Optimizing Distances Between Odor-baited Spheres on Perimeter Apple Trees for Control of Apple Maggot Flies

Ronald Prokopy, Isabel Jácome, and Everardo Bigurra
Department of Plant, Soil, & Insect Science, University of Massachusetts

For several decades, spraying apple trees with insecticide in July and August has been the standard approach to apple maggot fly (AMF) control. While this approach is likely to continue to be the standard in most orchards for decades to come, some growers would like an alternative approach that eliminates the need for insecticide application during summer months. One alternative that we have been studying for more than a decade is the surrounding of orchard blocks with odor-baited spheres on perimeter apple trees to intercept immigrating AMF before they can penetrate into interior rows.

In the Spring 2002 issue of *Fruit Notes*, we reported that the most effective odor bait to use in conjunction with perimeter spheres for maximizing AMF control under a broad range of orchard conditions is a five-component blend of synthetic attractive apple volatiles developed at Cornell University. In other issues of *Fruit Notes* preceding 2002, we presented data suggesting that odor-baited spheres deployed on perimeter trees may be more effective (a) in orchards comprised of small or medium trees than in orchards of large trees, (b) in orchards having particular arrangements of susceptible versus tolerant cultivars, and (c) in orchards bordered by open space than by hedgerow or woods. In addition, we suspected that sphere effectiveness might be greater in well-pruned than poorly-pruned perimeter trees.

To qualify as a viable alternative to spraying an orchard for AMF control, use of odor-baited spheres on perimeter trees must be cost-competitive; the fewer the number of spheres needed, the less the cost. Until now, distances between perimeter spheres in apple orchards have been assigned largely on an arbitrary basis (devoid of established guiding principles), varying from 2 to 45 yards apart.

Here, we developed an approach to assigning distances between odor-baited spheres or perimeter trees of apple orchards. It employs an index incorporating characteristics of four environmental variables: size of orchard trees, quality of pruning, cultivar composition and nature of bordering habitat.

Materials & Methods

Block layout. Our experiment was conducted in 12 blocks of apple trees in ten commercial orchards in Massachusetts. Each block consisted of seven rows of apple trees, was about 120 yards long, and averaged 35 yards deep in extension from a perimeter row that bordered open field, hedgerow, or woods to the seventh interior row. Each block was divided into two plots: one plot about 90 yards long, the other about 30 yards long. Blocks consisted of either small (M.9 rooted), medium (M.26 rooted), or large (M.7 rooted) trees that were either well, moderately, or poorly pruned in 2003. Each row of a block was comprised of the same cultivar, which was considered as being of relatively low susceptibility to AMF if McIntosh or Empire, moderate susceptibility if Cortland or Delicious, and high susceptibility if Fuji, Gala, or Jonagold. Each of the four sides of a block was bordered by grower-sprayed orchard trees, open field, hedgerow, or woods.

Pesticide sprays. Each plot in each block was sprayed by cooperating growers with insecticide and fungicide in April, May, and June to control a variety of insects and diseases. Thereafter, the smaller (30 x 35 yards) plot received two or three grower-applied sprays of insecticide in July and August to control AMF; whereas, the larger (90 x 35 yards) plot received no insecticide after June but received odor-baited spheres to control AMF.

Spheres. Each sphere trap was 3.5 inches in diameter, red in color, and coated with Tangletrap to

Table 1. Values ascribed to characteristics of four environmental variables as components of an index for assigning distances between odor-baited spheres on perimeter apple trees.

Value	Tree size	Quality of pruning	Cultivar susceptibility	Bordering habitat
1	Large	Poor	High	Woods
2	Medium	Fair	Moderate	Hedgerow
3	Small	Good	Low	Open*

*Also applies to bordering habitat consisting of grower-sprayed orchard trees.

capture alighting AMF. Spheres placed on perimeter trees to intercept immigrating adults were accompanied by a blend of five synthetic attractive fruit volatiles contained in a polyethylene vial. Spheres placed on interior trees to monitor adults that penetrated into plots were not baited. All spheres were deployed during the last week of June (before arrival of adults) and remained through harvest (in September). Deployment was at mid-canopy height in a way that maximized visual conspicuousness and attractiveness.

Index for assigning distances between spheres. The index used for assigning distances between odor-baited spheres on each side of each targeted plot was created by first prescribing a value of 1, 2, or 3 for each of tree size, quality of pruning, cultivar susceptibility, and bordering habitat for that side (Table 1) and then using the sum of the four values to determine distance between spheres (Table 2). Based on previous studies conducted in Massachusetts and Quebec, we chose 6 yards as a minimum distance between spheres and 18 yards as maximum distance. Given that this was the first year of using such an index and given that all test blocks were in commercial orchards where valuable fruit was at risk, we were reluctant to deploy spheres at distances greater than 18 yards apart. In some cases, the structure of a block (spacing of trees within and among rows) did not allow us to position spheres precisely according to assigned distances. In such cases, we compromised in favor of an assigned distance closest to the original.

Assessment of treatment performance. We used two methods of assessing treatment performance. First, every other week from trap deployment until harvest we counted and removed all AMF captured by eight unbaited spheres placed on interior trees of row 4 of baited-sphere plots and by four similarly-positioned unbaited spheres in grower-sprayed plots. Captures by such spheres were used as an indicator of relative numbers of adults that penetrated into interiors of plots. At the same time, we counted and removed all AMF captured by odor-baited spheres on perimeter trees and cleaned all baited and unbaited spheres of insects and debris, re-coating spheres with Tangletrap if necessary. Second, at harvest we sampled 20 fruit on each of five trees on each of the four sides of each baited-sphere and each grower-sprayed plot plus ten fruit on each of

Table 2. Index for assigning distances between odor-baited spheres on perimeter apple trees. Sum of values is derived from qualities of four environmental variables as given in Table 1.

Sum of values	Distance between spheres (yards)
4	6
5	7.5
6	9
7	10.5
8	12
9	13.5
10	15
11	16.5
12	18

five interior trees in each of rows 3 and 5 of each plot (total of 500 fruit per plot). All sampled fruit were picked and kept in a greenhouse for one month before examination for ovipositional punctures, confirmed by dissection of punctured fruit for signs of larval growth.

Treatment comparisons and data analysis. In both 2001 and 2002, the same 12 baited-sphere plots used here received odor-baited spheres on each side of each plot at arbitrarily prescribed distances of 6 or 11 yards apart. Also, in both 2001 and 2002, the same 12 grower-sprayed plots used here received similar pesticide treatments as here. Use of unbaited spheres on interior trees to monitor penetration of adults into plots and sampling of fruit for AMF damage in 2001 and 2002 were equivalent to procedures used here. To compare outcomes of the index-based approach of 2003 with the arbitrary approach of 2001 and 2002 for assigning distances between spheres, we subjected each year's data on number of baited spheres used on perimeter trees, number of AMF captured per unbaited monitoring sphere, and percent sampled fruit injured by AMF to analysis of variance.

For 2003 data, we used correlation analysis to determine the relationship between percent injured fruit on each of the four sides of each of the 12 baited-sphere plots and the value (1, 2, or 3) ascribed to that side for each of the following: tree size, quality of pruning, cultivar susceptibility, and bordering habitat. In addition, we used correlation analysis to determine relationships between mean numbers of AMF captured by interior unbaited monitoring traps in baited-sphere plots or percent fruit injured on interior trees of baited-sphere plots (100 fruit per plot) and tree size or quality of pruning for that plot. Whereas, in every case, tree size and quality of pruning were the same for all perimeter trees in a plot, thus permitting such analysis, cultivar susceptibility and border habitat differed among perimeter trees of the same plot and thus were excluded.

Results

Compared with the mean number of odor-baited spheres deployed on perimeter trees per plot in 2001 and 2002, the mean number deployed in 2003 was significantly fewer (33-39% fewer) (Figure 1). Even so, mean values in Figure 2 show that captures of AMF on unbaited monitoring traps at interiors of plots

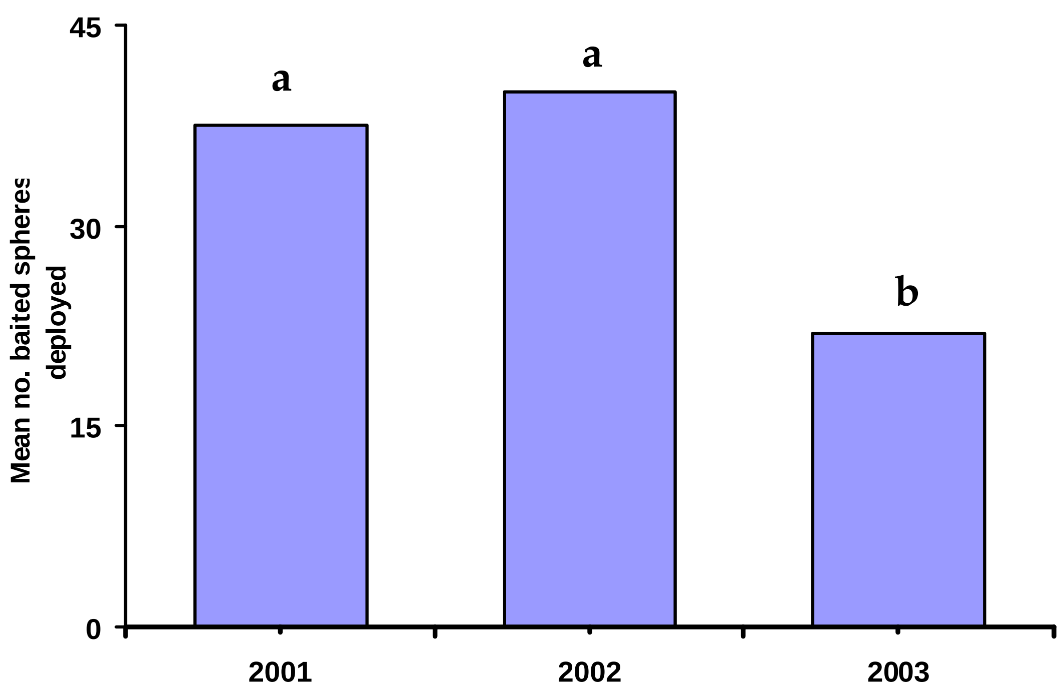

Figure 1. Mean number of odor-baited spheres deployed on perimeter apple trees in the same 12 plots in commercial orchards in 2001, 2002 and 2003. Means superscribed by the same letter are not significantly different at odds of 19:1.

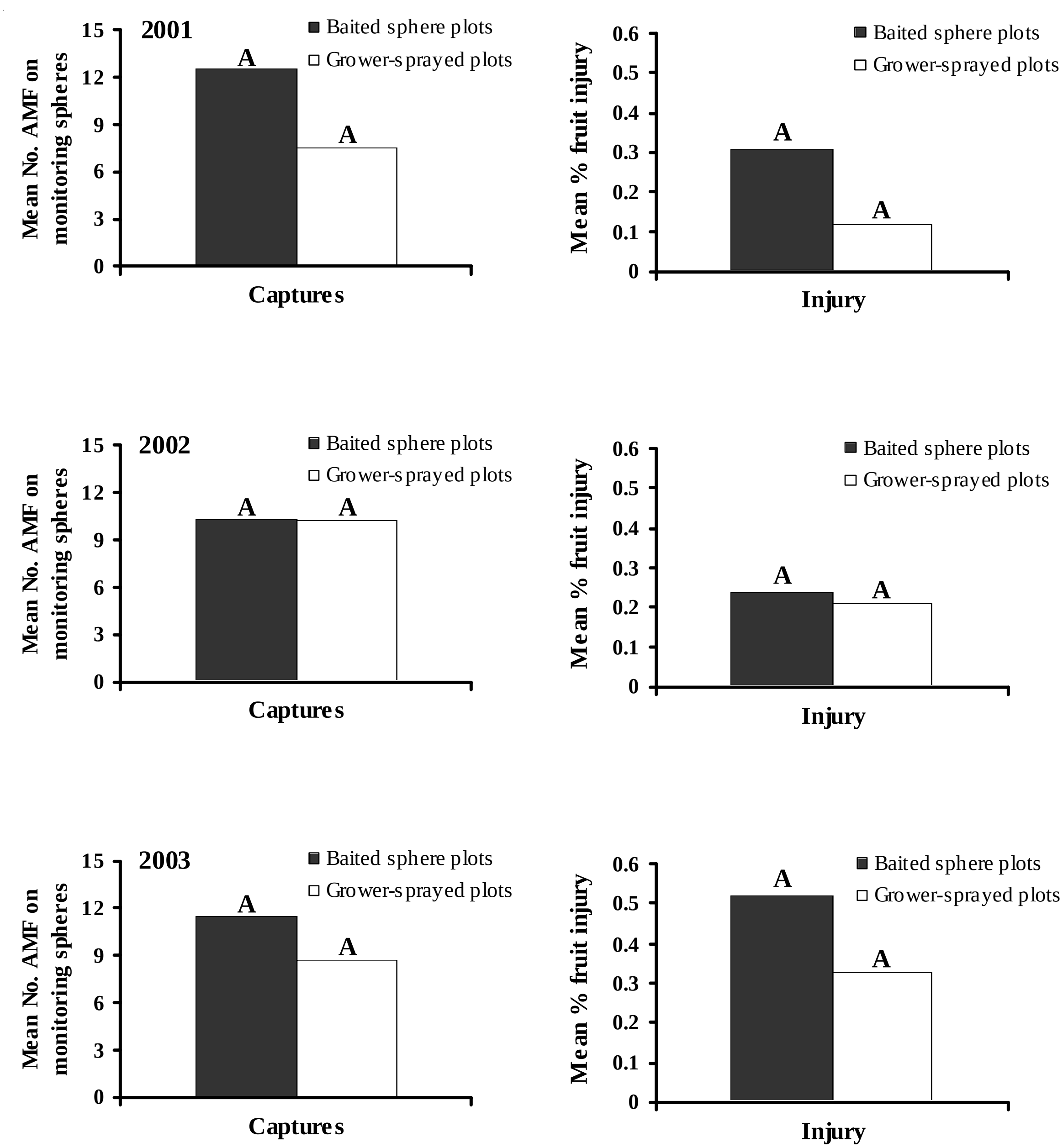

Figure 2. Mean number of AMF captured on interior unbaited monitoring spheres and mean percent injured fruit in baited sphere and grower-sprayed plots in 2001, 2002, and 2003. For each comparison, means superscribed by the same letter are not significantly different at odds of 19:1.

and plot-wide percent fruit injury were not significantly greater in baited-sphere plots (relative to sprayed plots) in any of the three years (2001, 2002, or 2003).

For 2003, percent fruit injured on perimeter trees comprising the four sides of baited spheres plots was significantly negatively correlated (at odds of 15 to 1) with values prescribed for quality of pruning but not significantly correlated with values prescribed for tree size, cultivar susceptibility or border habitat. For 2003, captures of adults by unbaited monitoring traps on interiors of baited sphere plots were significantly negatively correlated (at odds of 10 to 1) with values prescribed for tree size and quality of pruning but not with values prescribed for cultivar susceptibility or border habitat. Percent fruit injured on interior trees of baited-sphere plots was not correlated with values prescribed for tree size or quality of pruning.

Conclusions

Our findings for 2003 indicate that assigning distances between odor-baited spheres (on perimeter trees of plots in commercial apple orchards) according to an index incorporating characteristics of four environmental variables (tree size, quality of pruning, cultivar susceptibility, and border habitat) resulted in a level of AMF control no different from that achieved by sprays of insecticide in 2003 and no different from that of arbitrary assignment of distances between odor-baited perimeter spheres in the same plots in 2001 and 2002. Only 61-67% as many spheres were used under our new index system for determining distances between spheres in 2003 as under the arbitrary system used in 2001 and 2002.

Correlation analyses suggested that the index used here for assigning distances between odor-baited spheres on perimeter trees was reliable with respect to values prescribed for cultivar susceptibility and border habitat, but for future use it may require adjustment with respect to tree size and quality of pruning. Some of the analyses showed a significant negative correlation between tree size or quality of pruning and fruit injury by AMF or captures of AMF by interior monitoring traps, suggesting that distances between spheres prescribed by the index used here may have been too great to ensure high performance in plots of large and/or poorly pruned trees. One potential solution to this possible shortcoming would be to prescribe a value of less than 1 (rather than the value of 1 used here) for perimeter trees of large size and poor pruning. Doing so could, in some cases, require that spheres be placed closer than 6 yards apart. Conversely, for small-size perimeter trees that are pruned well, it may prove possible to assign a value 4 or more (rather than the value of 3 used here) and achieve acceptable control of AMF using odor-baited spheres positioned greater than 18 yards apart (the maximum distance apart allowed here).

On average, each of the 12 plots in this study received 24 odor-baited sticky spheres 12 yards apart on perimeter trees that encompassed about 1 acre of orchard. We estimate that it cost about $10 per sticky sphere for all materials and labor ($1.50 for sphere, Tangletrap, and odor plus $8.50 for labor to apply sticky, deploy spheres, periodically clean spheres of insects and debris, and replenish sticky). The estimated cost per plot of controlling AMF using odor-baited sticky spheres was therefore $240, compared with an estimated cost of about $45 per plot for control using insecticide (materials, spray equipment, and labor). If odor-baited sticky spheres were used to encompass a block of 10 acres rather than a 1 acre plot of apple trees, then 72 spheres (at 12 yards apart) would have been needed, costing a total of $720, or $72 per acre. This still is substantially greater than the cost of applying insecticide to control AMF ($45 per acre) and calls into question the economic wisdom of using sticky spheres for this purpose.

Ultimately, a replacement for sticky spheres is needed that is both less expensive and less messy to deploy and maintain. Such a replacement is on the horizon in the form of a red sphere topped by a disc comprised of spinosad (as insecticide), sugar (as feeding stimulant) and paraffin wax (as binder) (see a following article in this issue). Under high humidity, morning dew, or rainfall, spinosad and sugar seep from the disc onto the sphere surface, where they are ingested by alighting AMF, which then die. The total annual cost per odor-baited sphere of this type, amortized over a 10-year period, is estimated by its manufacturer (Pest Management Innovations, Harpers Ferry, West Virginia) to be about $3. Following initial deployment, such disc-capped spheres would require no further attention through harvest. Deploying odor-baited, disc-capped spheres on perimeter apple trees at distances prescribed by an index such as that put forward here could render behavioral control of AMF as effective and affordable as insecticide sprays, especially for large blocks of apple trees that are on dwarfing rootstock and well pruned.

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