INTEGRATED PEST MANAGEMENT OPTIONS FOR THE CONTROL OF *ACALYMMA VITTATUM* (FABRICIUS), THE STRIPED CUCUMBER BEETLE IN SOUTHWESTERN ONTARIO

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Abstract

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In response to increased grower concerns, research was undertaken to investigate field biology, insecticide resistance and integrated management of striped cucumber beetle (SCB), *Acalymma vittatum* (F.), the most important insect pest of Cucurbitaceae in Ontario. Mini-Masner and baited yellow sticky traps revealed that, in southwestern Ontario, SCB are univoltine, overwintered adults entering cucurbit fields as plants emerge or are transplanted. Field studies found that foliar application of currently recommended azinphosmethyl or endosulfan effectively protected cucurbit foliage for only four days. Laboratory bioassays identified acetamiprid, imidacloprid, thiamethoxam, carbaryl, and cypermethrin as potentially effective alternative insecticides for SCB control. Application of imidacloprid as a planting water or seed treatment respectively protected developing seedlings for as long as four and five weeks. Trap rows of squash grown from seed treated with imidacloprid did not provide consistent protection of cucumber seedlings. Planting water and, especially seed treatments for SCB control in cucurbits could realize significant economic and environmental benefits for Ontario growers. A sustainable integrated SCB management strategy for Ontario cucurbit growers is outlined.

Introduction

Recently, production of Cucurbitaceae (cucumbers, gherkins, pumpkins, squash and melons) in southwestern Ontario has more than doubled, rising from 2,515 ha in 1995 to 5,075 ha in 2000 (Anonymous 2000). Correspondingly, farm value of produce harvested rose by nearly 25% from \$19.5 million (Cdn \$) in 1995 to \$24.3 million (Cdn \$) in 1999 (Anonymous 2000). First reported in North America in the mid-19th century (Harris 1842), the striped cucumber beetle (SCB), *Acalymma vittatum* (F.), is considered the most important insect pest of Cucurbitaceae across the United States and southern Canada (Hoffmann et al. 1996). Adults feed on the cotyledons, leaves, flowers, and fruit, while the larvae are strictly root feeders (Matthewman 1951). Economic losses result from both direct feeding and the transmission of *Erwinia tracheiphila* (E.F. Smith) Holland, the bacteria responsible for bacterial wilt. If control measures are not implemented, Canadian yield losses due to direct feeding by SCB and the related spotted cucumber beetle, *Diabrotica undecimpunctata howardi* (Barber), have been estimated at 15%. Losses due to bacterial wilt can further reduce yields (Pitblado and Lucy 1994).

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Although SCB economic thresholds for cantaloupe and pickling cucumbers have been determined in the United States (Brust and Foster 1999), neither decision-making strategies nor integrated pest management (IPM) programs are presently practised in Ontario. While biology, seasonal density, behaviour and damage have been well documented for SCB in the United States (Lewis et al. 1990), laboratory and field studies on Canadian population dynamics and seasonality have not been published. Indeed, no Canadian work has been reported since Matthewman summarized SCB biology and control in 1951.

For a number of years, Ontario cucurbit growers have expressed concern about unsatisfactory SCB control in their fields. By 1997, this concern had increased to the point where "identification of insecticide resistance in cucumber beetle populations on cucurbits" was identified as a specific research priority by the Ontario Fruit and Vegetable Growers' Association. In response, research began in 1998 to improve management programs in Ontario fields. This paper summarizes subsequent observations on Ontario SCB field biology; compares efficacy and economics of current and experimental chemical SCB control tactics and, finally, recommends an integrated SCB control strategy for Ontario growers.

Materials and Methods

Field Biology

Adult SCB were monitored using: 1) modified mini-Masner (MM) traps (Masner and Goulet 1981; MacIntyre 2000) and, 2) yellow sticky traps baited with a synthetic cucurbit blossom kairomone (1:1:1 mixture of 1,2,4-trimethoxybenzene, indole, and *trans*-cinnamaldehyde [TIC])(Hoffman et al. 1996). In 1998 only, a single MM trap was located in the border row of a block of squash in Talbotville, Ontario. Insects were collected and identified weekly from June until September. Four yellow sticky traps, separated by 10 m, were located in a line in the border row of a large block of cucurbits on the same farm. Insects were counted weekly from mid-July until September in 1998 and from June until September in 1999; all traps and baits were changed when insects were counted. Trap height was adjusted each week to position traps 15–30 cm above the developing plant canopy. Data collected were used to establish seasonal SCB population trends.

Management

Chemical Control: In order to identify insecticides more toxic to SCB than currently recommended endosulfan, a culture was established from SCB collected near Talbotville, ON in September 1998 and subsequently continuously reared in the laboratory following a protocol modified from Cuthbert et al. (1968). Adults, maintained in mesh cages in walk-in insectaries (25 ± 1°C; 65 ± 5% RH; 16 L:8 D) at Southern Crop Protection and Food Research Centre (SCPFRC) London, were fed cucumber or squash seedlings, pollen and water *ad libitum*; larvae were reared on squash or cucumber seedlings (MacIntyre 2000). Seven insecticides were compared by direct-contact bioassay: 1. endosulfan (97.9% purity); 2. carbaryl (99.9%); 3. fipronil (97.1%); 4. acetamiprid (99.9%) (1–4, Aventis CropScience Canada, Regina, SK); 5. imidacloprid (97.1%) (Bayer Inc. Agriculture Division, Crop Protection, Toronto, ON); 6. cypermethrin (91.1%); and, 7. thiamethoxam (97.1%) (6–7, Syngenta Crop Protection, Guelph, ON). Groups of 10 adults were anaesthetized with CO_2 in clean, waxed pasteboard cups. Anaesthetized SCB were transferred to glass petri dishes and placed in the Potter spray tower. Five ml aliquots of the desired concentration of each technical grade insecticide solution in acetone-olive oil (Harris and Turnbull 1986) were sprayed onto beetles. Treated SCB were transferred into clean pasteboard cups containing a dental wick dipped in reverse osmosis water. A glass petri dish prevented escape. At least three bioassays were performed for each concentration of each insecticide. Bioassays were held at 27 ± 1°C and 65 ± 5% RH under continuous light. Control insects treated with only acetone-olive oil were included in each test. Mortality was counted after 24 hrs; data were corrected for natural mortality (<15 % for all bioassays) using Abbott's correction (Abbott 1925). Regression lines, LC_{50} and 95% Fieller limits for each insecticide were calculated using a log-probit analysis program (S103, Statistical Research Service, Agriculture and Agri-Food Canada).

Experiments were also undertaken to evaluate performance of recommended and experimental insecticides for SCB control under field conditions (MacIntyre-Allen et al. 2001).

Cultural Control: In addition to pest monitoring and chemical control, an SCB-IPM program may include cultural management. Radin and Drummond (1994) found that squash was an effective trap crop for cucumber. Expanding on their work, protection of pickling cucumbers by squash trap crops grown from either untreated or imidacloprid-treated seed was investigated at two sites (Lot 17, Concession 3 and Lot 3, Concession 9, Township of Delhi, R.M. Haldimand-Norfolk) in each of 2000 and 2001. At each site, a single trap row of squash seedlings (cv. Mini-Green Hubbard) was planted as the outside row of the experimental field. The trap row was divided into 25 m lengths. Three treatments were evaluated: Blank (no squash seedlings); Untreated (no seed treatment applied to squash seed); Treated (squash seed treated with imidacloprid [GAUCHO® 480F] @ 5.0 mg a.i./seed). At each site each year, all treatments were replicated down the row, at least three times, in a randomized complete block design. At regular intervals after planting the trap row, SCB feeding damage was counted in cucumber seedlings in the row adjacent to the trap row (Row 1) and in the fifth row from the trap row (Row 5). In each plot, SCB damage was evaluated in two sub-samples, separated by 3 m. The first sampled plant was located approximately 5 m from either end of the plot; damage was then counted in the next 20 (2000) or 15 (2001) plants in succession. The number of feeding scars was counted in each cotyledon and, as growth continued, in the 3–5 youngest true leaves on each plant. Damage was expressed as the number of feeding holes/cotyledon or leaf. Significance of observed differences in feeding damage among treatments in each cucumber row on each sampling date was estimated by Analysis of Variance and Fisher's Protected Least Significant Difference test (Statistix Analytical Software, Tallahassee Florida).

Benefit Analysis

To determine the relative costs of different methods of SCB management in cucumbers and squash, data on recommended planting densities were determined from the 2000–2001 Vegetable Production Recommendations (OMAFRA 2000). Grower costs of formulated insecticides were obtained either from Pesticides for Fruits, Vegetables and Field Crops in Ontario (Goodwin 2000) or directly from the manufacturer (Gustafson Partnership, Calgary AB). Labour costs for pesticide application were derived from the annual provincial summary of custom work rates (Anonymous 2002). To permit direct financial comparison, costs for each program were then calculated and expressed in terms of dollars/ha.

Results and Discussion

Field Biology

Mini-Masner traps effectively collected SCB for only the first three weeks of plant development. As rampant vine growth obscured the collecting screen, SCB collection efficiency decreased; for this reason MM traps were not installed in 1999 (Fig. 1). Baited sticky traps, however, remained effective throughout the entire season. The use of baited sticky traps would provide a relatively simple, fast and affordable method for growers to monitor SCB populations in their fields.

Our studies showed that in Ontario SCB are univoltine. Overwintered adults arrived *en masse,* in cucurbit fields the third week of June in both 1998 and 1999 (Fig. 1). SCB fed on available cotyledons and first true leaves; distribution throughout cucurbit fields was patchy with highest

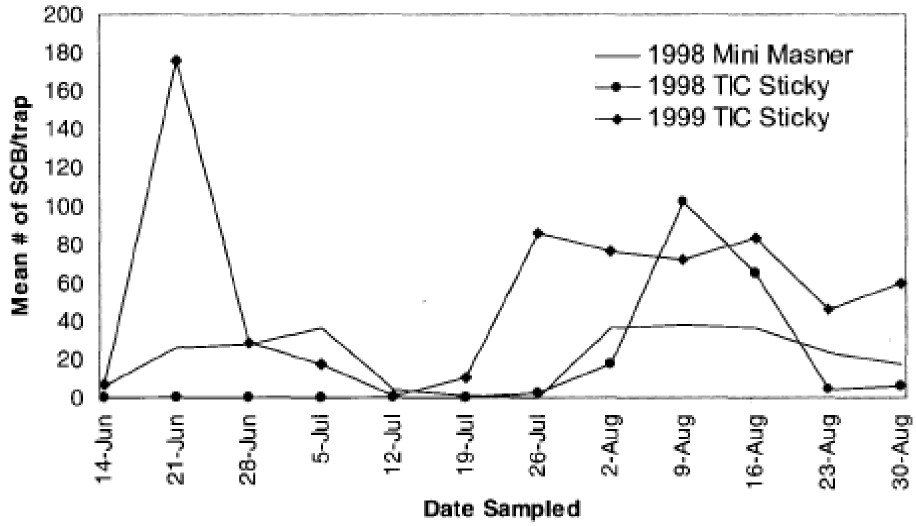

FIGURE 1. Mean number of striped cucumber beetles per Mini Masner and TIC baited sticky traps setup in squash fields in Talbotville, Ontario from June until September in1998 and 1999.

populations generally along field edges. Similar to observations by Pair (1997), the most severe damage observed occurred early in the season when plants ranged from the cotyledon to the 5th true leaf stage in both 1998 and 1999. Adult numbers decreased the last week of June with the death of overwintered adults. In the last week of July, populations increased as first generation adults began to emerge and feed on flowers and developing fruit (Fig. 1). Late season damage was not economically important in our trials.

SCB can also be directly counted on the developing vines. In the United States economic thresholds (ET) and economic injury levels (EIL) have been developed for cucumbers and muskmelons. While Burkness (1996) reported an EIL of 0.1–7.0 SCB per plant for processing cucumbers, equivalent to an ET ranging from 0.1–5.0 (75 % of EIL) SCB per plant, Brust and Foster (1999) proposed an ET of 0.5–1.0 SCB per plant for muskmelon. Although no similar work has been done in Canada, Ontario cucurbit growers could adopt these ET and EIL. To date, no EIL have been determined for either squash or pumpkin.

Management

Chemical Control: The next phase in the development of an effective IPM program is to examine different control tactics. At present, cucurbit growers in southern Ontario almost exclusively rely on foliar applications of endosulfan (THIODAN®) or azinphosmethyl (GUTHION®) to control SCB. Current Vegetable Production Recommendations indicate that growers should begin to spray when seedlings are breaking through the soil and repeat application when beetles reappear throughout the season (OMAFRA 2000). With only two chemicals available, insecticide resistance has become a concern.

Although direct contact bioassay studies in the laboratory did not identify resistance to either endosulfan or azinphosmethyl in any of 11 SCB populations sampled across southwestern Ontario, one population was identified with higher tolerance to both chemicals (MacIntyre 2000). While SCB tolerance to these two chemicals was evaluated in the laboratory, field studies of persistence

TABLE I. Relative toxicity of insecticides to laboratory-reared adult striped cucumber beetle, *Acalymma vittatum* treated in a Potter spray tower.

Insecticide	n[1]	Slope ± SEM	LC_{50}[2]	95% F.L.[3]	Relative Toxicity[4]
endosulfan	156	2.0 ± 0.4	556.0	500.0 – 762.0	1
thiamethoxam	170	2.0 ± 0.5	8.0	2.0 – 9.0	69
cypermethrin	200	2.0 ± 0.6	8.0	0.2 – 9.0	73
carbaryl	160	3.0 ± 0.6	5.0	0.0 – 6.0	102
fipronil	150	2.0 ± 0.5	2.0	0.1 – 3.0	251
imidacloprid	319	1.0 ± 0.6	1.0	0.1 – 4.0	400
acetamiprid	160	2.0 ± 0.4	0.3	0.0 – 3.0	1794

1 number of SCB tested
2 concentration (ppm)
3 Fieller limits
4 calculated by dividing the observed LC_{50} for endosulfan by the observed LC_{50} for the test insecticide

on vine foliage demonstrated that both endosulfan and azinphosmethyl effectively protected foliage for less than four days (MacIntyre-Allen et al. 2001). These observations had two major implications:

1) Growers applying either insecticide early in the season, as beetles began arriving from overwintering sites, would realize effective control for only a few days after the initial spray application. This lack of long-term control might explain why growers felt SCB were becoming resistant to both endosulfan and azinphosmethyl.
2) One application of either endosulfan or azinphosmethyl would not have adequately controlled SCB populations in either 1998 or 1999. Additional weekly sprays would have been required until plants became established.

Application of weekly sprays of only two chemicals contradicts a basic principle of both IPM and Integrated Resistance Management. While endosulfan and azinphosmethyl do have different modes of action, their relatively short residual activity dictated repeated application. Inclusion of other insecticides with different modes of action would therefore strengthen the control program. The two most promising experimental insecticides identified were acetamiprid and imidacloprid, respectively, 1794 times and 400 times more toxic than endosulfan (Table I). Fipronil, carbaryl, cypermethrin and thiamethoxam were also more toxic than endosulfan. Carbaryl, however, is currently under review in the USA as dictated by the Food Quality and Protection Act (1996); future Ontario recommendation for SCB management is therefore unlikely. Chloronicotinyl (acetamiprid, imidacloprid), pyrethroid (cypermethrin) and phenylpyrazole (fipronil) insecticides were all effective SCB control agents. Addition of these insecticides to the current arsenal would strengthen the current SCB management program and would help to slow the development of insecticide resistance.

The method of insecticide application can have a pronounced impact on duration of plant protection. For example, while imidacloprid and cypermethrin were quite toxic to SCB in the laboratory, foliar application of these insecticides did not provide more than four days' protection under field conditions (MacIntyre-Allen et al. 2001). Planting water and seed treatments of imidacloprid proved more persistent than foliar application. Planting water application of 6.0 mg a.i./plant protected seedlings for up to four weeks after planting. Seed treatment protected cucumber

TABLE II. Effect of squash-trap rows on damage to pickling cucumbers by striped cucumber beetle (SCB), *Acalymma vittatum*, in southwestern Ontario, 2000–2001.

		Mean Number SCB Feeding Holes/Leaf[1] for Indicated Site and Treatment[2]							
		Site 1				Site 2			
Row Counted[3]	Days after Planting[4]	Stage[5]	Blank	Untreated	Treated	Stage	Blank	Untreated	Treated
a) 2000:									
1	14	C	0.7 b[6]	2.2 a	0.4 b	C	0.3 b	0.6 a	0.2 b
5			0.2 b	0.4 a	0.1 b		0.6 a	0.6 a	0.2 a
1	21	1 TL	1.0 b	2.4 a	0.1 c	1 TL	0.6 b	1.2 a	0.6 b
5			0.3 a	0.4 a	0.3 a	C	2.1 b	3.8 a	1.6 b
1	28	3 TL	8.5 a	6.3 b	6.0 b	3 TL	0.8 a	1.1 a	1.1 a
5			2.8 a	2.4 a	1.9 a	5 TL	1.7 a	2.1 a	1.4 a
b) 2001:									
1	10	C	0.1 b	0.3 a	0.0 b	C	4.9 a	2.3 a	3.1 a
5			---[7]	---	---		---	---	---
1	17	2 TL	0.6 a	0.8 a	0.7 a	3 TL	6.7 a	4.3 a	5.6 a
5			0.8 a	0.0 a	1.0 a		2.3 a	2.9 a	2.3 a
1	24	4 TL	6.2 a	4.6 a	5.1 a	5 TL	10.2 a	9.3 a	10.8 a
5			4.8 a	1.7 a	4.4 a		5.0 a	5.0 a	5.2 a

1 Based on counts of damage to 2 × 20 (2000) or 2 × 15 (2001) cotyledons or youngest true leaves (maximum 4) per plot on each sampling date. A minimum of three replicates of each treatment was established at each site each year.

2 Blank: no squash plants in trap row; Untreated: squash grown from untreated seed; Treated: squash grown from seed treated with 5.0 mg a.i./seed imidacloprid.

3 Relative to trap row; Row 1 located adjacent to trap row; Row 5 was fifth row from trap row.

4 Days after planting trap row.

5 Cucumber growth stage when SCB damage assessed (C: cotyledon; TL: true leaf/leaves).

6 On each sampling date, values within a row for each site followed by the same letter are not significantly different as determined by ANOVA and Fisher's Protected LSD test.

7 Data not available.

seedlings for six and a half weeks when applied at 0.75 mg a.i. plant and squash seedlings for nearly three weeks when applied at 1.0 mg a.i./plant (MacIntyre-Allen et al. 2001).

Cultural Control: Preliminary results in 2000 indicated that in the first three weeks after planting, cucumber plants in the row immediately adjacent to the imidacloprid-treated squash plants had significantly less feeding damage than cucumber plants beside untreated squash plants (Table IIa). In the same time period, cucumbers beside blank lengths of the trap row had less damage than cucumbers beside untreated squash plants. Data collected from cucumbers five rows from the trap row were not as consistent. In site 1, 14 days and in site 2, 21 days after planting feeding damage was higher for cucumbers parallel to untreated squash compared to those parallel to treated squash (Table IIa).

Results were less promising in 2001 (Table IIb). SCB feeding damage was significantly reduced adjacent to treated squash plants only at site 1 and 10 days after planting. In both years however, SCB populations and consequent damage were generally quite low in the experimental fields. More work is needed to examine the potential benefits of trap rows under heavier adult pressure.

IPM also encourages the use of biological agents for control of pest populations. However, it is unlikely that under Ontario conditions insect biological agents would have a significant impact on SCB. Most cucurbits are short-term crops; pickling cucumbers, for example, grow from seed to harvest in as little as 51 days. Although a number of parasitoids including *Celatoria setosa* (Coq.) (Diptera: Tachinidae) and *Syrrhizus diabroticae* (Gahan)(Hymenoptera: Braconidae) can moderate SCB numbers, population densities of the parasitoids are generally too low in the early season to effectively prevent damage (Gould 1944). While we did identify low populations of *C. setosa* late in the season, no work was undertaken to identify conditions that would favour field populations of these agents. Neither of these biological agents are commercially available.

Benefit Analysis

Depending on the insecticide selected and the number of applications required, the cost of the current foliar SCB management program for cucumber ranges from approximately \$103.00–\$128.00/ha (Cdn \$) (Table III). Costs would increase if extended arrival of the over-wintered population (Fig. 1) required application of an additional insecticide and would decrease if only a single flush of SCB was recorded. Registration and application of cypermethrin and imidacloprid for foliar application would greatly reduce selection pressure without increasing the number of treatments; depending on the replacement insecticide, the cost of foliar SCB management could either increase marginally or decrease substantially (Table III).

Cucumber seed treatment might be an effective method for SCB management. Seed treatment was less costly (Table III) and protected developing seedlings significantly longer than any foliar application (MacIntyre-Allen et al. 2001). Cucumber seeding densities vary widely, depending on the end use of the crop. Final plant densities range from a high of 150,000 plants/ha for machine-harvested, pickling cucumbers, down to 20,600 plants/ha for hand-picked, slicing cucumbers. At the highest seeding density, the cost of seed treatment is competitive with the cheapest foliar control program (Table III). At lower seeding densities, the potential economic advantage of seed treatment is quite significant.

Planting water treatments also showed promise for SCB management in slicing cucumbers. A few growers seeking premium prices for early cucumbers, plant plug seedlings each year. We did not evaluate planting water treatments for cucumbers in our work. However, at lower planting densities, even if the 6.0 mg a.i./plant rate found effective in squash (MacIntyre-Allen et al. 2001) was applied to cucumber transplants, the cost of planting water treatment compares favourably with the current cost of foliar SCB control (Table III).

Costs of foliar protection against SCB for squash and pumpkin are the same as for cucumber (Table IV). Early in the season it may be possible to reduce product costs by as much as 60% if the

TABLE III. Relative costs of cucumber management programs for early season control of striped cucumber beetle, *Acalymma vittatum*, in south-western Ontario.

Cucumber Type	Pickling	Pickling	Pickling	Pickling	Pickling	Slicing	Slicing
Common Name	endosulfan	azinphosmethyl	cypermethrin	imidacloprid	imidacloprid	imidacloprid	imidacloprid
Trade Name	THIODAN® 4EC	GUTHION® 240SC	RIPCORD® 400EC	ADMIRE® 240F	GAUCHO® 480F	ADMIRE® 240F	GAUCHO® 480F
Unit Cost/L	$15.15	$14.00	$114.25	$246.85	$500.00	$246.85	$500.00
Application Method	foliar	foliar	foliar	foliar	seed treatment	planting water	seed treatment
# Applications	3	2	2	2	1	1	1
Rate Applied/ha	1.5 L	2.25 L	87.5 ml	0.2 L	85.4–260.0 ml[1]	465.0–695.0 ml[2]	32.0–48.0 ml[3]
Material Cost/ ha/Application	$22.73	$31.50	$10.00	$49.37	$42.70–$130.00	$114.79–$171.56	$16.00–$24.00
Labour Cost/ ha/Application	$20.00[4]	$20.00[4]	$20.00[4]	$20.00[4]	$0.00[5]	$0.00[6]	$0.00[5]
Total Cost/ ha/Application	$42.73	$51.50	$30.00	$69.37	$42.70–$130.00	$114.79–$171.56	$16.00–$24.00
Total Cost/ha for Program	$128.19	$103.00	$60.00	$138.74	$42.70–$130.00	$114.79–$171.56	$16.00–$24.00

[1] based on application rate of 0.75 mg a.i./seed to 55.0–167.0 × 10^3 seeds/ha, and assumes germination of 90% to give a final plant population of 50.0 (hand-pick)–50.0 (machine harvest) × 10^3 plants/ha (OMAFRA 2000)

[2] based on application of 6.0 mg a.i./plant to plant population of 20.6–30.9 × 10^3 plants/ha (OMAFRA 2000)

[3] based on application rate of 0.75 mg a.i./seed to 20.6–30.9 × 10^3 seeds/ha, and assumes germination of 90% to give a final plant population of 18.5–27.8 × 10^3 plants/ha (OMAFRA 2000)

[4] Anonymous 2002

[5] no additional charge for application as commercial seed-treaters include cost of application in the cost of the seed-treatment formulation. Small scale growers might have to consider cost of their own time should they treat seed on-farm.

[6] no additional charge for application as growers would add ADMIRE to starter solution (water ± starter fertilizer) which is deposited with each transplanted seedling

TABLE IV. Relative costs of squash/pumpkin management programs for early season control of striped cucumber beetle, *Acalymma vittatum*, in southwestern Ontario.

Common Name	endosulfan	azinphosmethyl	cypermethrin	imidacloprid	imidacloprid	imidacloprid
Trade Name	THIODAN® 4EC	GUTHION® 240SC	RIPCORD® 400EC	ADMIRE® 240F	ADMIRE® 240F	GAUCHO®
480F						
Unit Cost/L	$15.15	$14.00	$114.25	$246.85	$246.85	$500.00
Application Method	foliar	foliar	foliar	foliar	planting water	seed treatment
# Applications	3	2	2	2	1	1
Rate Applied/ha	1.5 L	2.25 L	87.5 ml	0.2 L	83.3–154.2 ml[1]	38.5–71.9 ml[2]
Material Cost/ ha/Application	$22.73	$31.50	$10.00	$49.37	$20.56–$38.06	$19.25–$35.95
Labour Cost/ ha/Application	$20.00[3]	$20.00[3]	$20.00[3]	$20.00[3]	$0.00[4]	$0.00[5]
Total Cost/ ha/Application	$42.73	$51.50	$30.00	$69.37	$20.56–$38.06	$19.25–$35.95
Total Cost/ha for Program	$128.19	$103.00	$60.00	$138.74	$20.56–$38.06	$19.25–$35.95

[1] based on application of 6.0 mg a.i./plant to plant population of 3.3–6.2 × 10^3 plants/ha (OMAFRA 2000)

[2] based on application rate of 5.0 mg a.i./seed to 3.7–6.9 × 10^3 seeds/ha, and assumes germination of 90% to give a final plant population of 3.3–6.2 × 10^3 plants/ha (OMAFRA 2000)

[3] Anonymous 2002

[4] no additional cost for application as growers would add ADMIRE to starter solution (water ± starter fertilizer) which is deposited with each transplanted seedling

[5] no additional cost for application as commercial seed-treaters include cost of application in the cost of the seed-treatment formulation. Small scale growers might have to consider cost of their own time should they treat seed on-farm.

grower applies the insecticide only in a band over small seedlings (OMAFRA 2000). Product cost ranges from approximately 53%–61% of the total cost of foliar application. Since plant populations of both squash and pumpkins are generally much lower than those for cucumber, transplanted seedlings of these crops are much more common. Planting water protection of those transplants is an attractive option; protection is more persistent (MacIntyre-Allen et al. 2001) and cost is much lower (Table IV). The benefits of seed treatment for protection of squash and pumpkin are slightly greater than planting water treatments (Table IV).

The benefits of planting water and, especially seed treatments for SCB control in cucurbits are more than economical. For example, such treatments may have less impact on beneficial insects. In contrast with non-systemic insecticides such as endosulfan and azinphosmethyl, application of a systemic insecticide such as imidacloprid is felt to be relatively safe for beneficial insects that do not feed directly on the treated plant (Pflüger and Schmuck 1991). Sublethal effects on a predator such as *Harmonia axyridis* (Pallas) and a parasitoid such as *Microplitis croceipes* Cresson have, however, been reported (Stapel et al. 2000; Vincent et al. 2000). Predators and parasitoids, however, are unlikely to play a significant role in SCB regulation early in the season (Gould 1944). Safety to pollinating insects such as introduced honeybees, *Apis mellifera* L. is also a concern. Recent comprehensive studies have, however, clearly shown that treatment of sunflower seed with imidacloprid posed no risk to honeybees (Schmuck et al. 2001).

Additional benefits of seed treatment include: reduced operator exposure; reduced soil erosion and compaction; and, a significantly reduced quantity of insecticide required for effective SCB control. For example, pumpkin seed treatment could require as little as 18.5 g a.i. imidacloprid/ha. Equivalent protection by foliar treatment would require at least two applications of imidacloprid ($48 \times 2 = 96$ g a.i./ha) or endosulfan ($600 \times 2 = 1{,}200$ g a.i./ha). The consequent environmental benefit ranges from 80.7% for imidacloprid to as high as 98.5% were endosulfan applied to developing seedlings.

Conclusion

Current production recommendations in Ontario suggest that cucurbit growers spray when seedlings are breaking through the soil and repeat application if SCB adults reappear (OMAFRA 2000). Our research demonstrated that cucurbit growers should begin to monitor fields with TIC-baited sticky traps at the time of seeding or transplanting. When SCB appear on traps, growers should begin to check cucumber and melon plants and apply azinphosmethyl or endosulfan at recommended rates when the population reaches the ET. As mentioned earlier, no ET have been established for squash and pumpkin; it is, however, unlikely that EIL for these crops would be lower than those for cucumber.

Although early season control is the main concern in Ontario, monitoring with TIC-baited sticky traps should continue throughout the season. If the first generation population increases above the ET, growers should rotate to azinphosmethyl or endosulfan depending on which insecticide was used for control of overwintered SCB. To further delay development of resistance to foliar insecticides, we recommend that current labels for cypermethrin and imidacloprid, insecticides with different modes of action, be expanded to include SCB control. Both insecticides provided short-term protection when applied to foliage.

Our research further indicated that imidacloprid, as a planting water treatment and, especially as a seed treatment, is an excellent alternative to foliar application of endosulfan or azinphosmethyl. We recommend extension of current Canadian labels for both ADMIRE® 240F (planting water treatment) and GAUCHO® 480FL (seed treatment) to include SCB control. Label extension would allow Ontario growers to avail themselves of the significant economic and environmental benefits of these applications and would further benefit the expanding Ontario cucurbit industry.

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