The Americas Journal of Plant Science and Biotechnology ©2011 Global Science Books

Optimizing the Delivery of GF-120 NF Naturalyte Fruit Fly Bait to Control Apple Maggot in Organic Orchards

Julia Reekie[1*] • Eric Specht[1] • Kathryn Carter[2] • Margaret Appleby[3] • Hannah Fraser[4] • Ken Wilson[5] • Lindsay Pink[6]

[1] Agriculture and Agri-Food Canada, 32 Main Street, Kentville, Nova Scotia B4N 1J5, Canada
[2] Ontario Ministry of Agriculture, Food and Rural Affairs, 1283 Blueline Road, Simcoe, Ontario N3Y 4N5, Canada
[3] Ontario Ministry of Agriculture, Food and Rural Affairs, R.R. #3, 95 Dundas Street East, Brighton, Ontario K0K 1H0, Canada
[4] Ontario Ministry of Agriculture, Food and Rural Affairs, 4890 Victoria Avenue North, Vineland, Ontario L0R 2E0, Canada
[5] R.R. #1, Thornbury, Ontario NOH 2P0, Canada
[6] Box 1072, Markdale, Ontario N0C 1H0, Canada

***Corresponding author*: * julia.reekie@agr.gc.ca**

ABSTRACT

The apple maggot (*Rhagoletis pomonella*) is a key pest of apples in eastern Canada and the United States causing fruit damage and significant economic losses. Research was conducted to optimize the delivery of a newly registered product, GF-120 NF Naturalyte Fruit Fly Bait (GF-120; active ingredient: spinosad) to control apple maggots in organic orchards. The effectiveness of applying GF-120 at two application intervals (7- and 14-day) and the potential of using perimeter sprays and alternate row spraying to control apple maggots were tested in apple orchards. The goal is to achieve acceptable level of pest control by using the minimum amount of control product. In a separate trial, application methods were refined for the maximum distribution of GF-120 within tree canopies and to prune fully grown, 45-year old 'McIntosh' large-sized trees for better penetration of GF-120 into inner tree canopies. Results showed that GF-120 should be applied every 7-10 days following label recommendations to adequately control apple maggots in orchards with severe pest pressure and resident infestations. If the apple maggot is not a resident pest, it is possible to apply spray to alternate tree rows or only to the perimeter of the orchard to control pest invasions. In orchards consisting of very large trees with dense foliage, uniform distribution and good penetration of GF-120 into tree canopies are extremely important to attain effective apple maggot control.

Keywords: *Malus* × *domestica*, perimeter spray, pruning, *Rhagoletis pomonella*, spinosad, spray intervals

INTRODUCTION

Apple maggot is one of the most serious pests in apple crops and there is zero tolerance for fruit infestation by apple maggot in the market place. Conventional growers often rely on organophosphate insecticides to control this pest (Reissig 2003). Although highly toxic to maggot flies and have a relatively long lasting residual toxicity in the field, these insecticides are also toxic to humans and other organisms (Reissig *et al.* 1980). Azinphosmethyl, one of the most toxic of the organophosphate insecticides (Gallo and Lawryk 1991), is currently under re-evaluation. It is likely that the rest of the organophosphate insecticides for apple crops will be restricted or eliminated in the near future. However, these active ingredients are key components of the insecticide program and their impending phase-out will potentially leave a gap in pest management practices. There is an urgent need for alternative pest management tools and transitional strategies from organophosphate insecticides to reduced-risk control products to enable growers to practice sustainable agriculture.

Organic growers have a very limited control material list to select from; premature drop and fruit damage caused by apple maggots can reduce saleable crop by as much as 75% (Robert Gardner, Gardner Orchards, pers. comm.). The only available organic apple maggot control products registered to date are Surround WP and GF-120 NF Naturalyte Fruit Fly Bait (Dow AgroSciences). Surround WP is a particle film kaolin clay product and its whitish colour interferes with visual cues used by maggot flies to locate hosts. With good coverage, it can provide the level of apple maggot control comparable to that of azinphosmethyl and spinosad treatments (Villanueva and Walgenbach 2007). However, it does not kill the pest and therefore offers no reduction in pest population. In addition, Surround WP is dusty to work with, making the work environment less than ideal.

According to Sciarappa *et al.* (2008), conventional growers are adopting organic production practices in record numbers. With the increase in the availability and adoption of reduced-risk products in agriculture, the risks to the environment and human health posed by the use of harmful pesticides will diminish. Since apple maggot is a serious pest for apple growers, it is important to develop reduced-risk tools and integrated approaches to manage apple maggots and to provide apple growers, organic as well as conventional, with alternative pest-management solutions. GF-120 is a naturalyte spinosad insecticide with low mammalian and avian toxicity but highly neurotoxic to apple maggots. It may be a good candidate to be considered in the implementation of new, reduced-risk approaches to managing crop pests. It contains only 0.02% spinosad and is listed by the Organic Materials Review Institute for use in organic production. Studies have shown that the baited formulation of this naturally produced compound is effective in the control of a number of fruit fly species (Burns *et al.* 2000; Peck and McQuate 2000; Vargas *et al.* 2002; Sciarappa *et al.* 2008). A recent study using GF-120 to control apple maggot flies has shown promise (Pelz *et al.* 2005), and efficacy trials conducted by Reekie *et al.* (2010) using GF-120 to control apple maggots had positive results. This spinosad-based product is suitable for use in both conventional and organic apple production.

Although GF-120 shows promise, its unusual bait-and-

Received: 11 December, 2009. Accepted: 11 May, 2011.

Original Research Paper

kill nature requires additional research to fine-tune application protocols and maximize its potential. This new product is formulated exclusively for maggot and fruit fly control. It is a stomach poison, with a sugar component in its formulation that attracts pests and is applied as large droplets (4-6 mm diameter) onto leaves (Sciarappa *et al.* 2008). By monitoring the level of pest infestations in the field, it can be determined when pest control is most needed. Synchronizing spray applications with the feeding habits of the maggots can increase product effectiveness, decrease pest populations and may help reduce the total number of spray applications required in a season.

In well-maintained commercial orchards, apple maggot is usually not a resident pest but rather an immigrant from neighbourhood neglected orchards and non-treated backyard apple trees (Chen *et al.* 2002). Every season, this pest invades the orchards searching for food and oviposition sites (Bostanian *et al.* 1999). Thus alternate strategies such as perimeter spray can effectively be implemented in orchards with no previous detectable resident apple maggot flies. Compared to the application of cover spray, perimeter spraying can reduce seasonal insecticide usage by 50% while maintaining a similar level of fruit injury (Trimble and Solymar 1997).

Only a small amount of GF-120 is needed to treat an area of orchard and uniform spray coverage is not essential. However, GF-120 can have a relatively short residual activity when it is exposed to hot and dry conditions (Yee *et al.* 2007). To ensure that GF-120 works to its full potential, trees with a dense growth form may need additional pruning to facilitate penetration of this product to the cooler, shaded inner tree canopy where its residual activity can be prolonged.

This study aims to optimize the delivery of GF-120 to control apple maggots in organic orchards by: 1. Varying application intervals to target the minimum amount of GF-120 required in a season without compromising apple maggot control; 2. Practicing perimeter spray or spraying alternate rows in an orchard to reduce the apple maggot pest populations and at the same time minimize the amount of control product used; 3. Refining the application methods for the maximum distribution of GF-120 within tree canopies and to prune large-sized trees for better penetration of GF-120 into the inner tree canopies.

MATERIALS AND METHODS

This project was conducted in 2008 in two Canadian provinces. In Nova Scotia, three field trials took place in two experimental orchards which were two and five acres (one acre = 0.4047 ha) in size. In Ontario, one field trial was conducted in a commercial orchard 12 acres in size. In each orchard, a randomized complete block design with four replications was employed. Unsprayed trees located at the edge of each orchard were used as controls to indicate the amount of pest pressure present. Trials were conducted using the GF-120 formulation applied at label rate of 1.5 L/ha except for the experiment in Ontario, where a higher rate of 2.25 L/ha was also used. Application followed methods as proposed by the registrant: GF-120 was applied diluted at a ratio of one part of product to four parts of water; using an ATV fitted with appropriate sprayer and nozzles, low volume of the product was applied and delivered as large bait droplets of 4-6 mm in diameter and uniform foliage coverage was not required. Apple maggot emergence was monitored using sticky yellow traps with lure. Spray application commenced soon after the capture of the first apple maggot fly and it was repeated every 7-10 days (or after a rain event) unless otherwise stated in the treatment protocol.

At harvest, 6-10 inner trees from each treatment plot of each trial were sampled and from each tree, 20 apples were randomly collected and placed inside a paper bag. Twenty apples from 16 control trees in each trial were also collected. After an incubation period at room temperature for 2-3 weeks, the skin surface was examined for maggot stings and the apples were cut in quarters to reveal any apple maggot injury. Each apple was given a value of '0' if it sustained no injury or '1' if injury was present.

Experiment 1

This trial was conducted in "Block 84", a 2-acre certified organic seedling ('Nova Easygro' × 'Ohlsen') research orchard located at the Research Centre in Kentville, Nova Scotia. This orchard is irregularly shaped with a tree-row spacing of 7 feet × 20 feet and there are 311 trees per acre. Since the lethal action of GF-120 against adult maggot flies occurs through ingestion, and feeding in flies is most intense during the first week after their emergence (Pelz *el al.* 2005), GF-120 was applied right at the emergence of the maggot flies and it was repeated a week following. After the initial applications, different frequencies of application were used to determine the optimal interval between applications. Trees received GF-120 applications every week were compared to those which received spray application once every two weeks. This experiment aimed to target the minimum amount of GF-120 used in a season to attain effective apple maggot control.

Experiment 2

Two trials were conducted at the "Sheffield Research Farm" located in Sheffield Mills, Nova Scotia in a 5-acre orchard consisting of 'Cortland' and 'McIntosh' cultivars on MM111 rootstocks. Untreated trees were located at the south and north ends of each row. Each treatment plot consisted of 50 trees with tree-row spacing of 13.8 feet × 26.7 feet with 118 trees per acre. Half of this 5-acre orchard block is certified organic while the other half is in transition to organic practice. Two rows of 'McIntosh' trees alternate with two rows of 'Cortland' trees such that rows 1 and 2 are 'McIntosh' and rows 3 and 4 are 'Cortland' and this arrangement repeats throughout the orchard. This orchard has no known history of resident apple maggot infestations and infestation level in 2007 was 11 and 18%, respectively in unsprayed 'McIntosh' and 'Cortland' trees located at the north and south ends of this orchard (Reekie *et al.* 2010). In October of 2007 after fruit harvest, apples heavily infested with apple maggots were collected and transferred to this orchard and approximately 1200 maggot-infested apples were placed at the north and south edges of the orchard to create a pest invasion situation for the 2008 season. If invasion is the only source of apple maggot attack, it may be possible to reduce the amount of pest control products used by applying GF-120 strategically to certain regions of the orchard and maintain acceptable levels of control within the orchard. To test this theory, different spray strategies employed were: 1) no spray control, 2) perimeter spray only, 3) spray applied to every tree row, 4) spray applied to every other tree row (and alternate the sprayed rows each time when a spray was applied).

Experiment 3

One trial was conducted in the "Barker Orchard", an organic 'McIntosh' orchard belonging to the Gardner Orchards located in Meaford, Ontario. This particular orchard block has very large 45-year old trees on standard rootstock. Tree-row spacing was 20 feet × 40 feet and there were 55 trees per acre. This project aimed to explore ways to optimize the delivery of GF-120 to large trees with dense tree canopies. For GF-120 to penetrate into the inner tree canopies, trees with a large growth form may require more pruning than the standard practice currently employed by the organic apple growers. To effectively control apple maggots in a large tree, more control product may be needed to compensate for the insufficient penetration into the dense tree canopy. Sprayer nozzles can also be adjusted at different spray angles to distribute GF-120 more evenly within the tree canopy for maximum apple maggot control. Six treatments were used:

1. Label rate of GF-120 (1.5 L/ha) applied with one pass to trees receiving standard pruning.
2. High rate of GF-120 (2.25 L/ha) applied with one pass to trees receiving standard pruning.
3. Label rate of GF-120 (1.5 L/ha) applied with two passes to trees receiving standard pruning.
4. High rate of GF-120 (2.25 L/ha) applied with two passes to trees receiving standard pruning.
5. Label rate of GF-120 (1.5 L/ha) applied with one pass to trees receiving extra pruning.

6. High rate of GF-120 (2.25 L/ha) applied with one pass to trees receiving extra pruning.

Trees in the plots designated as 'extra pruning' were pruned heavier than standard practice. For the plots designated to receive a 'two-pass' spray application, spray nozzles were adjusted as such that one pass directed the spray solution to the lower half of the tree while the other pass aimed to deliver spray solution to the upper half of the tree. For plots designated to receive a 'one pass' spray application, spray nozzles were aimed to deliver spray solution to the centre of the tree. At harvest, apples randomly sampled from each plots were collected separately from the upper and lower portions of each tree.

Data analysis

Contingency tables were used to assess differences in the presence or absence of apple maggot among treatments. Separate contingency tables were used to determine if the presence or absence of apple maggot was related to: a) application interval, b) application method, c) position on tree, d) rate of application, e) number of passes, and f) whether or not trees were heavily pruned. Analyses were conducted both on the basis of individual apples and individual trees (i.e. whether or not an apple contained a maggot and whether or not maggot was found on a particular tree). SAS (version 9.1 for personal computers) was used for all analyses. The 0.05 level of probability was used for tests of significance.

RESULTS AND DISCUSSION

Apple maggots were first caught on July 3 in "Block 84" and "Sheffield Research Farm" in Nova Scotia, and two female maggots were found on July 13 in the "Barker Orchard" in Ontario. GF-120 was first applied on July 3 and 14, respectively for Nova Scotia and Ontario and it was repeated every 5-10 days. For the 2008 season, GF-120 was applied 10 times in Nova Scotia (**Fig. 1**) and eight times in Ontario (**Fig 2**). Precipitations in the local area where trials took place were recorded (**Figs. 1** and **2**). Apples were harvested in September and apple maggot injury assessment was completed in October.

Nova Scotia trials

Three trials were conducted to determine the lowest amount of GF-120 needed to attain effective apple maggot control. In "Block 84", apple maggot pressure was very severe and the average level of fruit infestations reached 68.8% (**Table 1**). Increasing the application interval from weekly to bi-weekly failed to provide adequate control and the level of fruit injury increased from 3.3 to 10.2% (**Table 1**). Reissig (2003) also reported that bi-weekly application of spinosad did not provide adequate protection of apples from maggot attack likely due to the relatively short residual effectiveness of spinosad. On the other hand, spinosad applied on a weekly basis resulted in comparable apple maggot control as when organophosphate insecticides were applied. This investigation took place in orchards with relatively low pest pressure and the author suggested that spinosad may not be able to provide acceptable levels of control to protect high risk apple orchards that are located nearby heavily infested unsprayed hosts (Reissig 2003). In spite of the high pest pressure in "Block 84", injuries caused by apple maggot were considerably lower in apples treated with GF-120 (**Table 1**) and this suggests that GF-120 is likely to perform well in orchards where the activity of apple maggot flies is low to moderate.

The situation was different at the "Sheffield Research Farm" where no resident pest was found in previous seasons and the levels of maggot injury in apples were not significantly different, regardless of spray strategies deployed. Perimeter spray, alternate row spray and cover spray strategies practiced on 'McIntosh' and 'Cortland' apples resulted in less than 1.65% fruit damage even though pest pressure was moderately high with 35.3 and 30.6% damage in un-treated 'McIntosh' and 'Cortland' apples respectively

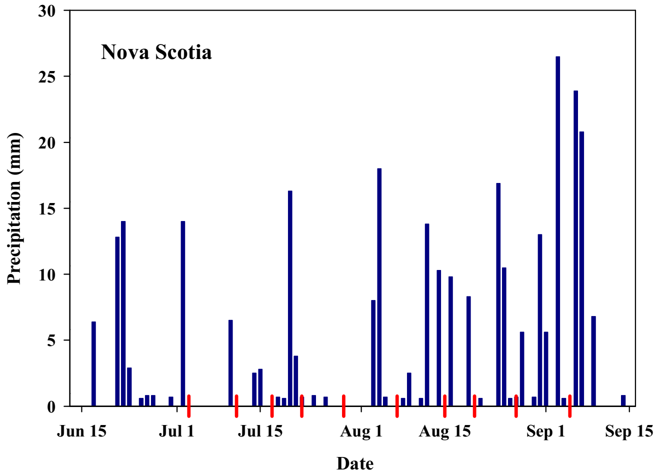

Fig. 1 Precipitation and GF-120 application in Nova Scotia. Precipitation recorded at the Environment Canada weather station in Kentville, Nova Scotia. Red tick marks indicate dates of GF-120 application: July 3, 11, 17, 22, 29, August 7, 15, 20, 27, September 5.

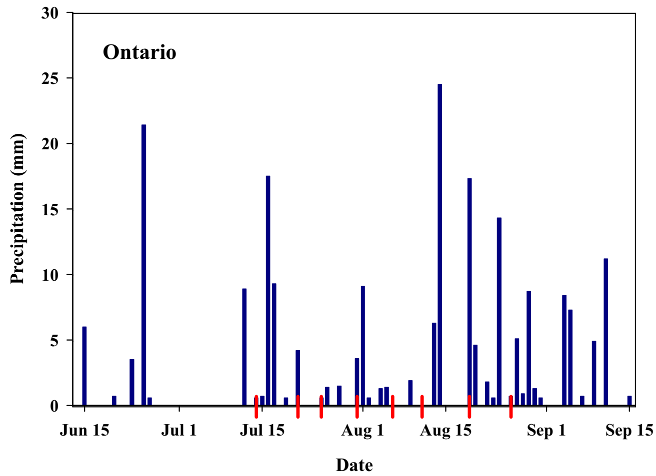

Fig. 2 Precipitation and GF-120 application in Ontario. Precipitation recorded at the orchard site in Meaford, Ontario. Red tick marks indicate dates of GF-120 application: July 14, 21, 25, 31, August 6, 11, 19, 26.

(**Table 1**). These alternative spraying strategies have essentially reduced the amount of GF-120 applied by more than 50% yet satisfactory apple maggot control is maintained. However, the benefit of perimeter and alternate sprays goes beyond saving cost, beneficial insects which are non-targeted pests in a cover spray are conserved and their populations can increase over time to exert their effect to keep other pest populations in check.

Researchers have found that the addition of an external feeding stimulant (sucrose) have significantly increased the effectiveness of pesticide-treated spheres in killing apple maggot flies (Stelinski *et al*. 2001; Prokopy *et al*. 2003). Feeding stimulant encourages prolonged feeding in flies resulting in the ingestion of a larger amount of insecticides. The probability of mortality was positively related to the duration of visit and feeding time (Duan and Prokopy 1988). Insecticide-treated spheres can achieve comparable control of apple and blueberry maggot flies as the use of organophosphate insecticides (Stelinski *et al*. 2001). Potentially GF-120 could be a good candidate for use in perimeter control as the sugar component in its formulation will attract and kill maggot flies before they can find their way into the interior of the orchards.

Perimeter control is not without its limitations; it has been demonstrated by a number of researchers in the past that perimeter spray (a.k.a. border control) and perimeter trapping are viable techniques to successfully manage immigrating adults and provide effective orchard-wide control

Table 1 Percentage of apple maggot infested apples in the trials conducted in Nova Scotia.

Treatment	Orchards		
	Block 84	Sheffield 'McIntosh'	Sheffield 'Cortland'
7-day Spray	3.30 a	-	-
14-day Spray	10.2 b	-	-
Perimeter Spray	-	0.20 a	0.40 a
Alternate Rows	-	1.25 a	1.25 a
All Rows	-	0.65 a	1.65 a
Control	68.8	35.3	30.6

Values followed by a common letter in a column for each trial are not significantly different at P<0.05.

Table 2 Percentage of apple maggot infested apples found on the upper and lower canopies of the tree for each spray treatment.

Rate	GF-120 (1.5 L/ha)		GF-120 (2.25 L/ha)	
Position	Upper	Lower	Upper	Lower
One-pass	11.73 a	4.33 b	6.80 a	3.25 b
Two-pass	2.75 a	2.75 a	6.37 a	5.05 a
Pruning	4.03 a	3.82 a	2.53 a	2.00 a

For each GF-120 rate, values followed by a common letter in a row are not significantly different at P<0.05.

Table 3 Percentage of apple maggot infested apples in the Ontario trial.

Rate	Pass	Pruning	'McIntosh'
GF-120 (1.5 L/ha)	1	Standard	8.00 a
GF-120 (2.25 L/ha)	1	Standard	5.08 bc
GF-120 (1.5 L/ha)	2	Standard	2.78 b
GF-120 (2.25 L/ha)	2	Standard	5.70 c
GF-120 (1.5 L/ha)	1	Extra	3.78 b
GF-120 (2.25 L/ha)	1	Extra	2.28 b
Control			42.00

Values followed by a common letter in a column are not significantly different at P<0.05.

in a few consecutive seasons, after which a cover spray will be needed for the following season(s) to regain acceptable level of apple maggot control and to reduce infestation of other arthropod pests (Trimble and Solymar 1997; Bostanian *et al*. 1999; Trimble and Vickers 2000). Often perimeter control can only achieve commercially acceptable apple maggot control in orchards with low to moderate infestation levels.

Ontario trial

The field trial in Ontario was conducted in an organic 'McIntosh' orchard consisting of very large trees. Apple maggot injury was 42% in untreated apples but the level of injury sustained depended on where the apples were located. Apples located in the upper areas of the tree had less apple maggot injury (31.4%) than apples from lower areas of the tree (52.6%) (data not shown).

Applying GF-120 through the orchard laneway only once (one-pass) did not adequately distribute GF-120 evenly into the large tree canopies and this was reflected in the different levels of fruit damage caused by apple maggot between the upper and lower parts of the tree. Maggot injury in apples was 11.73 and 6.80% in the upper part of the trees and 4.33 and 3.25% in the lower part of the trees for label and high rates respectively (**Table 2**). Interestingly, there was more fruit injury in the treated apples located in the upper half of the tree indicating that an insufficient amount of GF-120 was distributed to the upper part of the tree canopy with the 'one-pass' spray application. With the 'two-pass' spray application and/or 'extra pruning' treatments, there was no significant difference in the level of fruit injury between the upper and lower parts of the tree (**Table 2**). The 'two-pass' spray application and 'extra pruning' treatment were able to effectively distribute GF-120 evenly within the larger tree canopies.

Although using the label rate of GF-120 (1.5 L/ha) to control apple maggot infestation was able to reduce fruit injury from 42 to 8%, all other treatments tested in this field trial were superior to simply using the label rate. For example, a higher rate of GF-120 (2.25 L/ha) applied to the large trees in this 'McIntosh' orchard further reduced fruit injury to 5.08% (**Table 3**). Although the 'two-pass' label rate spray application was able to provide better apple maggot control than 'one-pass' label rate, this treatment used twice the amount of GF-120. 'Extra pruning' treatments, on the other hand, used the same amount of GF-120 as in the 'one-pass' spray applications but provided similar or better apple maggot control as the 'two-pass' spray applications (**Table 3**).

The size of a tree plays a role in determining how well GF-120 can work. When trees are unusually large, pruning out extra tree branches than what is normally done in a standard practice will open up the tree and allow GF-120 to penetrate into the inner tree canopy. In addition to a better distribution of GF-120 within the trees, the longevity of this control product is prolonged when it is not under direct sunlight. In the case of the 'McIntosh' orchard in this study, using the label rate combined with extra pruning was sufficient to reduce apple maggot injuries to below 3%, and it should be noted that increasing the rate of GF-120 provided no extra benefit to maggot control.

CONCLUSIONS

Undoubtedly, GF-120 is a useful apple maggot control product especially in organic orchards where few control products are permitted. Reekie *et al.* (2010) has established that GF-120 is as effective as Surround WP in the control of apple maggot. Surround WP is a kaolin clay product that forms a physical barrier on the fruits and deters adult maggot flies, whereas GF-120 is a neurotoxin which actively kills the adult flies through ingestion of the product. Compared to Surround WP, GF-120 is superior because it can reduce the pest population in an orchard over time. A trial carried out in 2007 in "Block 84" showed that applying GF-120 at label rate reduced fruit damage by apple maggot from 69 to 11% (Reekie *et al.* 2010). Our trial in 2008 was conducted in this same orchard using the label rate of GF-120. Results showed that fruit damage has further reduced to 3%, whereas apples not treated remained at 69% fruit damage level. Applying GF-120 to 'Block 84' over several seasons may likely reduce the resident apple maggot pest population to a minimum.

Knowing the previous history of the orchards will facilitate the implementation of different pest control methods to maintain acceptable levels of pest control. In certain circumstances, the amount of pest control products required can also be reduced. As demonstrated in this study, infestation severity, type of apple maggot infestation (i.e. resident pests as opposed to pest invasion), tree size and architecture are all crucial factors in determining the most appropriate application method to use. In addition, susceptibility to apple maggot attack is cultivar specific and this is another factor to be taken into consideration (Bostanian *et al*. 1999).

ACKNOWLEDGEMENTS

This research was funded by the Pest Management Centre Pesticide Risk Reduction Program of Agriculture & Agri-Food Canada.

REFERENCES

Bostanian NJ, Vincent C, Chouinard G, Racette G (1999) Managing apple maggot, *Rhagoletis pomonella* (Diptera: Tephritidae), by perimeter trapping. *Phytoprotection* **80**, 21-33

Burns RE, Harris DL, Moreno DS, Eger JE (2001) Efficacy of spinosad bait sprays to control Mediterranean and Caribbean fruit flies in commercial citrus in Florida. *Florida Entomologist* **84**, 672-678

Chen H, Felland CM, McPheron BA (2002) Population dynamics of apple maggot (Diptera: Tephritidae) in south central Pennsylvania. *Journal of Economic Entomology* **95**, 65-71

Duan JJ, Prokopy RJ (1988) Development of pesticide-treated spheres for controlling apple maggot flies (Diptera: Tephritidae): Pesticides and residueextending agents. *Journal of Economic Entomology* **88**, 117-126

Gallo MA, Lawryk NJ (1991) Organic phosphorus pesticides. In: *Handbook of Pesticide Toxicology: Organic Phosphorus Pesticides*, Academic Press, New York, NY, pp 917-1123

Peck SL, McQuate GT (2000) Field tests of environmentally friendly malathion replacements to suppress wild Mediterranean fruit fly populations. *Journal of Economic Entomology* **93**, 280-289

Pelz KS, Isaacs R, Wise JC, Gut LJ (2005) Protection of fruit against infestation by apple maggot and blueberry maggot (Diptera: Tephritidae) using compounds containing spinosad. *Entomological Society of America* **98**, 432-437

Prokopy RJ, Chandler BW, Wright SE (2003) Improved sugar delivery onto pesticide-treated spheres for controlling *Rhagoletis pomonella* (Diptera: Tephritidae). *The Canadian Entomologist* **135**, 909-918

Reekie J, Specht E, Carter K, Appleby M, Fraser H, Wilson K, Pink L (2010) The control of apple maggots in organic orchards with GF-120 NF Naturalyte* fruit fly bait. *Acta Horticulturae* **873**, 283-288

Reissig WH (2003) Field and laboratory tests of new insecticides against the apple maggot, *Rhagoletis pomonella* (Walsh) (Diptera: Tephritidae). *Journal of Economic Entomology* **96**, 1463-1472

Reissig WH, Weires RW, Soderlund DM (1980) Laboratory and field tests of insecticide against the apple maggot. *Journal of Economic Entomology* **73**, 752-754

Sciarappa W, Polavarapu S, Barry J, Oudemans P, Ehlenfeldt M, Palvis G, Polk D, Holdcraft R (2008) Developing an organic production system for highbush blueberry. *HortScience* **43**, 51-57

Stelinski LL, Liburd OE, Wright S, Prokopy RJ, Behle R, McGuire MR (2001) Comparison of neonicotinoid insecticides for use with biodegradable and wooden spheres for control of key Rhagoletis species (Diptera: Tephritidae). *Journal of Economic Entomology* **94**, 1142-1150

Trimble RM, Solymar B (1997) Modified summer programme using border sprays for managing codling moth, *Cydia pomonella* (L.) and the apple maggot, *Rhagoletis pomonella* (Walsh), in Ontario apple orchards. *Crop Protection* **16**, 73-79

Trimble RM, Vickers PM (2000) Evaluation of border sprays for managing the codling moth (Tortricidae: Lepidoptera) and the apple maggot (Tephritidae: Diptera) in Ontario apple orchards. *Journal of economic entomology* **93**, 777-787

Vargus RI, Miller NW, Prokopy RJ (2002) Attraction and feeding response of Mediterranean fruit fly and a natural enemy to protein baits laced with two novel toxins phloxine B and spinosad. *Entomologia Experimentalis et Applicata* **102**, 273-282

Villanueva RT, Walgenbach JF (2007) Phenology, management and effects of surround on behavior of the apple maggot (Diptera: Tephritidae) in North Carolina. *Crop Protection* **26**, 1404-1411

Yee WL, Jack O, Nash MJ (2007) Mortality of *Rhagoletis pomonella* (Diptera: Tephritidae) exposed to field-aged spinetoram, GF-120, and azinphos-methyl in Washington State. *Florida Entomologist* **90**, 335-342