Effects of Planting Density and IPM Level on Apple Fruit Quality and Crop Density, 1999 Results

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Many New England apple growers have been replanting their orchards with dwarf trees at densities of 400 to 1000 trees per acre. At the same time, our research team and a growing number of orchardists are reducing pesticide inputs by employing bio-intensive IPM methods to manage the diseases flyspeck and sooty blotch, pest mites, and the insect pests apple maggot and plum curculio. These pests account for almost all pesticide applications from about June 10 to harvest. The integration of these horticultural and pest-management practices into a third-level IPM program has been our focus for the last 3 years. This article reports on the effects of planting density and IPM level on apple fruit quality and crop density for the 1999 growing season.

The tree-fruit research team performed crop density and yield counts and collected apples for analysis in 48 apple orchard blocks as close to harvest as possible. As with other experiments of this 3-year study, there were six blocks per orchard and eight orchards. Blocks were comprised of McIntosh, with an occasional row of Cortland, or similar cultivar, and were seven rows by seven trees in size. At each orchard, there were two low-density blocks, two medium-density blocks, and two high-density blocks. One block at each density was managed

Table 1. Fruit quality characteristics of apples from blocks of different planting densities and IPM levels in 8 Massachusetts orchards, 1999.

Treatment type	Fruit weight (g)	Soluble solids (%)	Red color (%)	Flesh firmness (lbs)
Planting density				
High	145 a	13 a	68 a	19 a
Medium	130 a b	13 a	64 a	19 a
Low	126 b	12 a	58 a	19 a
IPM level				
First	132 a	13 a	65 a	19 a
Third	134 a	13 a	62 b	19 a

Means within each column and treatment type not followed by the same letter are significantly different at odds of 9 to 1.

Table 2. Number of fruit from apples trees at different planting densities and managed with different IPM levels, 1999.

Treatment type	Number of harvested apples per tree	Number of dropped apples per tree
Planting density		
High	155 c	13 c
Medium	291 b	18 b
Low	761 a	55 a
IPM level		
First	391 a	23 a
Third	423 a	36 a

Means within each column and treatment type not followed by the same letter are significantly different at odds of 19 to 1.

according to third-level IPM strategies, and the other was managed with traditional first-level IPM strategies.

What were the bio-intensive methods employed in our third-level blocks? Summer diseases were managed with a fungicide-reduction plan tailor-made for each block according to risk assessment. A flyspeck prediction model was developed with these results, and with continued environmental monitoring we hope to refine our understanding of orchard disease ecology. Traps that attract plum curculio visually and olfactorally were developed to monitor and manage this most challenging pest. Beneficial predatory mites were seeded into third level blocks to manage pest mites. Traps and products to manage the apple maggot with little or no insecticide are being refined each year.

Samples of 50 apples (150% more than in the 1997 evaluation) were selected for fruit quality evaluations from a larger sample of 200 fruit that were evaluated for pest incidence in each block at harvest. The 50 fruit were weighed, evaluated for percentage of red (scale 0-100%), assessed for firmness, and tested for soluble solids (sucrose). We evaluated a total of 2,400 apples from the 48 blocks.

There were significant differences among the three planting densities for weight. Apples in dwarf trees planted at high densities produced larger apples on average (145 g) (Table 1) than fruit in the low-density plantings (126 g), but medium density plantings (130 g) produced fruit which were not statistically different from those from either high or low planting densities. Planting density did not affect soluble solids, red color, or flesh firmness. Relative to IPM level, fruit produced under bio-intensive 'third-level-IPM' were less red (62%) than fruit in first-level blocks (65%), but no differences existed for fruit weight, soluble solids, or flesh firmness.

Just before commercial harvest, yield and crop density was estimated. At the corners and centers of each block, the total number of apples on and under the trees were counted. Also, 20 trees from each block (100% more than in 1997) were selected randomly and the circumference of a single representative limb, at the narrowest point before branching, was measured. All fruit from the point of measure to the end of the terminals (including subsequent branching) were counted.

Table 3. Estimated yield of apples trees at different planting densities and managed with different IPM levels, 1999.

Treatment type	Number apples per acre (1000's)	Bushels per acre
Planting density		
High	94 a	730 a
Medium	77 a	530 a
Low	77 a	510 a
IPM level		
First	79 a	560 b
Third	87 a	610 a

Means within each column and treatment type not followed by the same letter are significantly different at odds of 19 to 1.

In 1999, the number of fruit per tree was indirectly related to density (i.e., the high-density, or smaller trees, had fewer fruit than did low-density, or larger, trees), but estimated yield (either as number of fruit per acre or bushels per acre) was unaffected by density (Tables 2 and 3). Third-level IPM, on the other hand, resulted in similar number of apples per tree as first-level IPM but resulted in significantly greater estimated yields per acre (Tables 2 and 3). Crop density was not affected by IPM techniques but was slightly greater for low-density plantings than for high-density plantings (data not shown).

These data suggest that planting density affected some aspects of fruit quality and yield but not others. Clearly, a high degree of variability still exists among blocks in this trial. To further define the relationships, additional blocks will be required. All results to date, however, suggest that bio-intensive IPM can result in a similar product and yield with lower chemical inputs. As we finish analyzing related parts of this 3-year study, such as the effects of planting density on light penetration, temperature, and relative humidity in the apple tree canopy, we hope to improve our understanding of the complex interactions among horticulture, tree and orchard architecture, and IPM in apples.

Acknowledgements

We are grateful to the eight growers who participated in this study: Bill Broderick, Dave Chandler, Dave Cheney, Dave Shearer, Joe Sincuk, Tim Smith, and Mo Tougas. This work was also supported by State/Federal IPM Funds and SARE Grant #97 LNE 97-90 (USDA 96-COOP-1-2700).

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Storage and Shelf life of Several Promising Late-summer-maturing Apple Varieties

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Returns that growers in New England receive for their fruit is diminishing, since the cost of production is increasing faster than the price received for fruit. Growers are attempting to improve profitability on their farms in a variety of ways. One option that we would like to explore here is to increase and expand the sale of apples in the weeks prior to the start of the McIntosh season. New, high-quality varieties are available that ripen in late August and early September. These varieties appear to offer a real possibility for expanded sales. The purpose of this article is to communicate recent findings about the quality, storage potential, and shelf life of three of the most promising early-maturing new apple varieties, Ginger Gold, Sansa, and Sunrise. Paulared ripens at a similar time, thus it is included in this discussion as an industry standard.

Materials & Methods

All fruit used in this investigation were harvested from 5- and 6-year-old trees growing in the variety evaluation block at the University of Massachusetts Horticultural Research Center in Belchertown. This experiment was conducted in 1996 and 1997. In 1996, Ginger Gold, Sansa, and Paulared were evaluated, and in 1997, Sunrise was included with Ginger Gold, Sansa, and Paulared.

In each year, 100 fruit of each variety were harvested on August 29 for evaluation. Varieties were separated randomly into five bags of 20 fruit each. Four of the bags of each variety were placed in air

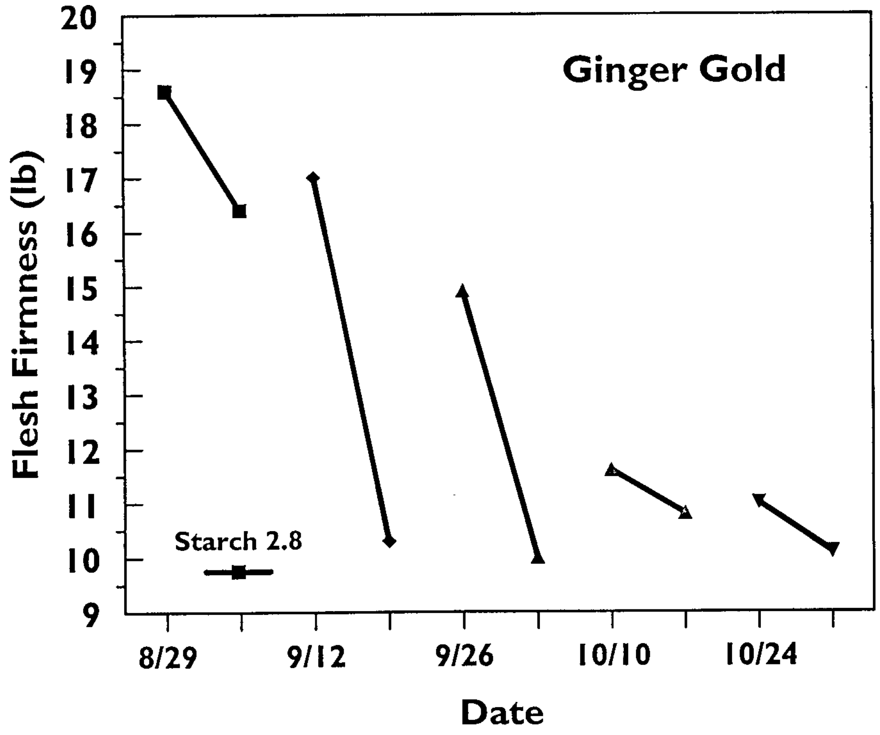

Figure 1. Flesh firmness of Ginger Gold fruit immediately following 0 (at harvest), 2, 4, 6, and 8 weeks of storage at 32°F (represented by the first point of each line) and after 1 week at room temperature (represented by the second point of each line).

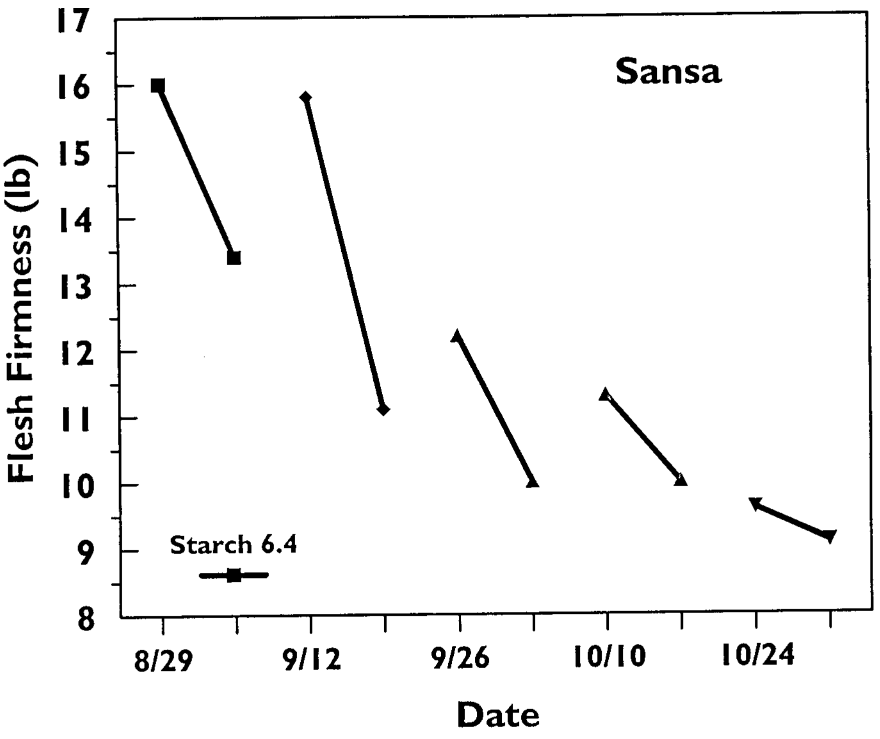

Figure 2. Flesh firmness of Sansa fruit immediately following 0 (at harvest), 2, 4, 6, and 8 weeks of storage at 32°F (represented by the first point of each line) and after 1 week at room temperature (represented by the second point of each line).

storage at 32°F for future evaluation. Flesh firmness of ten fruit was evaluated using a McCormick Fruit Company penetrometer. They were then cut in half and dipped in iodine solution and rated for starch staining on a scale of 1 to 8 using the Cornell Generic Starch Chart. The remaining ten fruit were kept at room temperature for 7 days, after which flesh firmness was measured. On September 12, September 27, October 11, and October 25 the remaining bags of fruit were removed from storage. Flesh firmness of ten fruit was assessed immediately, and firmness of ten fruit was measured after 7 days at room temperature.

Results

Results in 1996 and 1997 were very similar for all varieties, so only the 1997 data are presented.

Ginger Gold (Figure 1). The average starch rating of Ginger Gold fruit was 2.8 at harvest, and fruit had a flesh firmness of 18.6 pounds. When left a room temperature for 1 week, firmness dropped to 16.4 pounds. When Ginger Gold fruit were removed from storage 2 and 4 weeks after harvest flesh firmness was still very good, at 17 and 14.9 pounds, respectively. However, when these fruit were allowed to remain at room temperature for 1 week, flesh firmness drop abruptly to 11 pounds. Fruit stored for more than 4 weeks were soft, tasted somewhat grainy, and were considered to have marginal quality at best.

Sansa (Figure 2). When harvested on August 29, Sansa had an average starch rating of 6.4 and flesh firmness of 16 pounds. After 2 weeks in storage, firmness was similar. Fruit that were kept at room temperature after harvest or after 2 weeks of storage softened, but the taste of these fruit was still good because of the pear-like texture of the flesh. After a month in storage, flesh firmness dropped below 12 pounds, and after 6 weeks in storage, flesh firmness and fruit quality were marginal.

Sunrise (Figure 3). The average starch rating of Sunrise fruit at harvest was 6.1, and firmness was near 14 pounds. Firmness during the first 2 weeks of storage dropped little. Fruit that were allowed to remain at room temperature, either at harvest or after any length of storage, became extremely soft and commercially unacceptable for sale, with flesh firmness ranging between 6 and 8 pounds.

Paulared (Figure 4). The average firmness of Paulared at harvest was 15.5 pounds with a starch rating of 3.6. After storage for 2 or 4 weeks, fruit were still in good condition with firmness of 14.9 and 12.7 pounds, respectively. Fruit that were stored for 6 or 8 weeks had firmness between 10 and 11 pound and

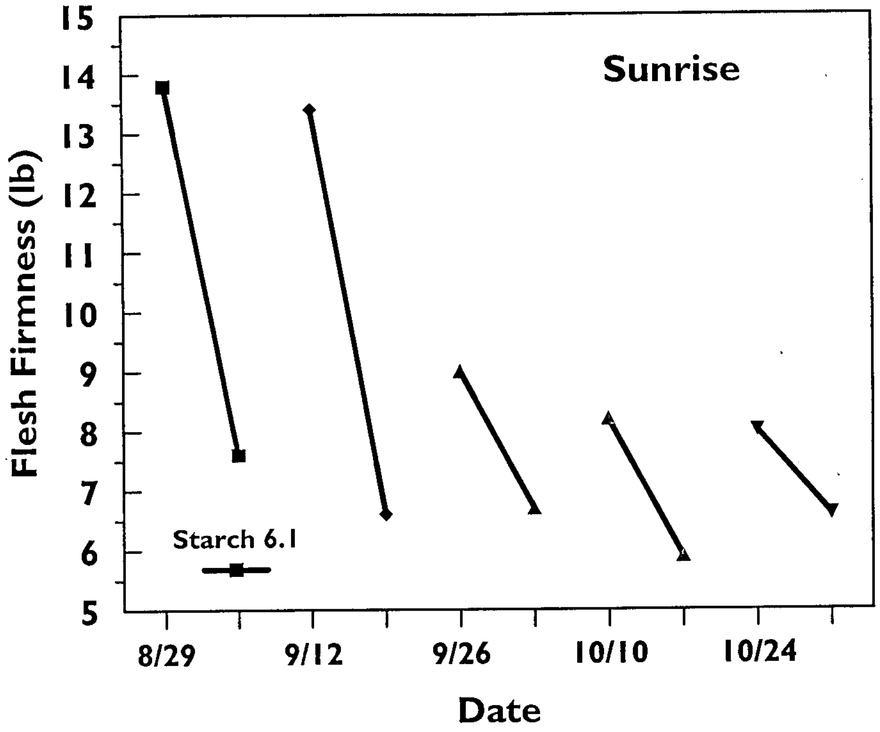

Figure 3. Flesh firmness of Sunrise fruit immediately following 0 (at harvest), 2, 4, 6, and 8 weeks of storage at 32°F (represented by the first point of each line) and after 1 week at room temperature (represented by the second point of each line).

were considered marginal. Paulared fruit that were kept at room temperature for 1 week after harvest had a firmness of 12.4 pounds and were considered quite good. However, any Paulared fruit that was placed in storage and then allowed to stay at room temperature for 1 week had flesh firmness of less than 9 pounds, and were judged to be marginal.

Discussion

The apples evaluated in this study should be considered summer or late-summer apples, and as such we should not expect them to have a long storage life. In general, that conclusion was confirmed in this study.

Experience has shown that the rate of ripening of Ginger Gold is slowed on the tree. Because it is mild tasting and has relatively low tannin content, it is picked commercially at a low starch rating, frequently below 2.0. Consequently the harvest period for Ginger Gold may exceed 3 weeks. However, once Ginger Gold is harvested and placed in cold storage, it has a storage potential of only 4 or 5 weeks. Ginger Gold is unlike some varieties in that when it softens to 12 pounds or lower, the flesh becomes grainy and undesirable. Ginger Gold should be sold before high-quality and better-storing Golden Delicious types are harvested.

Sansa is very similar in appearance and taste to Gala. To the untrained, it could be easily mistaken for Gala. Sansa at harvest and for a month after maintained good to excellent firmness and exceptional flavor. As Sansa softens it develops pear-like characteristics, making it acceptable at lower firmness than other varieties. However, given the similarity between Sansa and Gala, and the generally longer storage potential of Gala, we suggest that only sufficient Sansa should be planted to satisfy grower market demands up to and into Gala season.

At its prime, Sunrise is one of the crispest and best apples available. However, like many summer apples it maintains condition on the trees for only a short time. This study suggests that Sunrise has an extremely short storage life, and if any fruit is left at room temperature for a week, it would not be eatable. We believe that Sunrise is not a variety that should be grown commercially in New England because of uneven ripening on the tree and its limited storage potential.

The postharvest storage life of Paulared was similar to what we have learned to expect of this variety. It is a good McIntosh type to precede McIntosh on the market. However, after 6 weeks in storage, firmness dropped substantially, making these fruit a liability in the prime of McIntosh season. We believe that Paulared should be out of the storage and sold at least by the middle of McIntosh season. Frequently, the quality of apples purchased from roadside stands is very high. Growers attempt to maintain this quality by harvesting fruit at optimum quality and store it appropriately in cold storage. Unfortunately, many consumers who purchase apples take them home and put them in a fruit bowl. One fact that this study vividly pointed out was that storing fruit at room temperature for 7 days, especially after storage, may result in excessive deterioration of the quality of fruit, and thus potentially influencing return sales of later maturing fruit.

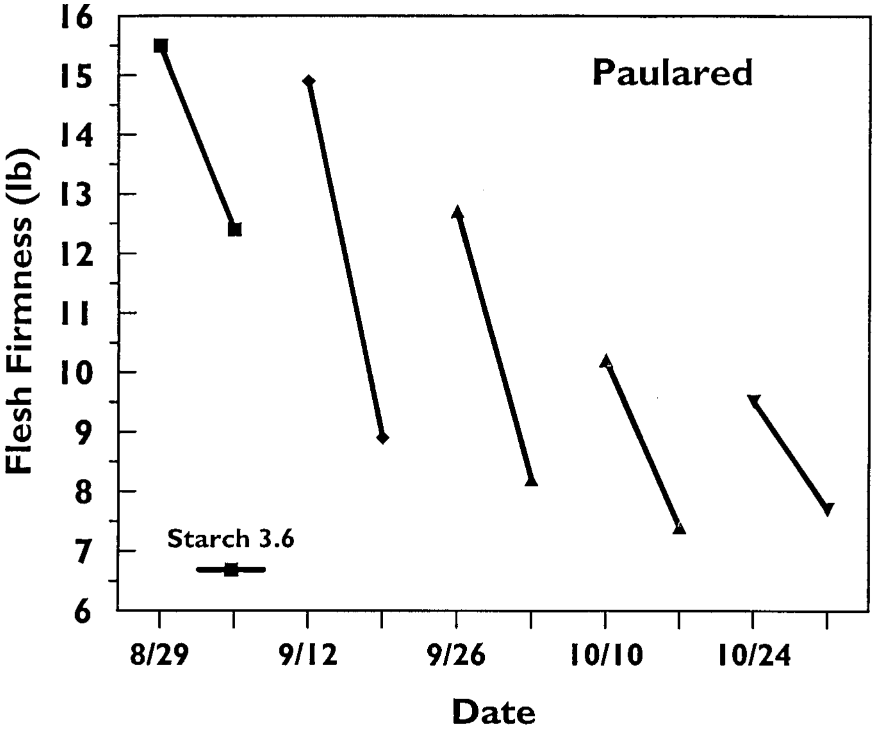

Figure 4. Flesh firmness of Paulared fruit immediately following 0 (at harvest), 2, 4, 6, and 8 weeks of storage at 32°F (represented by the first point of each line) and after 1 week at room temperature (represented by the second point of each

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Effects of Blossom Thinners on Peaches

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Peaches are thinned to increase fruit size, improve fruit quality, and reduce limb breakage. A number of physical methods have been devised to thin peaches including use of shakers, spraying of trees with a high-pressure stream of water, hitting limbs with rubber hoses or foam-covered sticks, and running ropes on a tractor-mounted frame through trees. No method of physically reducing crop load has been widely accepted due to variable or unsatisfactory responses.

The majority of fruit thinning on apples is done with chemicals that are applied after bloom. They cause thinning by either affecting hormone content or influencing carbohydrate distribution within rapidly developing fruit. Blossom thinner application may precede postbloom thinners so that less aggressive postbloom thinning is required. Unfortunately, all postbloom hormone-type thinners are ineffective on peaches. In recent years, several compounds have been report to reduce crop load on peaches when applied at or slightly before bloom. Among those chemicals most frequently evaluated are: endothall, pelargonic acid, sulfcarbamide, ammonium thiosulfate, and hydrogen cyanamide. There has not been universal acceptance of blossom thinners for use on peaches for several reasons. Some thinners have not been registered for use on fruit crops, results have been erratic and inconsistent, and there is a reluctance by growers to apply chemicals designed specifically to reduce fruit set before a crop has been set and initial crop load can be assessed.

Apples have been the primary crop grown by orchardists in New England, but the focus is changing due to global competition and low price. Increasingly, growers are decreasing their dependence on apples, reducing total acreage and diversifying into other crops, including peaches. Peaches can be a very lucrative crop, but only if large sized fruit are produced. Further, peaches are a more labor intensive crop, and labor requirements for hand thinning of peaches frequently coincides with cultural demands of apples. Therefore, there is intense grower interest in using blossom thinners to increase fruit size and to reduce the amount of time required to hand thin.

The purpose of this investigation was to evaluate the effects of the most promising blossom thinners on peaches. We also hoped to identify appropriate concentrations to use and to evaluate consistency of response.

Methods & Methods

Mature Garnet Beauty and Redhaven trees growing at the University of Massachusetts Horticultural Research Center in Belchertown were used in this investigation. Tree spacing was 17' x 24', giving a density of 107 trees per acre. Endothall, Wilthin, and ammonium thiosulfate (ATS) were evaluated in 1997, 1998, and 1999 on the same block of peach trees. Based upon phytotoxicity and thinner efficacy, thinner concentrations were adjusted yearly. Here, we are presenting 1999 data only, since we feel that the chemical concentration and timing of application are close to that which may ultimately be adopted for commercial application.

In each year, 18 Redhaven trees and 24 Garnet Beauty trees were blocked into three groups (replications) and four groups (replications), respectively, of six trees each. Within each replication trees were randomly assigned one of six treatments; control, two rates of Wilthin, two rates of ATS, and one rate of endothall.

In 1999, prior to the application of blossom thinners, three limbs on each tree, 10 to 12 cm in diameter, were tagged and measured. At the time of application, bloom on Garnet Beauty was estimated to be 60% open while that on Redhaven was judged to be 80% open. Treatments were applied on May 2 using a rear mounted airblast sprayer delivering 100 gallons of water per acre. Wilthin was applied at rates of 6 and 8 quarts per acre with 1 pint Regulaid per 100 gallons of spray. ATS was applied at 4 and 6 gallons per acre, and the endothall rate was 1.5 pints per 100 gallons. One tree per block was not sprayed and served as the control. Temperature at the time of application was

Table 1. Effects of Wilthin, endothall and ammonium thiosulfate (ATS) on fruit set, thinning required, and fruit size of Garnet Beauty and Redhaven peaches, 1999.

Treatment	Fruit/cm^2 limb cross-sectional area			Fruit weight (g)	Fruit diameter (in)
	Initial fruit set	Hand thinned off	Final set		
Control	25.7 a	18.8 a	6.9 a	136 d	2.51 d
Wilthin 6 qt/acre + 1 pt Regulaid	16.3 b	11.3 b	5.7 ab	151 cd	2.60 cd
Wilthin 8 qt/acre + 1 pt Regulaid	16.2 b	10.7 bc	5.5 ab	176 bc	2.73 bc
Endothall 1.5 pt/acre	14.8 b	8.5 bc	5.5 ab	184 b	2.79 b
ATS 4 gal/acre	10.9 bc	6.4 cd	4.5 bc	197 b	2.84 b
ATS 6 gal/acre	6.8 c	3.8 d	3.0 c	228 a	3.01 a

Means within columns not followed by the same letter are significantly different at odds of 19 to 1.

approximately 60°F with little wind, and by mid afternoon, the temperature had risen to the lower 70's. Initial set was determined by counting all persisting fruit on tagged limbs at the normal time for hand thinning, about 45 days after bloom, when fruit diameter averaged 1 inch. Hand thinning was done to a commercially acceptable level on each tagged limb, by spacing fruit to about 6 inches apart. The number of fruit hand thinned from each limb was counted and recorded. Initial fruit set, hand thinned fruit, and final set were calculated based upon the cross-sectional area of each limb. Ten fruit or the number of fruit ready for commercial harvest were sampled from the tagged limbs on July 23, 27, and 30 for Garnet Beauty, and on August 5, 10, and 12 for Redhaven. Harvested fruit were taken to the laboratory where they were weighed, the average fruit weight calculated, and then the diameter of each fruit measured with a hand-held fruit sizer.

Results

Blossom thinning treatments significantly reduced initial set and the number of fruit that needed to be removed by hand thinning (Table 1). ATS appeared to reduce initial set the most, although the 6-gallons-per-acre rate was the only one to reduce initial set and final set below that of endothall and Wilthin. Fruit weight and fruit diameter at harvest were increased by all blossom thinners. ATS increased fruit weight and diameter most dramatically, endothall was intermediate, while Wilthin had the smallest effect. The lowers rate of Wilthin, 6 quarts per acre, did not increase fruit weight or diameter relative to the control.

Discussion

One of the goals of this investigation was to identify concentrations of thinning chemicals that would consistently and effectively thin peaches. ATS caused excessive thinning, phytotoxicity, and shoot dyeback in 1997. Part of the response was due to the higher rate used than reported in other investigations. Another component was that the amount of spray deposited was increased in portions of the tree when the sprayer application was into the wind estimated to be 25 mph. Rates were lowered in 1998 and applications were made under favorable thinning conditions. Insufficient thinning was achieved at the low rate. Concentrations were again adjusted in 1999 to 4 and 6 gallons per acre, and application was made again under favorable thinning conditions. Based on these results we believe that consistent and effective thinning with ATS can be achieved if between 3 and 5 gallons per acre are applied in 100 gallons of water per acrer. The highest rate of endothall used was 1.5 pints per 100 gallon in 1999, and that seemed to thin appropriately. Wilthin was the weakest thinner used, and even when applied at 8 quarts per acre, which is, in general, higher than previously used, it was still a modest thinner at best.

The importance of blossom thinning at bloom to maximize fruit size at harvest has been recognized for many years. While thinning can be done if thinners are applied anywhere from pink to full bloom, the greatest response is when application is made near bloom. Thinners act by interfering with ovule fertilization, either by preventing successful pollination or by disturbing pollen tube growth. Results from this investigation suggest that timing of application may influence the thinners response. The best thinning results were obtained in 1999 when treatments were applied when blossoms were 65 to 80% open rather than closer to 100% which was the situation in the two previous seasons. If flowers open over a several-day period, especially under cool conditions, there may be ample opportunity for pollination and significant pollen tube growth of many flowers, before applications are made at full bloom .

It was observed that blossom thinners did not thin uniformly on the tagged limbs. There were some areas of the limb that set a less than optimal number of fruit, thus fruit were spaced more than 6 inches apart, whereas other areas were set heavier and require more hand thinning. The reduction in final set by ATS in 1999 documents that excessive thinning was done. Some hand thinning was also required on these same limbs indicating that there were also areas where fruit were clustered.

Successful blossom thinning treatments resulted in a reduction in hand thinning of between 50% to 80%. This reduction following blossom thinner use can translate into a significant labor savings. In general, it required about one hour to hand thin a control tree. At $7.50 per hour, the cost of hand thinning these trees would be about $800 per acre. A 50% to 80% reduction in hand thinning would be a savings of between $400 and $640 per acre.

Some of the blossom thinning treatments reported in this investigation resulted in a reduction in yield, as expressed by number of fruit per limb cross-sectional area. Fruit from these lower yielding trees may pay a grower more money than higher yielding hand-thinned control trees, because fruit on blossom thinned trees were larger, and higher prices are paid for larger fruit. There is little demand for a peach less than 2.5 inches.

We believe that blossom thinning of peaches in New England is a practice that can be reliably and very profitably used by growers. Key components for success include selection of the proper rate per acre of thinner to apply, application of the spray to mature plantings in 100 gallons per acre of water in an accurately calibrated sprayer, and spray in appropriate weather before most flowers are pollinated, generally before full bloom. In our estimation endothall and ATS hold the greatest commercial potential as blossom thinners on peaches.

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Comparison of Provado™ and Actara™ as Toxicants on Pesticide-treated Spheres

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As reported in previous issues of *Fruit Notes*, we believe that behavioral control using red spheres holds potential as an eventual replacement for use of insecticidal sprays against apple maggot flies (AMF). Toward this, we have developed pesticide-treated spheres, which are designed to kill alighting flies either by contact with or ingestion of a lethal dose of insecticide, which is bound in latex paint coating the sphere. Such an advance may alleviate the need for use of Tangletrap on spheres, which currently renders spheres too costly and laborious for wide-scale commercial use.

For spheres to become a viable alternative to chemical treatments for AMF control, we believe that four criteria must be met. Spheres must be:

1) easy and safe to deploy and maintain
2) as effective as insecticide sprays
3) able to endure through the 12-14 week AMF season
4) capable of maintaining fly-killing power with a very low dose of toxicant

Over the past 3 years, we have moved toward satisfying, but have not fully satisfied, all of the above criteria. Additional articles within this issue (see **Attracticidal Spheres**) highlight studies of the efficiency of various sphere types. Here, we present findings of a 1999 comparison of toxicants intended for use on spheres: imidacloprid (Provado) and thiamethoxam (soon to be labeled as Actara).

Materials & Methods

We formulated three rates each (2, 4, and 8%) of imidacloprid and thiamethoxam in latex paint and applied each mixture to 8-cm red wooden spheres (~3 grams per sphere). At each dose of each chemical, we prepared ten spheres, then subjected two spheres of each treatment to 0, 3, 6, 9, or 12 weeks of field exposure (encompassing the normal Massachusetts AMF season). For each treatment set, we also prepared and exposed two control spheres (treated with latex paint alone). In all, we used 70 wooden spheres in this experiment.

One set of spheres was retained in the laboratory for immediate testing (0 weeks field exposure) We placed all other spheres in a block of unsprayed, medium-sized Delicious apple trees on June 30. At 3-week intervals thereafter, we retrieved one set of 14 spheres for testing; spheres were removed from the field for assays on July 19 (3 weeks), August 10 (6 weeks), September 1 (9 weeks), and September 22 (12 weeks). Throughout the time of study, we recorded daily rainfall using a Campbell weather monitoring station.

Upon return to the lab, we performed two assays: exposure and subsequent mortality of flies on spheres without addition of feeding stimulant (yielding relative contact activity of toxicants) and exposure and mortality of flies on spheres after treatment with a 20% sucrose solution (yielding activity of toxicants after ingestion). We exposed thirty flies (individually) to each treatment, recorded time spent feeding or foraging on spheres, and assessed levels of fly mortality at 24, 48, and 72 hours post-exposure.

Results

Contact Toxicity (no feeding stimulant)

For spheres tested prior to weathering, exposure of flies to spheres treated with either chemical at any rate yielded mortality no higher than 45% (Figure 1). Subsequent tests of field-exposed spheres offered even lower contact toxicity (at all rates), with the exception of spheres exposed six weeks, which resulted in fly mortality nearly identical to unweathered spheres.

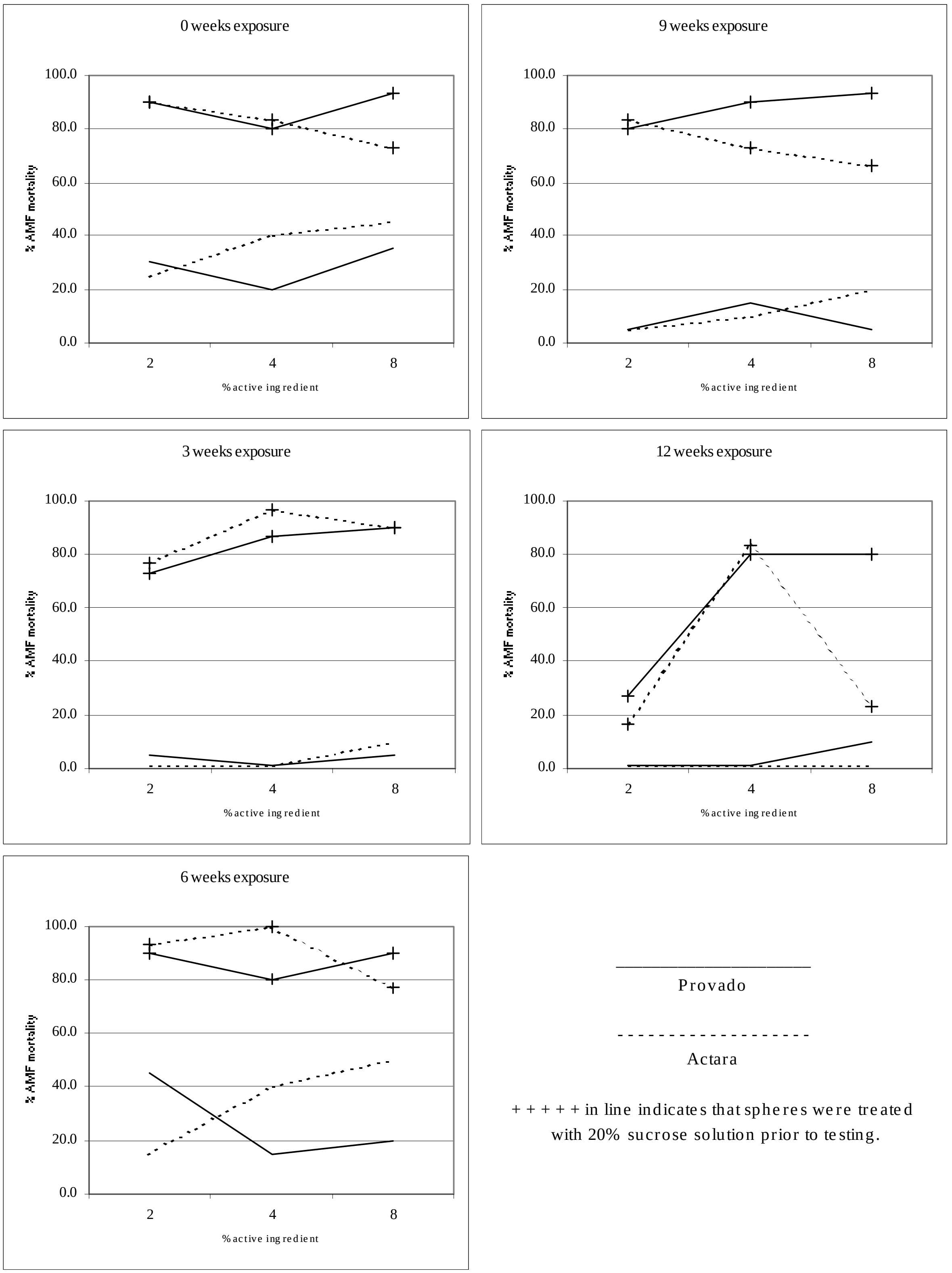

Figure 1. Mortality of apple maggot flies exposed to wooden pesticide-treated spheres subjected to 0, 3, 6, 9, or 12 weeks of field exposure after treatment with varying concentrations of insecticide. Flies were tested on spheres with or without sugar added to the surface prior to testing. Each point represents mortality of 30 tested flies.

Table 1. Period of exposure, sphere retrieval date, and cumulative rainfall during each testing interval.

Field exposure (wks)	Retrieval date	Cumulative rainfall exposure (inches)
0	June 30	0.0
3	July 19	1.4
6	August 10	2.1
9	September 1	6.1
12	September 22	17.0

Feeding Toxicity (20% sugar solution applied)

Before field exposure, spheres treated with either imidacloprid or thiamethoxam performed well, with both materials offering 90% kill of feeding AMF at the lowest dose (2%) (Figure 1). However, higher doses of each material did not necessarily correlate with greater efficiency. In fact, as the dose of thiamethoxam increased, fly mortality decreased.

Through nine weeks of field exposure, spheres treated with imidacloprid retained a high level of fly-killing power—offering levels of control nearly identical to fresh spheres. Spheres treated with thiamethoxam also exhibited good (77%) to excellent (100%) control at low and moderate doses, while mortality of flies exposed to the high dose began to decline steadily after three weeks of field exposure.

Disappointingly, the low rates of both materials faltered after twelve weeks of field exposure, as eleven inches of rain fell in the interval between nine and twelve weeks (Table 1). However, the moderate rates (4%) of imidacloprid and thiamethoxam maintained a reasonable level of fly-killing activity (80 and 83% control, respectively). At the high dose, imidacloprid retained toxicity through twelve weeks, while mortality after exposure to thiamethoxam dropped markedly.

Conclusions

Imidacloprid and thiamethoxam stem from the same chemical family (neonicotinoids), and are known to have similar modes of action and spectra of activity. Given this, it is not surprising to see that patterns of toxicity against foraging and feeding AMF on spheres were very similar for the two chemicals. It appears that the major difference between the two (for use on spheres) is the formulation. The flowable formulation of Provado (imidacloprid) mixes easily into paint and is retained nicely within the latex for slow release, even at relatively high doses (up to ~10% a.i.). Actara, on the other hand, is in a wettable granular formulation, and must be thinned in water (1:1) before introduction into the paint. Because of this, much more liquid must be added into the paint, leaving far less latex per sphere to retain the active ingredient. This is the probable cause of rapid loss of thiamethoxam activity at high doses under heavy rainfall.

It is clear from this study that pursuit of contact toxicity using either of these materials is fruitless. However, in the presence of feeding stimulant (sucrose), low doses of either material offers good AMF control through nine weeks of field exposure. Not surprisingly, under the extreme rainfall conditions of September, efficacy of these low doses declined. We are nonetheless encouraged by the performance of these materials on field-exposed spheres at low and moderate doses, and feel that either can be formulated to achieve our goal: reliable, safe control of flies throughout the 12-14 week AMF season.

Acknowledgements

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Commercial Orchard Trials of Attracticidal Spheres for Controlling Apple Maggot Flies

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For nearly a decade, we have been engaged in development and refinement of pesticide-treated spheres as a substitute for sticky-coated spheres for controlling apple maggot flies (AMF). This endeavor has given rise to two rather different types of pesticide-treated spheres.

The first type consists of a wooden sphere coated with a mixture of pesticide, latex paint (as a residue-extending agent for pesticide), and sucrose (as a feeding stimulant for alighting flies). Because we have been unable to find an effective residue-extending agent for sucrose (which is washed away during rainfall), we have taken an alternative route and attempted to re-supply sucrose to the sphere surface through placement of a cap of hardened sucrose on top of a sphere. Ideally, sucrose would distribute gradually from the cap onto the sphere surface during rainfall, leaving a film of ample feeding stimulant after drying.

The second type consists of a sphere whose body is comprised of a mixture of moistened sugar, flour, and glycerin. After drying, this type of spheres looks and feels as though it were a hardened ball of pie-dough. Under rainfall, sugar seeps through the coat of latex paint and pesticide applied to the sphere surface and ideally provides a continuous supply of feeding stimulant to the sphere surface.

Here, for each of 3 years, we compared the effectiveness of odor-baited pesticide-treated wooden spheres and odor-baited pesticide-treated sugar/flour spheres with that of odor-baited sticky spheres or insecticide sprays for controlling AMF in commercial orchards.

Materials & Methods

Tests were conducted in 1997, 1998, and 1999 in each of eight commercial apple orchards in Massachusetts. Each orchard contained four blocks of medium-sized apple trees (M.26 rootstock) comprised almost exclusively of the cultivars McIntosh and Cortland. Each block consisted of 49 trees in a seven x seven arrangement: seven perimeter-row trees and six successively internal rows of seven trees each. During the first week of July each year (i.e., just before AMF immigration), each of the 24 perimeter trees in three blocks per orchard received an odor-baited sphere. All spheres were red in color, 3 inches diameter, baited with a polyethylene vial containing synthetic fruit odor attractant (butyl hexanoate) and hung 2 to 3 yards above the ground from apple tree branches in a way that maximized visual apparency and attractiveness. None of the three blocks was treated with insecticide within the 3 weeks prior to sphere deployment and none received insecticide after sphere deployment. The fourth block in each orchard was treated by the grower with two or three sprays per year of azinphosmethyl or phosmet to control AMF.

For wooden spheres, the surface was treated once with red gloss enamel paint and then after drying, was overlaid with a mixture containing 70% of the same paint, 20% sucrose, and 10% Provado (containing 20% imidacloprid). Imidacloprid is just as toxic to apple maggot flies and just as durable in latex paint as dimethoate, the insecticide of choice for previous versions of pesticide-treated red spheres, and is safer than dimethoate for handling of treated spheres. Painted spheres were allowed to dry and then equipped with a disc (0.75 inch tall x 1.5 inches diameter) of caramelized (hardened) sugar affixed to the top of each sphere (Figure 1) In 1997, discs atop wooden spheres originated from a mixture of 61% sucrose, 17% fructose, and 22% water, which, after heating to 150^{o}C, was poured into 0.75-by-1.5-inch moulds and allowed to cool and harden. It turned out, however, that such discs dissipated in rainfall or dew more quickly than desired. Therefore, in 1998, we used the same type of disc as in

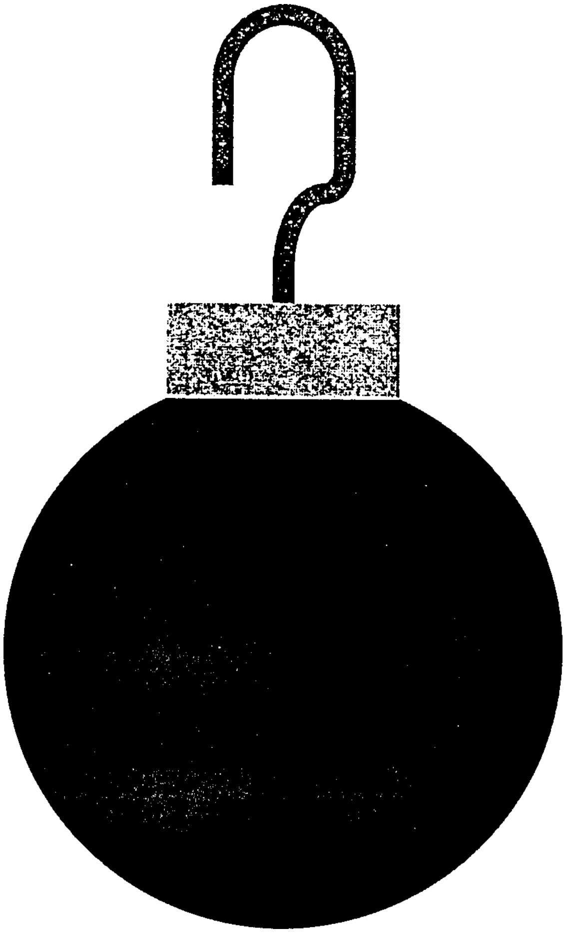

Figure 1. Schematic illustration of a wooden pesticide-treated sphere capped with a disc comprised of hardened sucrose.

1997 but placed each disc in an open 0.75-by-1.5-inch plastic Petri dish to extend residual amount available. Again, rainfall and dew caused too rapid a dissipation of discs. In 1999, discs were formed from a mixture of 15% paraffin wax and 85% sucrose. Wax and sugar were heated separately to 150°C until liquid and then blended. After cooling, the resulting granular mixture was compressed into a mould, where it hardened. No Petri dishes were used beneath discs in 1999. Residual amount of sugar available in discs after rainfall was much greater in 1999 than in 1997 or 1998. Discs atop spheres were replaced every 2, 4, and 6 weeks, respectively, in 1997, 1998, and 1999.

For sugar/flour spheres, ingredients of sphere bodies each year were very similar: 18% pre-gelatinized corn flour, 18% wheat flour, 22% granulated sucrose, 21% corn syrup (containing fructose), 7%glycerin, 8% water, 5% cayenne pepper (aimed at deterring rodents feeding on spheres), and 1% sorbic acid (an anti-microbial agent). Each sphere was formed by hand around a cord in the center and was dried in an oven for hardening. Drying time and temperature proved important to sphere durability under field conditions. In 1997, spheres were dried at 125°C for 48 hours, in 1998 at 140°C for 72 hours, and in 1999 at 200° C for 2 hours. Sphere durability improved successively each year, with spheres in 1999 maintaining integrity throughout the 3-month period of deployment provided they were not consumed by rodents.

After hardening, sugar/flour spheres received two coats of latex paint, as described for wooden pesticide-treated spheres. Each year, sugar/flour spheres were replaced once (at midseason). In 1997, and to a lesser degree in 1998, replacement was necessary primarily because of pre-mature crumbling of spheres following rainfall. Indeed, in both years, spheres should have been replaced more than once for complete continuity of sphere presence in orchard blocks. In 1999, there was little pre-mature crumbling but a greater amount of feeding by rodents, sometimes resulting in complete consumption of some spheres.

For sticky spheres, Tangletrap was applied to the sphere surface. Each sticky sphere was cleaned of all insects and debris every two weeks and retreated with Tangletrap (if necessary) to maintain fly capturing effectiveness.

To evaluate the success of each treatment in controlling AMF, we monitored comparative amounts of fly penetration into blocks by hanging one unbaited sticky-coated red sphere from each of four trees near the center of each block and counted captured flies every 2 weeks, at which time spheres were cleaned of insects and debris and retreated with Tangletrap if needed. In addition, every 2 weeks we examined ten fruit on each of ten randomly selected interior trees per block (20 fruit on each of ten trees at harvest) for oviposition punctures made by AMF. Fruit with suspected punctures were dissected to confirm larval presence.

Results

Assessment via captures of AMF on interior unbaited monitoring traps (Figure 2) showed that each year, significantly more flies were captured on moni-

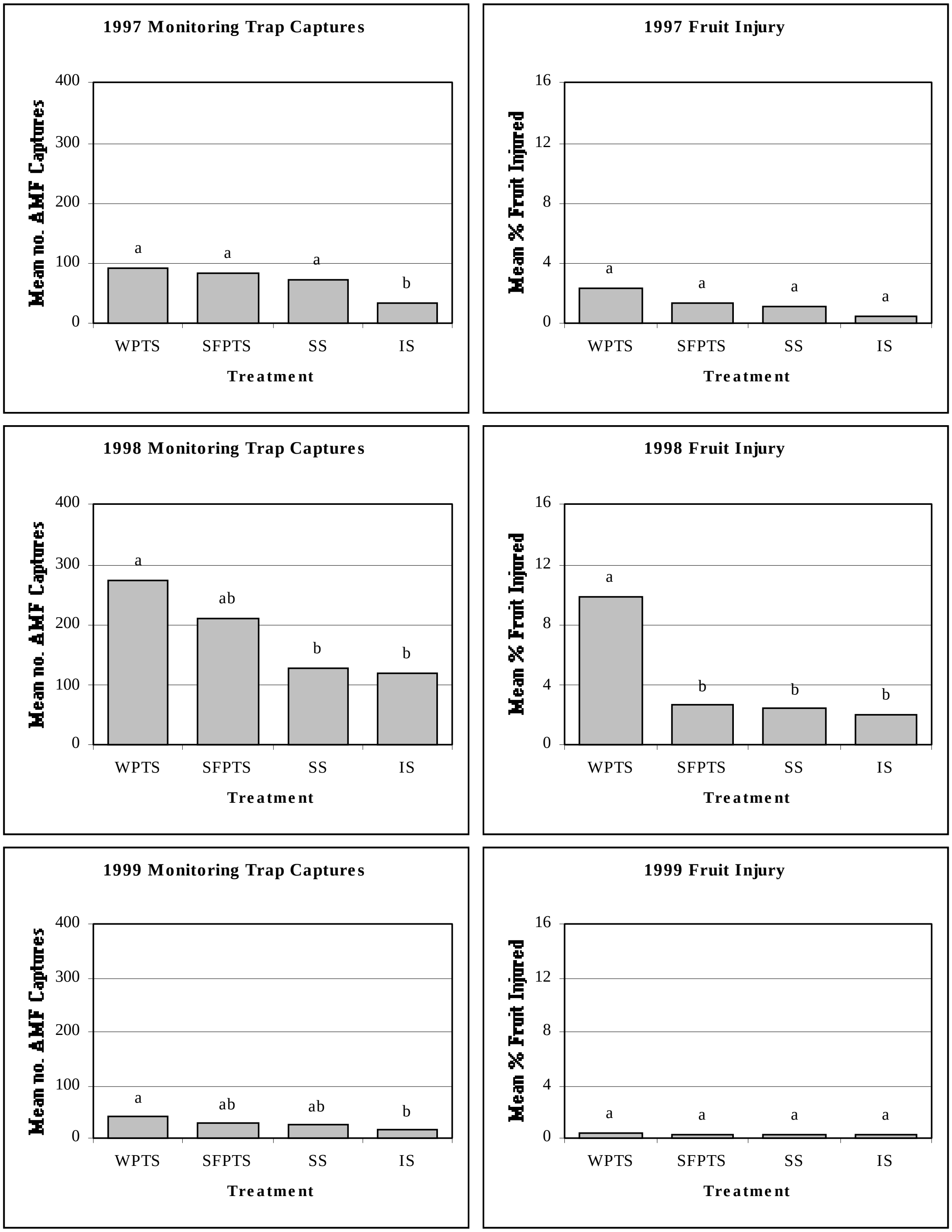

Figure 2. Mean number of apple maggot adults captured per block on interior unbaited monitoring traps and mean percent of fruit injured by apple maggot flies. Means superscribed by a different letter are significantly different at odds of 19:1. WPTS= wooden pesticide-treated spheres, SFPTS=sugar/flour pesticide-treated spheres, SS=sticky spheres, IS=insecticide sprays.

toring traps in blocks surrounded by wooden pesticide-treated spheres than in blocks sprayed with insecticide. In 1997, blocks surrounded by sugar/flour pesticide-treated spheres or sticky spheres likewise received significantly more flies on interior monitoring traps than did sprayed blocks, but there were no significant differences among these treatments in 1998 or 1999. Each year, the rank order (most to least) in which blocks received flies on interior monitoring traps was the same: wooden-pesticide treated spheres, sugar/flour pesticide-treated spheres, sticky spheres, and insecticide sprays.

Assessment via fruit injury by AMF (Figure 2) showed no significant differences among any of the four treatments for any year except 1998, when significantly more injury occurred to fruit in blocks surrounded by wooden pesticide-treated spheres than in blocks of any other treatment. Each year, the rank order (most to least) in which blocks received injury was the same: wooden pesticide-treated spheres, sugar/flour pesticide spheres, sticky spheres and insecticide sprays. The only exception was in 1999, when damage was low in all treatments and there was no numerical difference in injury among the latter three treatments.

Conclusions

Our findings revealed a consistent pattern in ability of odor-baited red spheres to intercept AMF and prevent injury to fruit. Each year, sticky-coated spheres were slightly less effective than insecticide sprays. Each year, sugar/flour pesticide-treated spheres were only slightly less effective than sticky-coated spheres, with comparative effectiveness essentially equal in 1999. Each year, wooden pesticide-treated spheres were less effective than sugar/flour pesticide treated spheres, with comparative effectiveness being similar in 1999.

It is gratifying that 1999 versions of wooden and sugar/flour pesticide-treated spheres were more effective (relative to sticky spheres and insecticide sprays) than 1997 or 1998 versions. Even so, further improvements are needed. In the case of wooden pesticide-treated spheres, an improved disc of wax and sucrose atop spheres is needed to ensure a continuous replenishing of sucrose to the sphere surface over the entire 3-month season of sphere deployment. In the case of sugar/flour pesticide-treated spheres, there is need for an inexpensive and more effective substitute for cayenne pepper for deterring feeding on spheres by rodents. Cayenne pepper is prohibitively expensive at concentrations greater than the 5% concentration used here, which was ineffective. There is also need for the private firm (Fruit Sphere Inc.) that has recently contracted to manufacture sugar/flour spheres to do so using an extruder and/or injection moulder so as to produce affordable spheres that are more uniform in shape, size, and hardness than the spheres used here, which were formed by hand. Ideally, manufactured sugar/flour spheres would remain completely intact until autumn or winter, when freezing would cause breakdown and disintegration.

Before improved versions of wooden or sugar/flour pesticide-treated spheres can be recommended for broad usage as a substitute for insecticide sprays to control AMF, such spheres need to be evaluated in larger blocks of apple trees than used here and deployment patterns of spheres need to be optimized so as to minimize the number of spheres per acre needed to achieve reliable control. Factors such as composition and arrangement of cultivars within orchard blocks, tree size, and fruit color and density can affect degree of sphere apparency to AMF, and hence can have a strong bearing on the number and arrangement of spheres needed for behavioral control.

Acknowledgements

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Effects of Tree Size and Planting Density on Control of Apple Maggot Flies with Odor-baited Red Spheres

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There is an increasing tendency among New England apple growers to replace trees on semidwarf rootstocks with dwarf trees. Although this has clear advantages from the orchard-management perspective, little is known about the impact of this horticultural practice on pest control. Behavioral control of apple maggot fly (AMF), a key pest of apples in Massachusetts, relies on interception of females immigrating into orchards using sticky red spheres. Female AMF are intercepted by traps placed on perimeter trees before they can penetrate and cause damage to fruit within the orchard.

It is a widely known fact that some insects modify their behavior on plants of different sizes. It is conceivable then, that changes in AMF behavior on apple trees of different sizes could affect their response to interception traps and result in more or less fruit damage.

As part of a study encompassing the effect of tree size on all IPM practices in apple orchards, we studied the effect of tree size and planting density on control of AMF using odor-baited red spheres.

Materials & Methods

We conducted experiments during the growing seasons of 1997, 1998, and 1999 in eight commercial orchards in Massachusetts. In each of the orchards, we selected six square blocks of apple trees, two each of small, medium, and large trees (M.9, M26, and M.7 rootstock, respectively). All blocks consisted of seven rows of McIntosh and/or Cortland trees perpendicular to the hedgerow or woods at the orchard margin (Figure 1). All blocks in every orchard were sprayed until early June to control insects and diseases. Thereafter, one block of each tree size in each orchard received odor-baited traps hung on perimeter trees every 6 yards to intercept immigrating flies (IPM blocks). The other three blocks received insecticide to control AMF (control blocks). To compare populations of flies inside IPM and control blocks, we placed four unbaited spheres near the center of each block and counted the number of flies captured by those spheres every 2 weeks. Fruit injury was compared by sampling 20 fruit on 10 trees at the interior of each block every 2 weeks.

Additionally, we released flies marked with different colors at the interior and exterior of IPM blocks of different tree sizes. Marked flies released inside blocks allowed us to determine the fate of flies that are able to penetrate IPM blocks, whereas flies released outside blocks permitted us to assess to what extent immigrating flies are intercepted by perimeter traps before entering IPM blocks of different tree sizes.

Results

To compare results in IPM and control blocks, we calculated the ratio of wild AMF captures by interior monitoring spheres in IPM vs. control blocks. Ratios were greater than one for all block types in 1997 and 1998, indicating slightly greater captures of wild AMF by monitoring traps in IPM blocks (Figure 2). Ratios were highest for large trees, although this pattern did not hold during 1999. Injury to fruit was less in IPM blocks than in control blocks of small trees whereas the reverse was true for blocks of large trees (Figure 3).

Marked AMF released inside blocks were recovered in larger percentages by perimeter traps in IPM blocks of small and medium sized trees than by those in blocks of large trees in 1997 (Figure 4). In 1998, there was no detectable pattern in recovery of released AMF. For marked AMF released outside of IPM blocks, more AMF were intercepted by perimeter traps

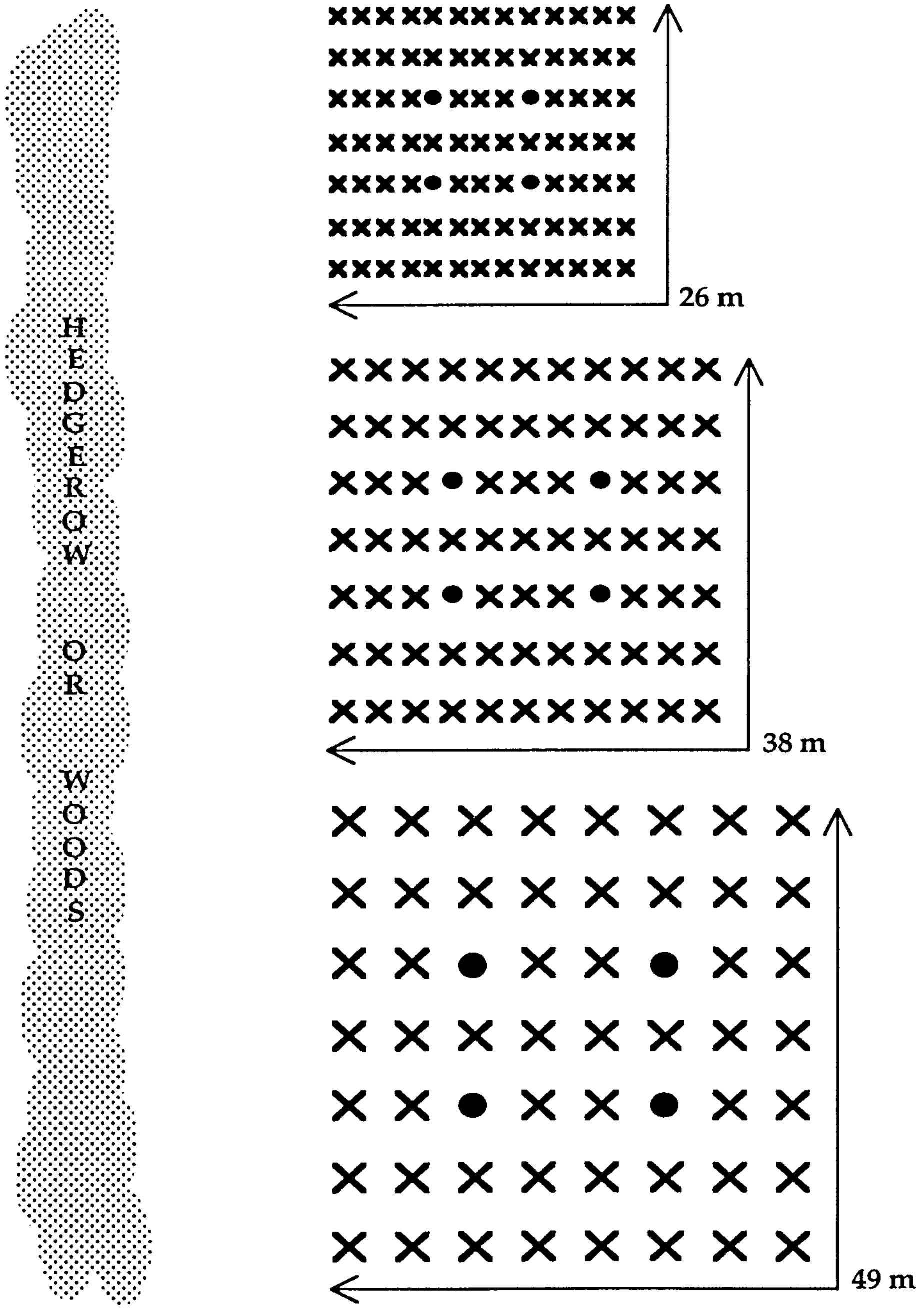

Figure 1. Illustration of IPM and control blocks of small, medium, and large trees (all blocks were comprised of seven rows). Circles indicate the position of interior monitoring traps.

on trees in the line of traps nearest to woods or hedgerows when those traps were placed on small trees than when they were placed on medium sized and large trees (Fig.5).

Conclusions

The level of AMF control provided by odor-baited spheres and insecticide sprays was roughly comparable

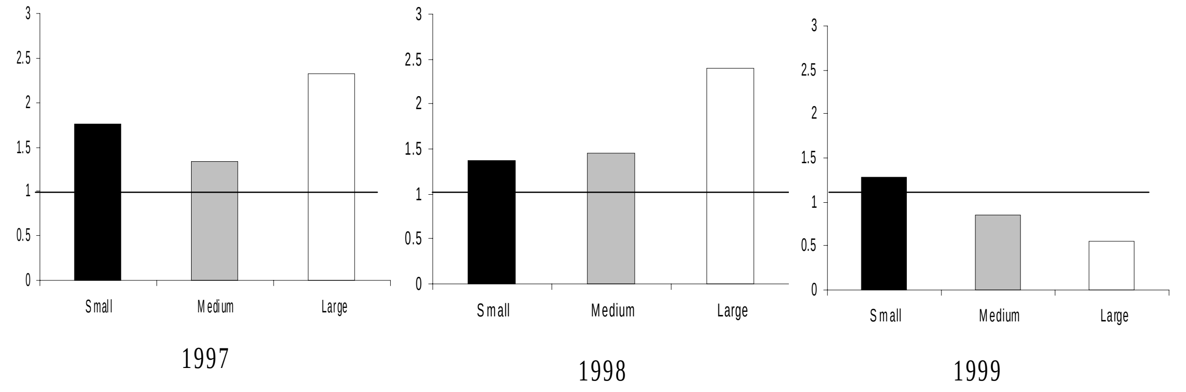

Figure 2. Ratios of the number of AMF captured on unbaited interior monitoring traps in IPM blocks:control blocks. Small, medium, and large refer to the tree size category.

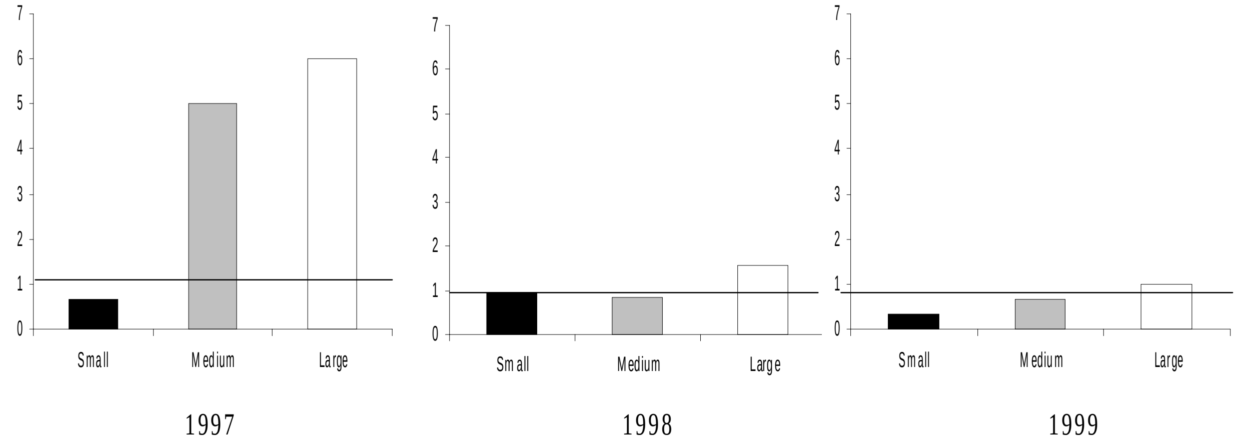

Figure 3. Ratios of the percent fruit injury by AMF in IPM blocks:control blocks. Small, medium, and large refer to the tree size category.

for all tree sizes. Although more AMF were caught by interior traps in IPM blocks in comparison to control blocks of each tree size, injury was slightly lower for fruit sampled in IPM blocks composed of small trees. Our results for wild AMF suggest that the level of control provided by red sphere traps increases when traps are placed on small trees. This view is further supported by the fact that we recovered more marked AMF on traps in blocks of small trees. Perhaps this was because those traps were more apparent to fruit-searching AMF on trees that have less leaf canopy volume. As a consequence, flies immigrating into IPM blocks will have a higher probability of being intercepted by traps placed on small trees when compared to the probability of being intercepted by traps on large trees.

Together, our results suggest that the trend among New England growers in adopting smaller tree sizes aids in maximizing the effectiveness of odor-baited spheres for controlling AMF.

Acknowledgments

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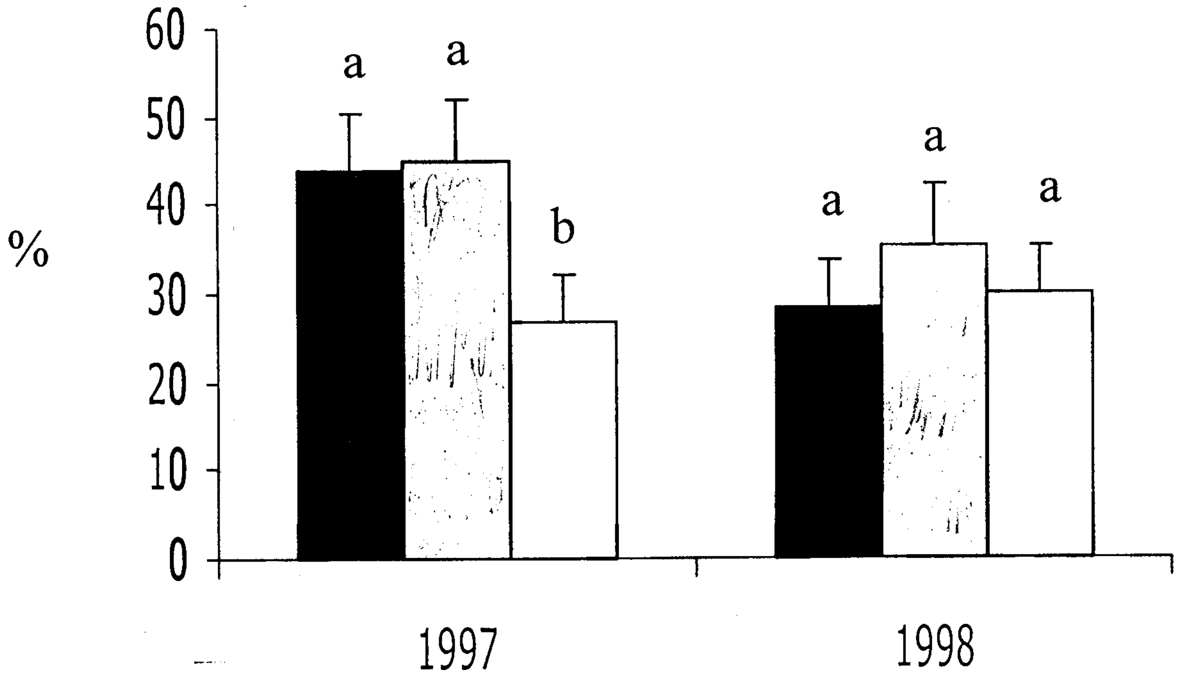

Figure 4. Percent recovery by baited perimeter traps of apple maggot flies released inside IPM blocks of small (black bar), medium (gray bar), and large (white bar) trees.

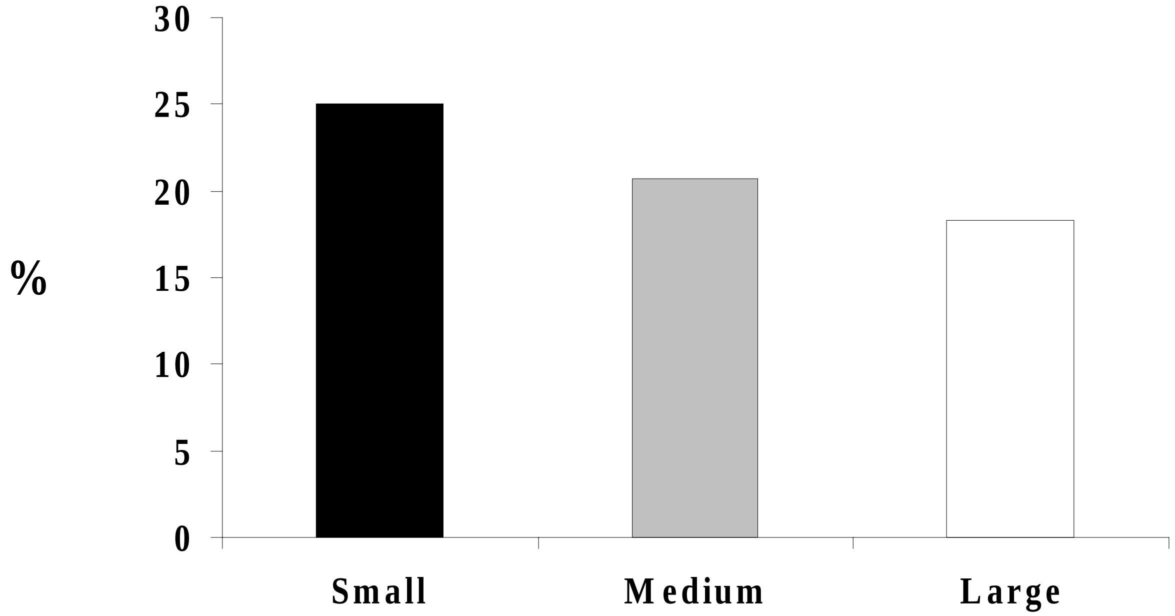

Figure 5. Percent recovery by baited perimeter traps of apple maggot flies released outside IPM blocks of small, medium, and large trees.