials and Methods

Pest Phenology. The phenology of *C. rosaceana* in Minnesota was determined using trap data from five orchards located in the four major apple growing regions in Minnesota. The locations of the monitoring orchards were La Crescent (La Crescent region), Faribault (Hiawatha region), White Bear Lake (St. Croix region), Hastings (St. Croix region), and Fairhaven (Metro West region). One Pherocon 1C "wing" trap (Trécé Inc., Salinas, CA) baited with one *C. rosaceana* eastern pheromone rubber septa lure (Trécé Inc., 1 mg of total pheromone dosage) was placed in each orchard in the third and last week of May 2001 and 2002, respectively, before the commencement of *C. rosaceana* flight (as determined in a preliminary study conducted in 2000). Each trap was placed on an apple limb at a height of $\approx$1.5 m above the ground. Pheromone lures were replaced every 4 wk in accordance with manufacturer recommendation, and trap liners were cleaned after each weekly count and replaced as necessary.

Traps were checked weekly counting and recording the number of *C. rosaceana* males per trap. In addition, the orchards were periodically sampled for pest larvae and damage. Where possible, the following phenology data were noted and recorded for each orchard: date of first moth capture in traps, date when larvae/pupae first seen, number of pest generations, date of flight peak, beginning of second generation, and peak of second flight. The Leaf Wetness & Temperature logger (Spectrum Technologies, Inc., Plainfield, IL) was used to relate pest phenology to degree-day (DD)

Table 1. Composition of commercially produced *C. rosaceana* sex pheromone lures evaluated during 2001 and 2002 field seasons in Minnesota

Component	Eastern blend		Western blend	
	Amount (mean ± SD) of components (mg)	Ratio of components	Amount (mean ± SD) of components (mg)	Ratio of components
Z11-14:Ac[a]	0.792 ± 0.006	100	0.815 ± 0.005	100
E11-14:Ac	0.028 ± 0.001	3.6	0.023 ± 0.0003	2.8
Z11-14:OH	0.038 ± 0.002	5	0.005 ± 0.0002	0.7
Z11-14:Al			0.004 ± 0.0005	0.5

Five rubber septa lures of each type were extracted and analyzed.
[a] Dosage of the major pheromone component, Z11-14:Ac, per septum was approximately 0.8 mg in both types of lures.

accumulations in all five orchards. One logger was placed in each orchard at the end of March each year, when the average temperatures were still too low for any accumulation of degree-days at base 10°C. A base temperature of 10°C was used to calculate degree-day accumulation because the developmental threshold for third instars (the principal overwintering stage of *C. rosaceana*) has been reported to be ≈10°C (Gangavalli and Aliniazee 1985). Data from each logger was downloaded weekly onto a computer laptop via a cable. Using the product software, the degree-day (at base 10°C) summary was generated from the daily temperature data for each orchard.

Experimental Pheromone Lures. All lures evaluated in this study were silicone red rubber-septa (5 by 9 mm), custom-prepared by Scenturion Inc. (Clinton, WA) by using 1-mg total pheromone dosage per lure. Lures were placed in airtight containers and stored in a freezer until needed. Two different pheromone lures mimicking the blends produced by the two known geographical strains of *C. rosaceana* in North America were tested. The pheromone blend produced by *C. rosaceana* females from eastern United States and Canada (eastern lure) consisted of three components: Z11–14:Ac, E11–14:Ac, and Z11–14:OH. The second type of lure mimicked the pheromone blend produced by females from western parts of North America (western lure). This four-component lure consisted of the "eastern" three-component pheromone blend (Z11–14:Ac, E11–14:Ac, and Z11–14:OH), plus a fourth component, Z11–14:Al, at ≈0.5% of the major component, Z11–14:Ac.

To confirm lure identity, composition, and dosage, lures of each type were extracted and analyzed. Fresh rubber-septa lures from the batch used in the field experiments were mailed to Dr. James Miller's laboratory at Michigan State University (East Lansing, MI) for extraction and analysis. Rubber septa lures were extracted individually in UV-quality hexane by using dodecyl acetate (12:Ac) as internal standard. Briefly, the internal standard was mixed with hexane to make a 122 ng/μl solution. A known amount of this solution was then placed into 15 vials. The 15 vials were grouped into three sets of five vials. The first set of five vials received one eastern lure each. The second set of five vials received one western lure each. Each lure was cut into six pieces and all pieces of the lure plus the cutting substrate were soaked in the solution for ≈24 h. The third set of vials was for standards. The first vial contained only hexane + internal standard solution. Each of the remaining four vials contained hexane + internal standard solution + 25 μl of a stock solution of a component standard. The stock solutions were made by adding 10 μl of neat component solution to 490 μl of UV-quality hexane. The component standards were Z11–14:Ac, E11–14:Ac, Z11–14:OH, and Z11–14:Al. The final concentrations of these solutions were ≈80 ng/μl. One microliter of each solution was analyzed by gas chromatography (DBWax-ETR capillary column, flame ionization detector). Chemical analysis of the rubber-septa lures confirmed the identity and dosage of both lure types (Table 1).

Field Evaluation of Traps and Lures. Experiments were conducted during the 2001 and 2002 field seasons at two commercial apple orchards (sites). The first orchard was located near Faribault (southeast Minnesota), whereas the second was located in Hastings (east central Minnesota). Two trap types, Pherocon 1C "wing" trap and Pherocon VI "delta" trap were evaluated. Both traps were manufactured by Trécé Inc. and supplied by Great Lakes IPM Inc. (Vestaburg, MI). Each orchard was divided into four blocks where the experiment was replicated. The following four treatments consisting of different trap and lure combinations were deployed in each block: 1) wing trap baited with eastern lure, 2) wing trap baited with western lure, 3) delta trap baited with eastern lure, and 4) delta trap baited with western lure. In addition, one unbaited (control) trap of each type was placed in each block. In each block, traps were randomly placed along a single row of apple trees at ≈1.5 m above the ground and spaced apart by at least 20 m. Traps were deployed in the third and last week of May 2001 and 2002, respectively, before the commencement of *C. rosaceana* spring flight. Traps were checked weekly counting and recording the number of *C. rosaceana* males per trap. Captures of male redbanded leafroller, *Argyrotaenia velutinana* (Walker), lady beetles, and other beneficial insects were also counted and recorded per trap to determine trap and lure specificity. The position of each trap was rerandomized every 2 wks to minimize potential effect of trap position on capture. Pheromone lures were replaced every 4 wk in accordance with manufacturer recommendation, and trap liners were cleaned after

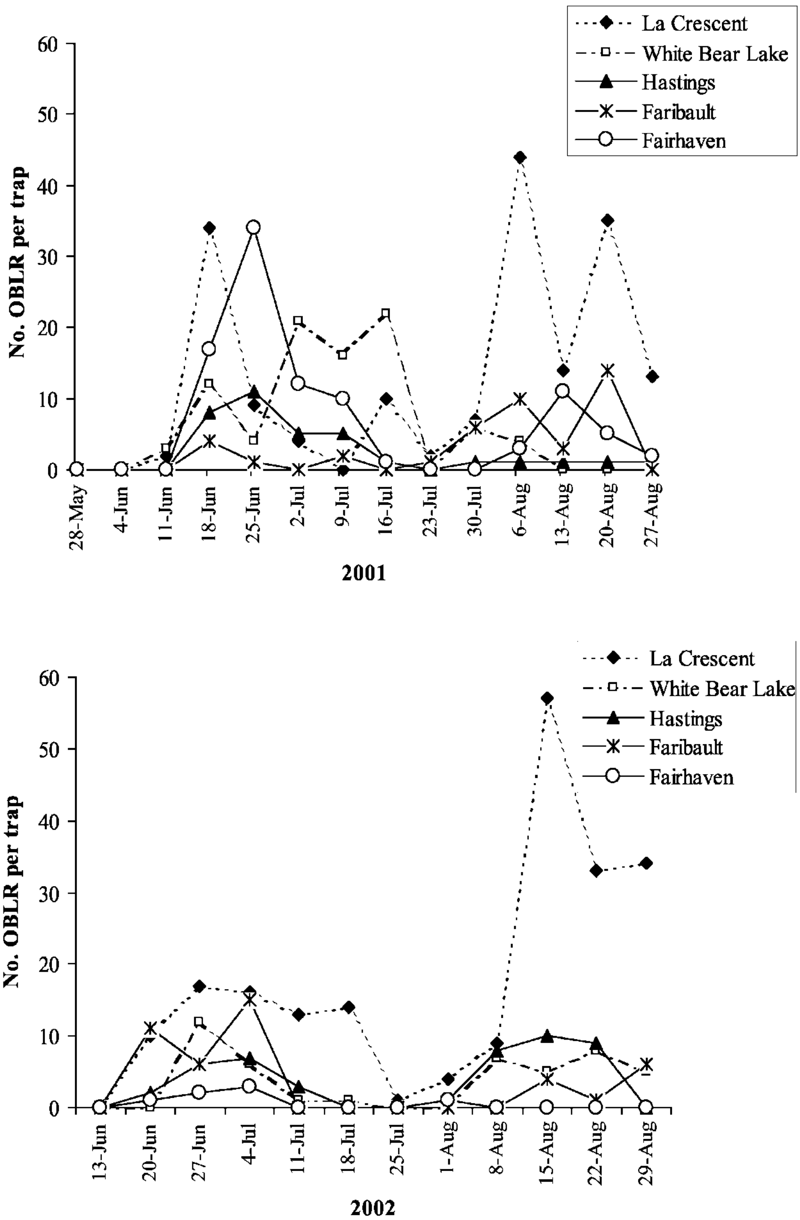

Fig. 1. Seasonal phenology of *C. rosaceana* (OBLR) in Minnesota. Figure shows weekly capture of *C. rosaceana* in a wing trap baited with eastern sex pheromone blend of *C. rosaceana* during 2001 and 2002 field seasons at five locations in Minnesota.

each weekly count and replaced as necessary. Actual capture in pheromone traps was calculated by subtracting captures in unbaited control traps of each type from captures in pheromone-baited traps. For each orchard and during each year, mean weekly trap capture was calculated for each treatment using the four blocks as replicates. The seasonal mean capture of *C. rosaceana* and other insects per week were also calculated for each treatment. Data were transformed using the square-root method ($\sqrt{x + 0.5}$) and analyzed with analysis of variance (ANOVA). Means were compared using the Tukey–Kramer honestly significant difference (HSD) comparison for all pairs (JMPIN version 4.0.2, SAS Institute 1985). Significant differences were established at the 95% confidence level ($P < 0.05$).

Results and Discussion

Pest Phenology. Two distinct flight activity periods of *C. rosaceana* males were recorded during both 2001 and 2002 seasons in all five orchards (Fig. 1), indicating that two generations of *C. rosaceana* occur each year in Minnesota. Two generations per year have also

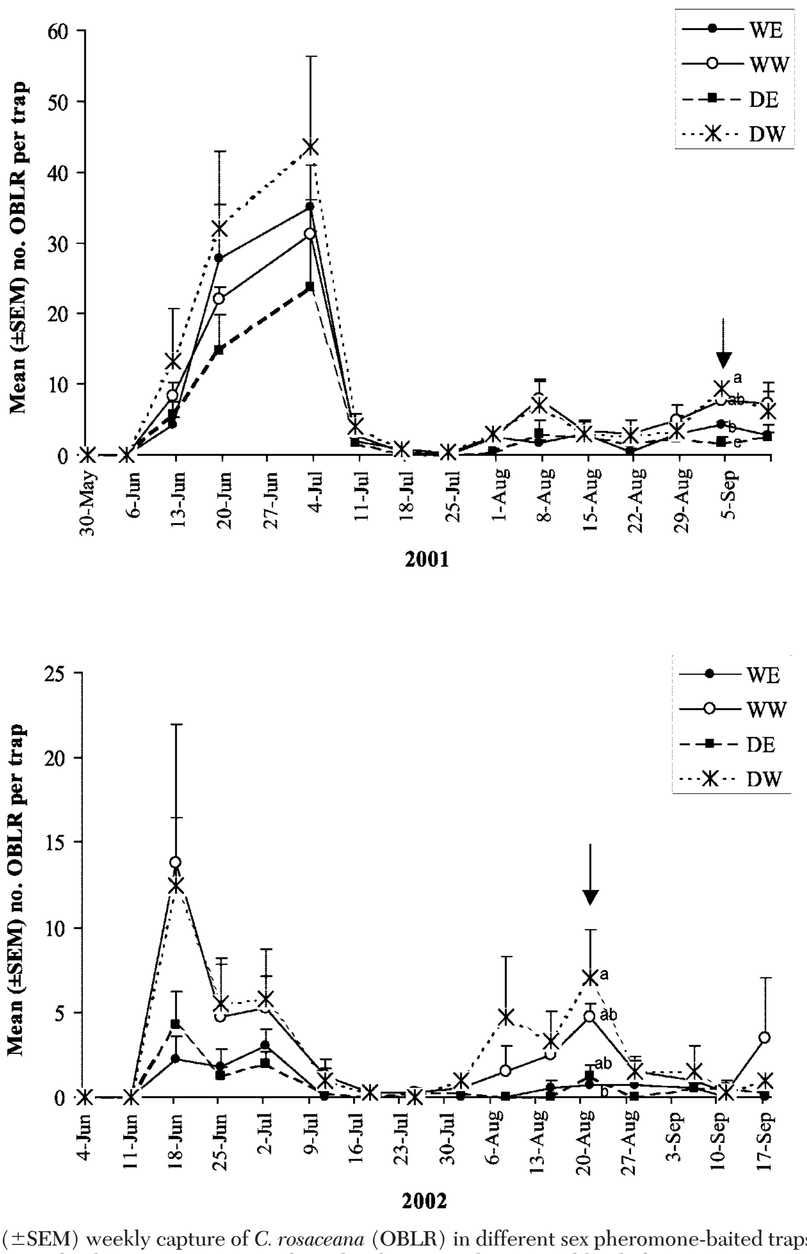

Fig. 2. Mean (±SEM) weekly capture of *C. rosaceana* (OBLR) in different sex pheromone-baited traps during 2001 and 2002 field seasons in Faribault, MN. WE, wing trap baited with eastern pheromone blend of *C. rosaceana*; WW, wing trap baited with western pheromone blend of *C. rosaceana*; DE, delta trap baited with eastern pheromone blend of *C. rosaceana*; DW, delta trap baited with western pheromone blend of *C. rosaceana*. Arrow indicates weeks in which a significant difference was recorded among treatments. Means within the same week followed by the same letter are not significantly different (Tukey–Kramer HSD, $P < 0.05$).

been reported for *C. rosaceana* in most other parts of North America, although the population pressure of the second flight may vary from year to year and location to location (Martin 1958, Madsen and Madsen 1980, Onstad et al. 1985, Delisle 1992, Agnello et al. 1996). Maltais et al. (1989), however, reported one single generation for *C. rosaceana* in Armagh, Quebec, although this report has been linked to poor synthetic pheromone blends (Delisle 1992).

Sampling and observational data indicate that overwintered *C. rosaceana* larvae resumed activity in late April ~60 DD base 10°C. In both years, this period corresponded to the tight cluster stage of apple development in south and central Minnesota. Emergence and flight activity of first generation moths began ~275 DD base 10°C. In many south and central Minnesota orchards, this occurred during the second and third week of June. The slight delay in moth

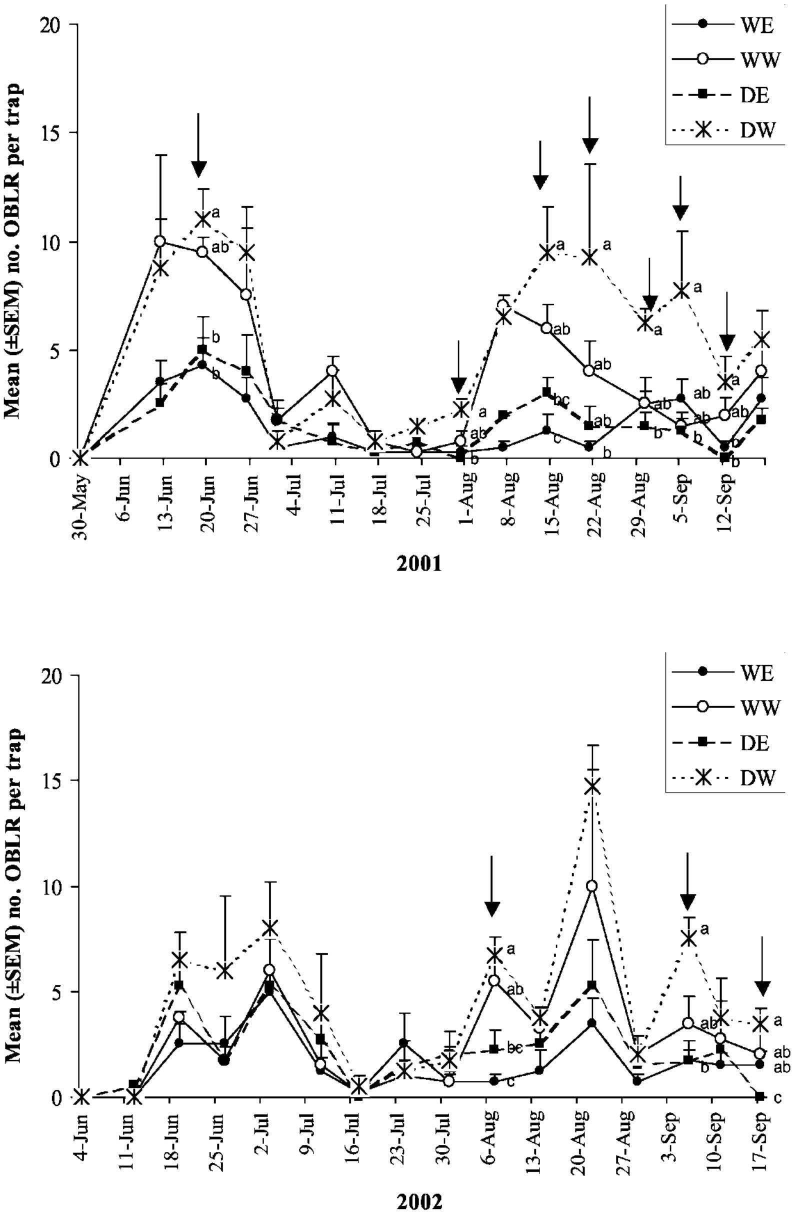

Fig. 3. Mean (±SEM) weekly capture of *C. rosaceana* (OBLR) in different sex pheromone-baited traps during 2001 and 2002 field seasons in Hastings, MN. WE, wing trap baited with eastern pheromone blend of *C. rosaceana*; WW, wing trap baited with western pheromone blend of *C. rosaceana*; DE, delta trap baited with eastern pheromone blend of *C. rosaceana*; DW, delta trap baited with western pheromone blend of *C. rosaceana.* Arrow indicates weeks in which a significant difference was recorded among treatments. Means within the same week followed by the same letter are not significantly different (Tukey–Kramer HSD, $P < 0.05$).

emergence in 2002 was probably due to relatively cooler spring temperatures compared with 2001. In the southeastern location of La Crescent, the first flight reached its peak a week after it began (peak flight occurred around third week of June), and ended around the third week of July, in both years of this study (Fig. 1). Delisle (1992) also reported a short duration between the start and peak of first flight of *C. rosaceana* in eastern Canada. In comparison with the relatively warmer La Crescent location, moth emergence and flight activity were delayed by ~1 wk in the relatively northern and cooler location of Fairhaven, where the first flight began around the third week of June and peaked around the fourth week of June (Fig. 1). In La Crescent, the second flight began around the end of July (≈885 DD base 10°C)

Table 2. Seasonal mean capture of *C. rosaceana* and other insects per week in wing and delta traps baited with eastern or western sex pheromone blend of *C. rosaceana* during 2001 and 2002 field seasons in Faribault, MN

Year	Trap-lure combination	Mean (± SEM) trap capture per week[a]			
		OBLR	RBLR	LDB	BNF
2001	WE	5.48 ± 0.60bc	0.11 ± 0.04ab	0.04 ± 0.03	0.30 ± 0.06ab
	WW	6.34 ± 0.45ab	0.21 ± 0.06a	0.02 ± 0.02	0.16 ± 0.05b
	DE	3.78 ± 0.66c	0.05 ± 0.03b	0.03 ± 0.02	0.64 ± 0.13a
	DW	8.06 ± 1.13a	0.09 ± 0.04ab	0.03 ± 0.02	0.39 ± 0.08ab
	P	<0.001	0.049	0.79	0.003
2002	WE	0.59 ± 0.22b	0.00 ± 0.00	0.03 ± 0.02	0.31 ± 0.10
	WW	2.56 ± 0.57a	0.02 ± 0.01	0.00 ± 0.00	0.11 ± 0.04
	DE	0.67 ± 0.19b	0.00 ± 0.00	0.03 ± 0.02	0.31 ± 0.10
	DW	2.83 ± 0.46a	0.02 ± 0.01	0.00 ± 0.00	0.22 ± 0.07
	P	<0.001	0.58	0.25	0.31

BNF, all beneficial insects; DE, delta trap baited with eastern pheromone blend of *C. rosaceana;* DW, delta trap baited with western pheromone blend of *C. rosaceana;* LDB, lady beetles; OBLR, obliquebanded leafroller; RBLR, redbanded leafroller; WE, wing trap baited with eastern pheromone blend of *C. rosaceana;* WW, wing trap baited with western pheromone blend of *C. rosaceana.*

[a] Means within a column and the same year followed by the same letter are not significantly different (Tukey–Kramer HSD $P < 0.05$).

and quickly reached its peak in the first 2 wk in August. This second generation flight was bigger in size than the first (Fig. 1). Furthermore, the flight activity of second generation moths continued well into September at the two research sites of Faribault and Hastings (Figs. 2 and 3).

Comparing the two years of this study, moth pressure was generally higher in 2001 than 2002 in many of our monitoring sites. The decrease in moth pressure in 2002 may be the result of the relatively colder 2001–2002 winter temperatures, which may have caused an increased mortality of overwintering larvae.

Field Evaluation of Traps and Lures. The mean weekly capture of *C. rosaceana* in the four different types of pheromone-baited traps during the 2001 and 2002 seasons are shown in Fig. 2 (for Faribault), and Fig. 3 (for Hastings). Considerable differences were recorded in the weekly capture of *C. rosaceana* males among treatments at both sites, although these differences were not significant during each week. Generally, the delta trap baited with western lure captured more males than the remaining three treatments. In most of the weeks in which a significant difference in trap capture was recorded, the wing trap baited with eastern lure consistently captured significantly fewer *C. rosaceana* males than the delta trap baited with western lure. Trap captures of *C. rosaceana* in unbaited control traps were very minimal, and in most cases zero.

The season-long mean trap capture of *C. rosaceana* and other insects per week in Faribault and Hastings are shown in Tables 2 and 3, respectively. In Faribault, delta trap baited with western lure captured significantly ($P < 0.001$) more *C. rosaceana* males than delta trap baited with eastern lure and wing trap baited with eastern lure in 2001 and 2002 (Table 2). In Hastings, delta trap baited with western lure captured significantly more *C. rosaceana* males than the remaining three traps in 2001 (Table 3; $P < 0.001$). However, trap capture in delta trap baited with western lure was only significantly higher than in the two traps baited with eastern lure in 2002 (Table 3; $P < 0.001$). Total season-long trap capture of *C. rosaceana* males (per four traps) in delta traps baited with western lure (DW) was two-fold and four-fold greater than captures in delta traps baited with eastern lure (DE) in Faribault in 2001 (DW = 561, DE = 242) and 2002 (DW = 181, DE = 242), respectively. Similar results were obtained

Table 3. Seasonal mean capture of *C. rosaceana* and other insects per week in wing and delta traps baited with eastern or western sex pheromone blend of *C. rosaceana* during 2001 and 2002 field seasons in Hastings, MN

Year	Trap-lure combination	Mean (±SEM) trap capture per week[a]			
		OBLR	RBLR	LDB	BNF
2001	WE	1.47 ± 0.23c	0.03 ± 0.02	0.09 ± 0.04	2.41 ± 0.69
	WW	3.84 ± 0.41b	0.02 ± 0.02	0.23 ± 0.06	2.00 ± 0.34
	DE	1.63 ± 0.24c	0.02 ± 0.02	0.09 ± 0.04	1.78 ± 0.25
	DW	5.34 ± 0.44a	0.00 ± 0.00	0.08 ± 0.03	1.42 ± 0.24
	P	<0.001	0.56	0.06	0.54
2002	WE	1.61 ± 0.29c	0.00 ± 0.00	0.06 ± 0.03	0.19 ± 0.05
	WW	2.75 ± 0.36b	0.02 ± 0.01	0.05 ± 0.03	0.11 ± 0.04
	DE	2.16 ± 0.30bc	0.00 ± 0.00	0.00 ± 0.00	0.17 ± 0.06
	DW	4.38 ± 0.40a	0.00 ± 0.00	0.06 ± 0.03	0.34 ± 0.09
	P	<0.001	0.39	0.25	0.11

BNF, all beneficial insects; DE, delta trap baited with eastern pheromone blend of *C. rosaceana;* DW, delta trap baited with western pheromone blend of *C. rosaceana.* LDB, lady beetles; OBLR, obliquebanded leafroller; RBLR, redbanded leafroller; WE, wing trap baited with eastern pheromone blend of *C. rosaceana;* WW, wing trap baited with western pheromone blend of *C. rosaceana.*

[a] Means within a column and the same year followed by the same letter are not significantly different (Tukey–Kramer HSD $P < 0.05$).

in Hastings where the delta trap baited with western lure outperformed the delta trap baited with eastern lure by three-fold in 2001 (DW = 342, DE = 104) and two-fold in 2002 (DW = 280, DE = 138).

Ranking the four treatments, the delta trap baited with western lure performed best followed by the wing trap baited with western lure. The delta trap baited with eastern lure was a distant third, whereas the wing trap baited with eastern lure was generally the least attractive. These data suggest a strong effect of lure type in which the western lure was consistently superior, and a subtle effect of trap type in which the delta trap was slightly better. Similar results were obtained for first and second flights at both sites, indicating little or no seasonal changes in response to the pheromone blends. The slightly better performance of delta trap over wing trap is not related to a difference in liner catch surface area: liner catch area is slightly greater in wing trap (394 cm^2) than in delta trap (379 cm^2). More likely, the difference in trap capture efficacy may be related to trap design.

The trap captures of sympatric redbanded leafroller, *A. velutinana* and beneficial insects were monitored to determine the selectivity of the four pheromone-baited traps (Tables 2 and 3). In most cases, trap captures of redbanded leafroller and beneficial insects were too low for any meaningful comparison. Although, there was a general trend for slightly higher captures of redbanded leafroller in wing traps than in delta traps, this was only significant during the 2001 season in Faribault (Table 2). In addition, a slight but significant difference was recorded among treatments in the number of total beneficial insects captured in Faribault in 2001 with delta trap baited with eastern lure capturing more beneficial insects than wing trap baited with western lure (Table 2). No significant differences were recorded among treatments in the numbers of lady beetles captured at both sites (Tables 2 and 3).

In this study, the four-component western lure was found to be superior in attractancy at both sites, suggesting that the predominant endemic population of *C. rosaceana* in Minnesota is similar in pheromone-mediated flight behavior to the strain found in British Columbia and many parts of western North America. The three-component eastern lure has been found to be optimally attractive to feral populations of *C. rosaceana* in New York and Quebec (Weatherston et al. 1976, Hill and Roelofs 1979, Thomson et al. 1991, Delisle 1992), whereas the western lure comprising of relatively lower concentrations of E11–14:Ac and Z11–14:OH, and an additional fourth component Z11–14:Al has reportedly captured more *C. rosaceana* males than the three-component eastern lure in British Columbia and Ontario (Weatherston et al. 1976, Vakenti et al. 1988). However, this evidence of different geographical pheromonal strains of *C. rosaceana* in North America (Thomson et al. 1991, Delisle 1992) is being challenged by recent reports suggesting the occurrence of Z11–14:Al in the pheromone blends of eastern populations of *C. rosaceana* (El-Sayed et al. 2001, 2003). El-Sayed et al. (2003) detected relatively smaller amounts of Z11–14:Al in the pheromone glands of females from Quebec, Michigan, and New York, but found no effect of this compound on trap catch. The authors inferred that North American populations of *C. rosaceana* exhibit "monomorphic" pheromone variation rather than "polymorphic" variation, because moths from their study locations contained different amounts and ratios of the same four compounds. Monomorphic (quantitative) and polymorphic (qualitative) variations in sex pheromone blends have been reported for different geographical populations of many insects (Klun and Cooperators 1975, Madsen and Madsen 1980, Arn et al. 1983, Durant et al. 1986, Gronning et al. 2000).

The results of this study demonstrate that the delta trap baited with western lure provided a more efficient monitoring system for *C. rosaceana* males during both flight periods. Thus, delta trap baited with western lure is recommended for monitoring *C. rosaceana* in Minnesota. However, fruit growers who prefer the wing trap may still achieve good monitoring data by using wing trap baited with western lure. The delta trap is slightly more expensive ($4.68 per set) than wing trap ($3.35 per set), but this initial higher cost may be offset because the delta type is more durable and can be reused over multiple seasons. Pheromone mating disruption is increasingly being evaluated as a pest management strategy against leafrollers and other moth pests in North America (Deland et al. 1994; Agnello et al. 1996; Lawson et al. 1996; Shorey and Gerber 1996; Fadamiro et al. 1998, 1999; Isaacs et al. 1999). The western lure should provide better mating disruption of *C. rosaceana* in Minnesota, although the notion that higher mating disruption efficacy will result from the use of optimal blend needs to be investigated.

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