Phytoprotection

Managing apple maggot, *Rhagoletis pomonella* [Diptera : Tephritidae], by perimeter trapping

Répression de la mouche de la pomme, *Rhagoletis pomonella* [Diptera : Tephritidae], par le piégeage en bordure de vergers

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Article abstract

Perimeter trapping is an effective physical method to control apple maggot (*Rhagoletis pomonella*) in apple (*Malus pumila*) orchards. It provided 99.5 to 100 % clean fruit at harvest in commercial orchards. The traps were red spheres (9 cm diam) or yellow boards (28 cm x 21.5 cm) sandwiched between the two halves of red spheres. They were coated with a sticky material and baited with butyl hexanoate. The number of traps per plot was a function of the length of the plot facing a possible entry site of *R. pomonella*. In plots adjacent to forest, traps were placed at ca. 10 m intervals on the row, or on the outer most tree of every row. Sides of plots adjacent to prairie grass or a chemically-treated plot had traps at approximately 20-m intervals. To achieve commercially acceptable apple maggot control, the activity of the pest should be low to moderate. Susceptiblity to apple maggot attack varied from one apple cultivar to another. Therefore, this criterion should be considered when perimeter trapping of apple maggot is envisaged.

Managing apple maggot, *Rhagoletis pomonella* [Diptera : Tephritidae], by perimeter trapping

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Perimeter trapping is an effective physical method to control apple maggot (*Rhagoletis pomonella*) in apple (*Malus pumila*) orchards. It provided 99.5 to 100 % clean fruit at harvest in commercial orchards. The traps were red spheres (9 cm diam) or yellow boards (28 cm x 21.5 cm) sandwiched between the two halves of red spheres. They were coated with a sticky material and baited with butyl hexanoate. The number of traps per plot was a function of the length of the plot facing a possible entry site of *R. pomonella*. In plots adjacent to forest, traps were placed at *ca.* 10 m intervals on the row, or on the outer most tree of every row. Sides of plots adjacent to prairie grass or a chemically-treated plot had traps at approximately 20-m intervals. To achieve commercially acceptable apple maggot control, the activity of the pest should be low to moderate. Susceptiblity to apple maggot attack varied from one apple cultivar to another. Therefore, this criterion should be considered when perimeter trapping of apple maggot is envisaged.

[Répression de la mouche de la pomme, *Rhagoletis pomonella* [Diptera: Tephritidae], par le piégeage en bordure de vergers]

Le piégeage des adultes de la mouche de la pomme (*Rhagoletis pomonella*) en périphérie des vergers de pommiers (*Malus pumila*) est une méthode de lutte physique efficace. En vergers commerciaux, il a permis d'obtenir de 99,5 à 100 % de fruits sains à la récolte. Les pièges consistaient en des sphères rouges (9 cm diam.) ou des panneaux jaunes (28 cm x 21,5 cm) insérés entre deux demi-sphères rouges. Ils étaient enduits de colle et appâtés d'hexanoate de butyle. Le nombre de pièges installés a été déterminé en fonction de la longueur de la façade directement exposée à un site d'infestation potentielle par le *R. pomonella*. Dans les parcelles, sur les côtés adjacents à un boisé, les pièges étaient placés à environ 10 m de distance sur le rang, ou sur les pommiers à l'extréminté de chacun des rangs. Sur les côtés adjacents à des prairies de graminées ou à des vergers traités chimiquement, on a placé les pièges à environ 20 m d'intervalle. Afin

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d'obtenir un niveau de contrôle acceptable par les pomiculteurs, les populations de la mouche de la pomme doivent être de faibles à modérées. La sensibilité aux attaques de la mouche de la pomme a varié d'un cultivar à l'autre. Ce facteur doit être considéré si l'on veut appliquer cette méthode en conditions commerciales.

INTRODUCTION

The apple maggot, *Rhagoletis pomonella* (Walsh) [Diptera : Tephritidae], is a key pest of apples (*Malus pumila* L.) in eastern Canada and the United States. It is a native insect of North America and its original host is hawthorn (*Crataegus* sp.). However, with the introduction and commercial production of apples in north America, it has permanently expanded its host range to include cultivated apples. In Canada, abandoned orchards and hawthorn trees support large populations of *R. pomonella* from Ontario to Nova Scotia. In a non-treated apple orchard, a 10-yr study showed that this pest caused on average 16.9 % crop loss in Quebec annually (Vincent and Bostanian 1988). Growers monitoring adult activity with red spheres apply on average 1.1 insecticidal treatments per season in Quebec (Bostanian *et al.* 1984) and 2.2 to 3.1 treatments in Massachusetts (Prokopy *et al.* 1990). Meanwhile, in southern Ontario, three to four insecticidal treatments are applied against this pest (Trimble and Solymar 1997).

R. pomonella adults immigrate into commercial orchards annually searching for food and oviposition sites. They are attracted to the honeydew of aphids and the odors emitted by ripening apples. Newly emerged flies are sexually immature and feed on honeydew for 7 to 10 d before they mate and start to oviposit. Prokopy (1968) suggested that immature flies are attracted to yellow panels because these panels mimic apple foliage. In contrast, sexually mature flies are attracted to developing fruit, the preferred site for mating and oviposition. Consequently, mature flies are attracted to red spheres that mimic a maturing apple (Prokopy 1968). To detect the presence of *R. pomonella*, Kring (1970) developed an efficient trap that consisted of a yellow panel placed in between the two halves of a red sphere. The performance of these red spheres was further improved when they were baited with natural (Fein *et al.* 1982) or synthetic volatiles (Reissig *et al.* 1985). The use of apple volatiles to detect the presence of *R. pomonella* in apple orchards was reported by Bostanian *et al.* (1993) and Stanley *et al.* (1987).

Investigations on the behavior of *R. pomonella* to invade commercial orchards from neighbouring habitats, along with recent developments in traps and chemical attractants, paved the way for the implementation of border sprays and perimeter trapping. The latter strategy is also known as trapping-out in Canada and the USA. Both programs attempt to reduce post-bloom insecticide usage in orchards, as such treatments may have adverse effects on nontarget arthropods (Bostanian *et al.* 1984).

For timing border sprays, the activity of *R. pomonella* is monitored around the periphery of a block of apple trees. When the action threshold is reached, an insecticide treatment is applied to a 50-m wide strip, around the outer margin of a block. Using this technique, Trimble and Solymar (1997) controlled adults and larvae of codling moth (*Cydia pomonella* (L.)) [Lepidoptera : Tortricidae] and *R. pomonella* adults throughout the season in four commercial apple orchards in Ontario. They estimated that during a typical season, this approach would require 50 % less insecticide than complete block treatments, while maintaining a similar level of fruit injury.

For perimeter trapping, traps are used instead of insecticide applications to control *R. pomonella*. The traps are placed on the periphery of an orchard. Consequently, a high proportion of invading flies are intercepted before they enter the interior of the block. In

Massachusetts, Prokopy (1975) showed that unbaited red sticky spheres, deployed at a density of about one per 100 apple fruit, substantially reduced *R. pomonella* infestations in well-pruned, standard apple trees. Similar results were also reported from New York State by Reissig *et al.* (1984). With the advent of apple volatiles to attract *R. pomonella* in the early eighties, the technique was further improved and fewer traps were used per block (Mason *et al.* 1994; Prokopy *et al.* 1990). More recently, the sticky material was replaced by an insecticide (Duan and Prokopy 1995a, 1995b). However, insecticide-treated traps had to be re-treated at least once with the insecticide and with sucrose, a feeding stimulant, after every rainfall. This was cumbersome in Massachusetts, and would be expensive in Quebec because of the high frequency of rainfall.

In this study, we report the results of perimeter trapping from 1988 to 1992 in Quebec. Our objectives were to: 1) develop a perimeter trapping strategy to provide commercially acceptable control of *R. pomonella* at different densities; 2) evaluate whether certain apple cultivars may be more susceptible to *R. pomonella* attack in a perimeter trapping program; 3) validate the technique in large commercial plots.

MATERIALS AND METHODS

An exploratory study was carried out in a 'Britemac' plot in 1987. The plot was situated in an orchard such that the East and West sides of the plot faced a forest about 10 m away, whereas the North and South sides faced apple plots treated systematically with insecticides. A baited trap was placed 2 m above the ground on the outer most tree of a row for each of the four cardinal points. After 11 wk of *R. pomonella* activity, 748 and 224 flies were captured on the two traps facing the forest (*i.e.* East and West sides). In contrast the two traps placed on the North and South sides and facing the insecticide-treated plots, captured 29 and 33 flies respectively. This suggested that forests could be sources of immigrant flies into the plot, therefore the sides of the experimental plot facing these forests had to have many more traps than sides contiguous to another apple plot that was regularly treated with insecticides for *R. pomonella*.

Based on this preliminary observation, the strategy of perimeter trapping was evaluated in two stages. The first stage (1988-1991) was carried out in experimental plots at Frelighsburg, Quebec, with different apple cultivars and different *R. pomonella* densities (Table 1). The variable number of traps used was based on the location of the plot in relation to its surrounding habitats. The second stage (1991-1992) validated the technique in commercial orchards located in the main apple-growing regions of Quebec (Table 2).

The size of each plot, number of rows, total number of traps per plot, placement of the traps in relation to each other, the distance between traps, the distance between the side of a plot and the forest for each plot are presented in Figures 1 and 2.

Traps similar to the one developed by Kring (1970) were used in the exploratory study and the experimental plots. Each trap was a yellow panel (28 cm x 21.5 cm) sandwiched between the two halves of a plastic red sphere (9 cm diam). Each trap was baited with butyl hexanoate, enveloped in a semi-permeable membrane (Consep Membranes Inc., Bend, Oregon). The baits were stapled to a corner of the yellow panel. The entire traps were coated with a thin coat of insect adhesive (*i.e.*, Tangletrap™; Tanglefoot Co., Grand Rapids, Michigan). In the commercial plots, red spheres (9 cm diam) replaced the yellow panel / red sphere combination. This was based on Bostanian *et al.* (1993), who indicated that a significant difference in the total number of flies captured by either of these two traps could not be shown.

Table 1. Perimeter trapping of apple maggot, *Rhagoletis pomonella*, in experimental apple plots, Frelighsburg, Quebec

Year	Plot designation	Cultivar	Number of traps plot^{-1}	Mean number of flies caught trap^{-1} month^{-1}			Total number of flies season^{-1}	Number of apples examined	Uninjured fruit (%)
				July	August	Sept.			
1988	A	Empire	6	22.1	187.5	10.2	1319	2606	99.9
	B	Jerseymac	9	52.8	348.6	24.1	3826	2000	62.0
1989	A	Empire	6	0.5	3.0	0.5	24	1268	98.9
	C	Empire	6	7.0	82.8	10.8	604	1304	98.3
	D	McIntosh	8	0.5	37.9	7.0	363	1567	96.1
1990	C	Empire	6	1.5	39.5	8.3	296	1474	99.1
	D	McIntosh	8	39.8	91.1	26.6	1260	2524	88.0
1991	E	McIntosh	21	16.9	57.8	3.5	1562	2100	97.0

Table 2. Cultivar composition of three commercial apple orchards in Quebec, 1991-1992

Orchard designation	Locality	Plot size (ha)	Total number of rows	Cultivars (by row numbers)						
				Cortland	Empire	Jerseymac	McIntosh	Paulared	Spartan	Vista Bella
F	Rougemont	3.5	35	32-34	6, 7, 11-16, 19-24, 29, 30	18	2, 3, 8-10	1, 27, 28	4, 5, 25, 26, 31, 35	17
G	Dunham	1.4	17	1, 2, 7-10	-	3-6, 11-17	-	-	-	-
H	Mont St-Hilaire	4.3	29	-	1-22	-	-	23-29	-	-

Stage 1: experimental plots

The rows in these plots were 4.5 m apart with 2 m between the trees in the row. The traps were hung on branches 2 m above the ground and positioned so as to be visible from outside the tree canopy.

R. pomonella flies caught on the traps were counted and removed from the traps once a wk. After 2-3 wk of service in the orchard, the traps were cleaned or replaced by clean ones. *R. pomonella* density or abundance in a plot was classified as follows: < 500 as low density, 500-1000 as moderate density; 1001-1500 high density; > 1500 as very high density. At harvest, percent uninjured fruit was estimated (Table 1) from several thousand apples that had been picked at random and dissected for *R. pomonella* injury.

In 1988, an 'Empire' (0.51 ha) and a 'Jerseymac' (0.7 ha) plot, hereafter referred to as plot A and B, were used (Fig. 1, Table 1). A 12-m path separated the South side of plot A from the North side of plot B. Both plots were 10 m away from the edge of a deciduous forest on their East and West sides.

In 1989 trapping-out was evaluated in three plots. The arrangement of the traps in plot A was identical to the previous yr. Plot C was an 'Empire' (0.57 ha) and plot D was a 'McIntosh' (0.90 ha) (Fig. 1, Table 1).

Plot C differed from all the other plots, because it was not on the periphery of a forest on any side. It was 200 to 300 m away from the edges of a forest on the West and North sides. Several hawthorn trees were identified in the forest on the North side. The remaining East and South sides faced apple plots (Fig. 1, A) that were treated once with phosmet (O,O-dimethyl phosphorodithioate S-ester with N-(mercaptomethyl) phthalimide) (1.75 kg a.i. ha^{-1}) when the action threshold of four flies per four traps had been attained.

In 1990, the study was repeated as in 1989 in plots C and D. In 1991, the study was continued only in plot D. However, because of population increases of *R. pomonella* in 1990, the number of traps was increased from 8 to 21 and it is referred to as plot E in Table 1 and Figure 1.

Stage 2: commercial plots

Orchard designation, locality, size, number of rows and cultivar composition of the plots are summarized in Table 2. The traps in the commercial perimeter trapping plots were maintained exactly the same way as the experimental plots at Frelighsburg. Furthermore, each perimeter trapping plot had a chemically-treated reference plot. These reference plots could not be strictly considered in the statistical sense as control plots, nevertheless, they were conservative benchmarks for comparison with the commercial experimental plots. The data from the commercial perimeter trapping plots and their respective chemically-treated reference plots were statistically analyzed by comparing two proportions for the normal approximation of the chi-square test, as described by Zar (1996) (example 23.23, page 554), the null hypothesis being that percent uninjured fruit from either of the plots should be the same.

Plot F (3.5 ha) was bordered by forest on the North, South, and East sides. On the West side, it was bordered by chemically-treated apple trees on the West side (Fig. 2). The chemically-treated reference plot was located across a passageway approximately 10 m wide on the South-East corner of the perimeter trapping plot.

Plot G (1.4 ha) was bordered by a vineyard on the North side and a forest on the East side. On the West side it bordered the chemically-treated reference plot and other chemically-treated apple plots on the South side (Fig. 2).

Plot H (4.3 ha) was surrounded by forest trees on the East and West sides. On the North side it bordered the chemically-treated reference plot and on the South side it was adjacent to prairie grass (Fig. 2).

The chemically-treated reference plots were approximately the same size as their respective perimeter trapping plots. In each of these plots, an unbaited trap was placed at each corner and another four in the centre of the plot.

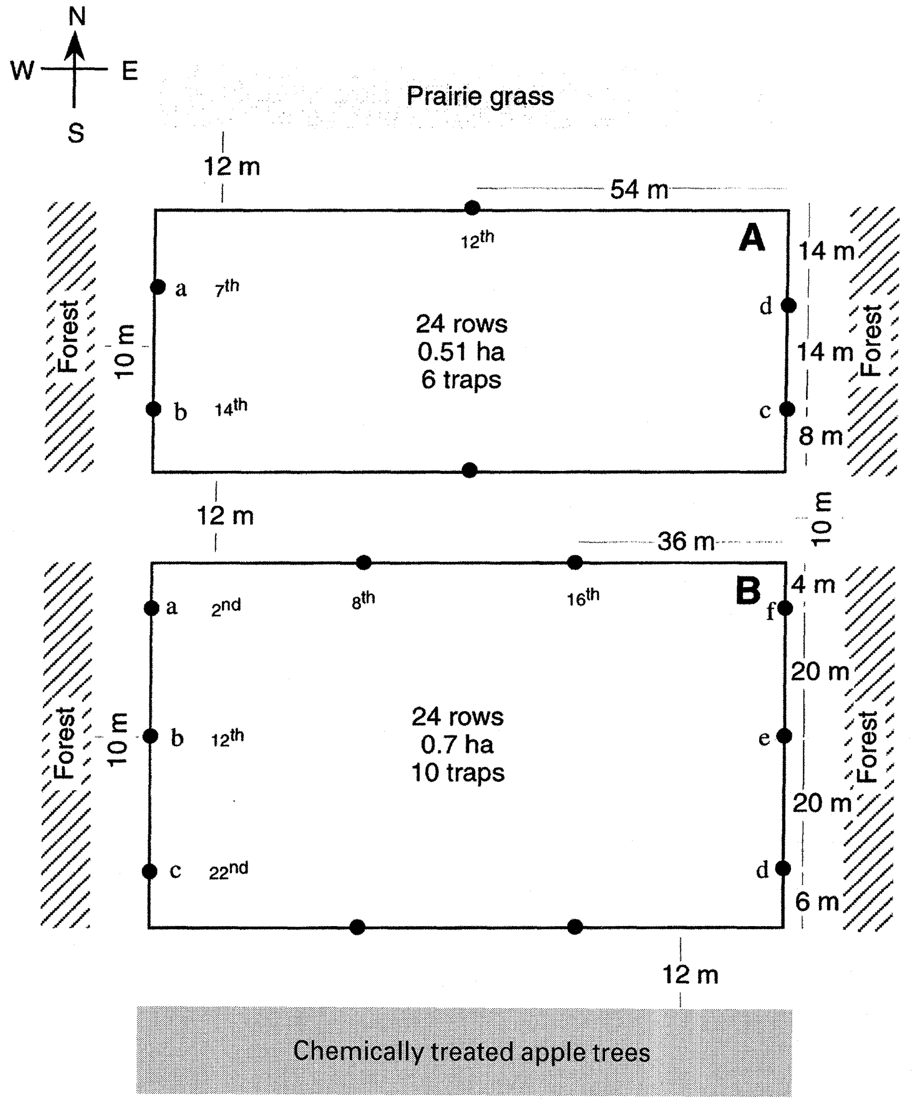
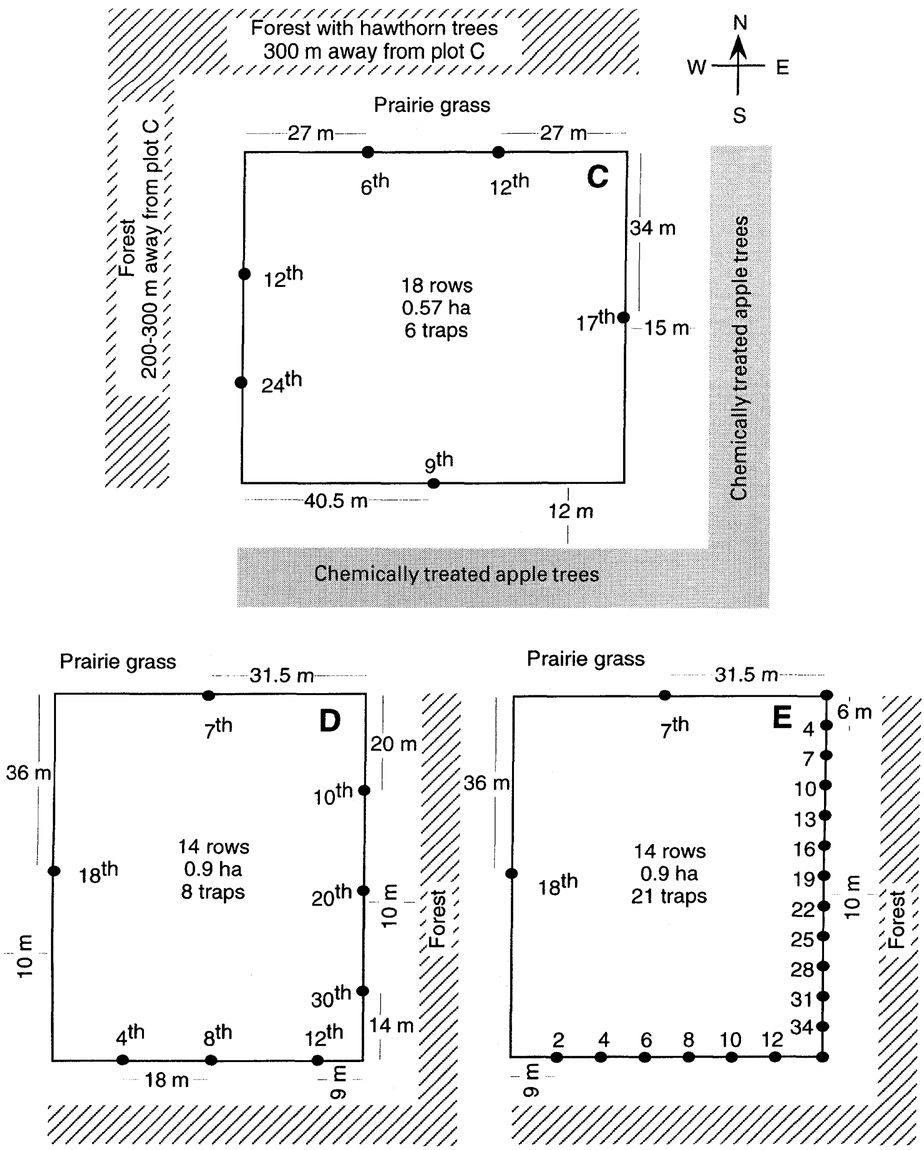


Figure 1. Experimental apple plots (A to E) at Frelighsburg, Quebec, where perimeter trapping of apple maggot, *Rhagoletis pomonella*, was evaluated. The rows were oriented North to South and arabic numerals (abcdef in A and B) within each plot indicate the position of a tree on which a trap was placed. Distances between adjacent traps, between the plot and their surroundings are reported outside the plots in m.


Forest with hawthorn trees
300 m away from plot C
N
W
E
S
Prairie grass
27 m
27 m
C
6th
12th
34 m
Forest
200-300 m away from plot C
12th
18 rows
0.57 ha
6 traps
17th
15 m
24th
9th
Chemically treated apple trees
40.5 m
12 m
Chemically treated apple trees
Prairie grass
31.5 m
D
7th
20 m
36 m
10th
18th
14 rows
0.9 ha
8 traps
20th
10 m
Forest
10 m
30th
4th
8th
12th
14 m
18 m
9 m
Prairie grass
31.5 m
E
7th
6 m
4
7
10
13
16
19
22
25
28
31
34
36 m
18th
14 rows
0.9 ha
21 traps
10 m
Forest
2
4
6
8
10
12
9 m

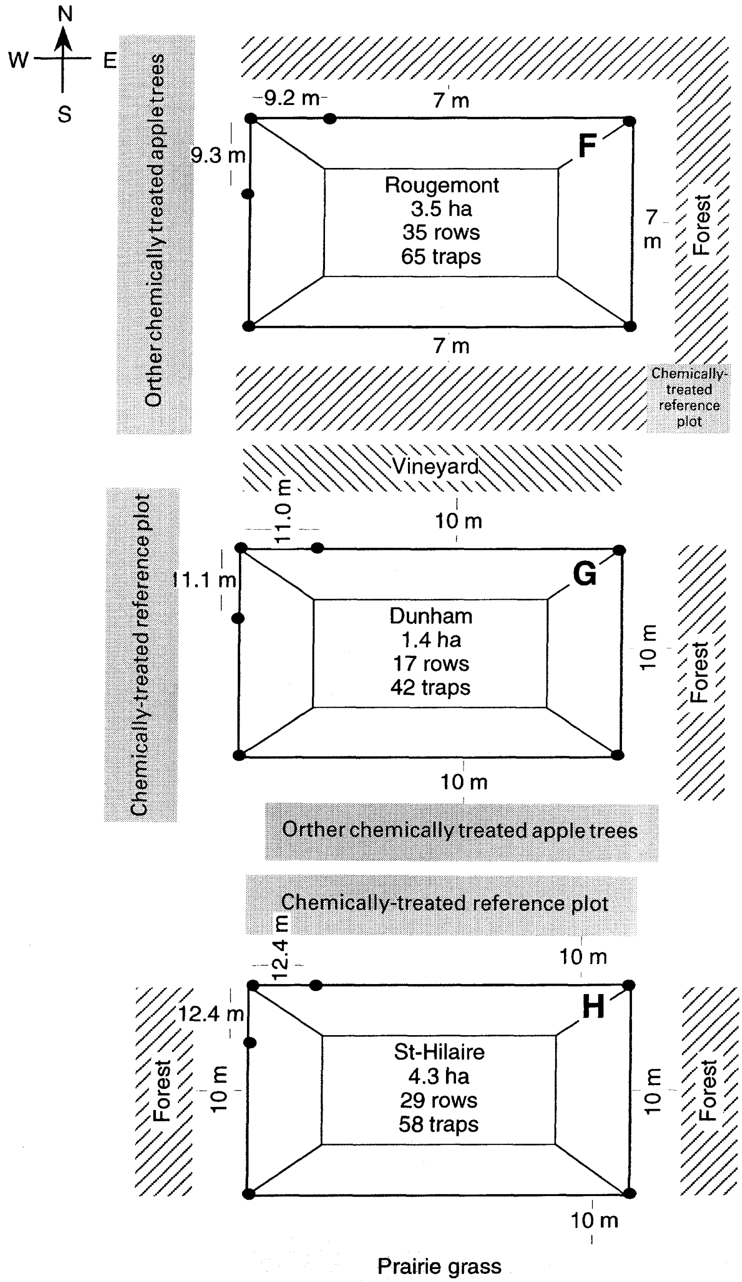


Figure 2. Commercial apple plots (F to H) where perimeter trapping of apple maggot *Rhagoletis pomonella* was validated at the main apple-growing regions of Quebec. The rows were oriented North to South. The distances between rows were as follows : in plot F 4.6 m; in plot G 5.5 m and in plot H 6.2 m. Distances between trees on a row were as follows: in plot F 3.1 m; in plot G 3.7 m; and in plot H 6.2 m. Traps were placed at the four corners of each plot and on the perimeter of the plots as follows: in plot F at every 9.3 m on the row and at every 9.2 m between rows; in plot G at every 11.1 m on the row and at every 11.0 m between rows; in plot H at every 12.4 m on the row and between the rows.

These traps were used to monitor fly density on the periphery and the interior of the plots. When the sum of captured flies on the four traps placed on the periphery reached the action threshold of four flies per plot, then a chemical treatment was recommended (phosmet, 1.75 kg a.i. ha^{-1}).

At harvest 1000 apples were examined from each plot for *R. pomonella* injury. In order to obtain an unbiased sample, each plot was divided into four peripheral sub-plots and a fifth sub-plot in the centre of the plot (Fig. 2). The sub-plots were about 5 row deep (23 m). Two hundred apples from each sub-plot were picked randomly at harvest and examined for *R. pomonella* injury as described above.

RESULTS

Stage 1: experimental plots

Irrespective of apple cultivar, *R. pomonella* were most numerous in August (Table 1). In 1988, *R. pomonella* density was high in plot A where 1319 flies were captured. In plot B it was even higher for 3826 were captured. Trap catches per mo show 2.4, 1.9 and 2.4 times more flies caught in plot B, than plot A, during July, August and September respectively (Table 1). Furthermore, when we examine the total number of flies captured in 1988 on the different traps facing the forest in the two cultivars (Table 3) we note that 2.6 times more *R. pomonella* were captured in the 'Jerseymac' plot than the 'Empire' plot. A *t*-test showed a significant difference between the captures. Finally, the percentage of uninjured apples was considerably less in plot B ('Jerseymac'; 0.7 ha) than in plot A ('Empire'; 0.51 ha) (Table 1). Since, the plots of these two cultivars were adjacent to each other it suggests that 'Jerseymac', an early maturing cultivar, is more susceptible to *R. pomonella* attack or more attractive, relative to the traps, than 'Empire' under the same conditions.

In 1989, *R. pomonella* densities were considerably lower in 1988 and in plot A, only 24 flies were captured throughout the season. Despite the low density of the flies, 98.9 % of the apples from this plot were uninjured at harvest time compared to 99.9 % in 1988. In plot C ('Empire'; 0.57 ha), 604 flies were captured (moderate density) and 98.3 % of the apples were free of *R. pomonella* injury. In plot D ('McIntosh'; 0.90 ha), 3.9 % of the apples had *R. pomonella* injury at harvest and a total of 363 flies (low density) were captured by the eight traps.

In 1990, only 296 flies (low density) were captured throughout the season in plot C and 99.1 % of the apples were free of injury at harvest. In plot D, *R. pomonella* density was substantial as 1260 flies had been captured and only 88 % of the apples were free of *R. pomonella* injury at harvest (Table 1). In 1991, *R. pomonella* were again numerous in that plot (plot E) and 1562 flies were captured throughout the season. However, the number of traps had been increased from 8 to 21 and consequently, 97 % of the fruit were free of *R. pomonella* injury at harvest (Table 1). Therefore, increasing the number of traps improved the management of *R. pomonella*.

Stage 2: commercial plots

Table 4 summarizes the results from 2 yr of testing in commercial orchards. In 1991, the quality of the apples from plot F (perimeter trapping) was the same as the chemically- treated reference plot and no injuries could be detected. A total of 284 flies were captured in the perimeter trapping plot. In 1992, fly density increased throughout the season and 739 flies (moderate density) were captured in this plot, The increase of *R. pomonella* in the plot decreased fruit quality by 0.5 % at harvest. In the chemically-treated reference plot, none of the samples showed *R. pomonella* injury.

In the perimeter trapping plot G, 99.8 % of the apples were free of *R. pomonella* injury while 99.9 % in the chemically-treated reference plot were free of *R. pomonella* injury. A total of 409 flies were captured on the traps in the perimeter trapping plot.

At the perimeter trapping plot H, 1891 flies, were captured on the traps in 1992 and 99.8 % of the apples were free of *R.*

Table 3. Number of apple maggot, *Rhagoletis pomonella*, captured on baited traps from July to mid-September in two different apple cultivars facing a forest in Frelighsburg, Quebec, 1988

	Number of flies caught on a trap						Mean[ψ]	Standard error
Trap designation[ξ]	a	b	c	d	e	f		
'Empire'[†]	212	107	215	487	–[‡]	–	255.3	81.2
'Jerseymac'	428	390	919	667	899	604	651.2	91.9

ψ Significantly different at 0.05 using *t*-test.
ξ See Figure 1 for placement of traps.
† The number of traps placed is a function of the length of the plot facing the forest and not the area of the plot ('Empire' 36 m, 2 baited traps; 'Jerseymac' 50 m, 3 baited traps).
‡ No traps.

Table 4. Perimeter trapping and chemical control of apple maggot, *Rhagoletis pomonella*, in commercial apple orchards in Quebec

						Uninjured fruit (%)[a]	
Year	Plot designation	Locality	Number of traps plot^{-1}	Mean number of flies trap^{-1} season^{-1}	Total number of flies season^{-1}	Trapping out plot	Chemically-treated reference plot
1991	F	Rougemont	65	4.4	284	100.0 NS[b]	100.0
	G	Dunham	42	9.7	409	99.8 NS	99.9
1992	F	Rougemont	65	11.4	739	99.5 NS	100.0
	H	Mont St-Hilaire	58	32.6	1891	99.8 NS	99.9

[a] Percent of uninjured fruit is based on the dissection of 1000 apples per plot at harvest.
[b] NS: % of damage not significantly different at $P = 0.05$. Test for comparisons of proportions (Zar 1996).

pomonella injury at harvest. In the chemically-treated reference plot, the percentage of clean fruit was 99.9 %.

DISCUSSION

These results indicate that perimeter trapping is an alternative tactic to control AM in uniform plots of 'Empire' and 'McIntosh' apples in Quebec. The technique is also applicable in mixed plots of 'Spartan', 'Cortland', 'Empire', 'Paulared', 'Jerseymac' and 'Vista Bella' (Table 2, plots F and G). It may be inapplicable in uniform plots of 'Jerseymac' or may require more traps or other changes in the program.

The traps intercept a large proportion of the females on the perimeter of the plot before they penetrate into the interior of the block and lay eggs on apples. The net result is a residual population of *R. pomonella* in the interior of the plot insufficient to cause injuries of economic significance. The method was developed with several apple cultivars under the harshest conditions possible, *i.e.* low to very high *R. pomonella* densities in plots that were contiguous with forest habitats. The findings from the experimental plots were instrumental for continuing the study in a commercial context, again with plots that were within 10 m of the forest. The results show that it would be applicable to organic growers who are restricted in the use of synthetic insecticides. Commercially acceptable *R. pomonella* control was also reported by Prokopy *et al.* (1990) and Mason *et al.* (1994). They deployed one trap every 5 m along the perimeter of the experimental block. They also had all unmanaged apple, pear, hawthorn and quince trees cut down within 100 m from the experimental plots. In our studies fewer traps per plot were used. The disposition of traps depended on the location of the plot in the orchard. On sides facing forests, possible entry sites of *R. pomonella* into the plot, traps were placed slightly over 10 m apart, twice the distance reported to be effective in Massachusetts (Prokopy *et al.* 1990). On sides facing prairie grass or conventionally chemically-treated apple plots, traps were 12.4 to 36 m apart. In summary the number of traps per plot is a function of the length of the plot facing a possible entry site of *R. pomonella*.

As noted on earlier, *R. pomonella* appears to be less numerous in Quebec (Bostanian *et al.* 1984) than Massachusetts (Prokopy *et al.* 1990) or Ontario (Trimble and Solymar 1997). Therefore, perimeter trapping would need fewer traps and less servicing throughout the season. This would make the technique more economical in Quebec than in either of the other regions. Furthermore, no effort was made in our study to cut down possible sources of *R. pomonella* from wild or neglected Rosaceae. This was based on Maxwell (1968) who reported that *R. pomonella* females move several hundred m while foraging for hosts. Therefore, cutting down nearby unmanaged host trees would likely have little impact on *R. pomonella* activity.

Finally, it is worth mentioning that the orchard should initially be free of *R. pomonella* populations and therefore most if not all *R. pomonella* injuries should be caused by flies coming from adjacent habitat. With an infested plot, it is suggested that a chemical control program be used along with the collection of all infested apples on the ground, before the larvae leave the apples and enter the soil to hibernate, for one to two seasons before implementing perimeter trapping.

There are limits to the implementation of perimeter trapping as a viable method for *R. pomonella*; control and as pointed out by Wildbolz (1988) for Swiss apple orchards, other fruit-injuring arthropods, controlled by treatments made against key pests, may increase in numbers and necessitate insecticide use. Nevertheless, perimeter trapping for *R. pomonella* is a non-chemical control technique, which when coupled with the early season peripheral zone treatment for plum curculio, *Conotrachelus nenuphar* (Herbst) (Chouinard *et al.* 1992, Vincent *et al.* 1997), should have no adverse effects later on in the season to many non-target species. Such an approach would allow beneficial species to attain maximum abundance and exert their effect on pest populations.

Our results indicate that perimeter trapping is a viable technique to control *R. pomonella* in uniform blocks of 'McIntosh' and 'Empire' apples. It is also applicable in mixed orchards with the following cultivars: 'Spartan', 'Cortland', 'Empire', 'Paulared', 'Jerseymac', and 'Vista Bella'. It is not effective in uniform plots of 'Jerseymac'. On sides of blocks facing forests, baited traps are hung on branches 2 m above the ground at 10-m intervals. On sides facing prairie grass or conventionally chemically-treated apple plots, baited traps are placed 12.4 to 36 m apart. It is not necessary to remove unmanaged host trees within a ring of 100 m.

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