Pursuit of Effective Pesticide-treated Spheres for Controlling Apple Maggot

Starker Wright, Bradley Chandler, Russell Fleury, and Ronald Prokopy
Department of Entomology, University of Massachusetts

For many years, we have reported in *Fruit Notes* progress toward development of effective trapping systems for behavioral control of apple maggot fly (AMF). Until recently, the bulk of this research has been built upon deployment of sticky-coated red spheres for direct control of AMF. Exhaustive field research has convincingly shown that surrounding mid-sized blocks (trials performed in plots up to ~ten acres) with odor-baited sticky red spheres (five yards apart) to intercept immigrating AMF can provide very good control without need for summer insecticides. However, the sticky material used to trap and kill alighting AMF is very difficult to handle and requires frequent maintenance to ensure trap effectiveness.

To address this shortcoming, we have developed and tested a series of prototype pesticide-treated spheres (PTS) to substitute for cumbersome sticky-coated spheres. In concept, AMF land on a PTS, receive a toxic dose of insecticide, and die. However, consistent lethality to AMF can only be assured if flies are strongly induced to feed upon the sphere surface and ingest a very small (but lethal) dose of insecticide. Because of this, PTS must maintain a detectable residue of feeding stimulant (such as sucrose) associated with toxicant at the sphere surface. Unfortunately, under conditions of rainfall, both insecticide and sucrose lose residual activity very quickly. Latex paint is very effective in preserving residual activity of insecticide—we have evaluated all orchard-labeled insecticides and have found imidacloprid (Provado) to be the most toxic to AMF at a very low dose in latex paint. In fact, a dose of 2%-4% (a.i.) imidacloprid in latex paint is sufficient to kill 80% of flies alighting on wooden PTS after 12 weeks of field exposure (and 12 inches of rainfall), provided that PTS have been retreated with feeding stimulant. Thus, the key to successful development of commercially viable PTS for direct control of AMF lies in maintaining the residual effectiveness of sucrose on spheres under field conditions. Although the problem can be stated simply (maintain sugar on spheres throughout a northeastern summer), we have struggled for many years to achieve a firm solution.

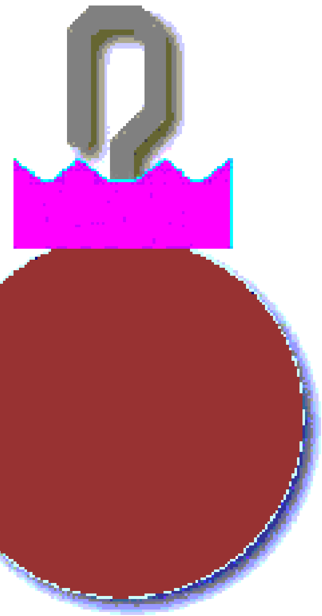
Materials & Methods

We have developed two approaches to providing a continuous supply of sucrose on the surface of a PTS to ensure fly feeding and consistent toxicity to AMF. In 1999, we developed a prototype disc comprised of sucrose bound in paraffin wax that is placed atop a wooden PTS (as described in *Fruit Notes*, Fall 1999). Under rainfall, sugar is distributed along with water onto the sphere surface, renewing sucrose lost from the sphere surface during runoff. For deployment in 2000, we modified these sucrose/wax caps in three major ways: (a) we doubled the mass of the cap to 50 grams to extend the endurance of each cap; (b) we increased the diameter to 2 in. (from 1.25 in.) to maximize surface area and sucrose output; and (c) we designed a hydraulic mold system that presses eight flutes into each cap to ensure uniform distribution of sucrose-bearing runoff.

Our second approach involved a collaborative effort (with the USDA lab at Peoria, IL) toward development of a sphere whose entire body consists of a mixture of sugar and starches (as reported in *Fruit Notes*, Fall 1997), such that under rainfall, sugar is emitted through the latex paint onto the sphere surface. Both of these sphere types have undergone extensive laboratory testing, revision, and fine-tuning in the past several years. Here, we report on commercial-orchard trials of our best versions of each sphere type for the 2000 growing season.

In 28 small plots (~49 trees each) of apple trees across seven commercial orchards, we compared the effectiveness of our newest versions of PTS (Figure 1) against sticky spheres and insecticide sprays for control of AMF. Both wooden and sugar/flour PTS were treated with latex paint containing 2% (a.i.) imidacloprid. For this trial, three plots per orchard were equipped with spheres positioned about five yards apart on all perimeter trees, and one grower-sprayed plot served as the orchard control. One plot of each experimental treatment was emplaced in each orchard: (a) wooden PTS bearing a 50 gram cap of 85% sucrose:15% paraffin wax (each cap 2 in. diameter, fluted for even runoff distribution); (b) sugar/flour PTS produced by a private manufacturer (FruitSpheres Inc.), distributed alternately with either black or red paint (to gauge rodent-deterrent effects of sphere color); (c) sticky-coated wooden spheres; and (d) two to three insecticide sprays. Caps atop wooden spheres and all sugar/flour spheres were replaced at mid-season (after six weeks of field exposure) with fresh versions of each. Treatment effectiveness was judged by comparing numbers of feral AMF

(a)



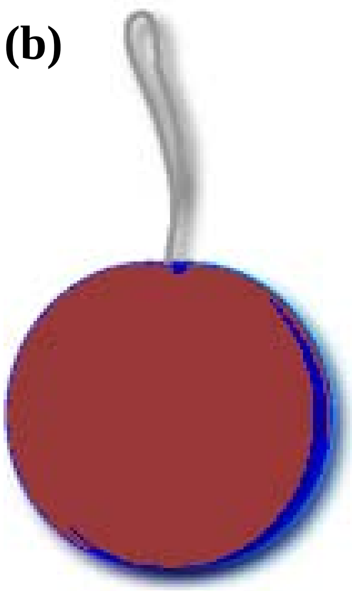
Wooden Pesticide-Treated Sphere

Sphere Body: 8.4-cm wooden sphere.

Feeding Stimulant: 42.5g sucrose bound with 7.5g paraffin. Ingredients are heated to 302°F, granulated, and pressed to form 2” caps with 8 flutes. Sugar is released from the top of the sphere during rainfall.

Surface: Red latex paint containing 2% (a.i.) imidacloprid.

(b)



Sugar/Flour Pesticide-Treated Sphere

Sphere Body: 7.7-cm sphere, consisting of the following: 38g water, 90g sugar, 83g corn syrup, 158g corn flour, 3.7g Cayenne pepper, 0.4g sorbic acid.

Feeding Stimulant: 173g sucrose and fructose bound in sphere body. Sugar is released from the body of the sphere during rainfall.

Surface: Red latex paint containing 2% (a.i.) imidacloprid.

Figure 1. Schematic illustrations of PTS used in 2000: (a) wooden PTS bearing a sugar/wax cap, and (b) sugar/flour PTS.

captured on interior unbaited monitoring traps (four traps on central trees of each plot) and percent injury to fruit in samples taken five times from July to September.

In addition to measurements of whole-plot treatment effectiveness, we assessed the structural durability of each PTS type bi-weekly from June to September. For these assessments, we recorded the percentage of spheres impacted by the two most commonly damaging influences: feeding on caps or spheres by rodents and mold growth on sphere surfaces. For each of four sample sites, we also recorded the amount of rainfall accumulated during each sample period as a factor potentially leading to premature breakdown of sphere effectiveness (through wash-off of sugar and/or toxicant).

At the mid-point (6 weeks of field exposure) and end (12 weeks of field exposure) of the trial, we retrieved indi-

Table 1. Captures of feral AMF on unbaited monitoring traps and percent injury to fruit by AMF in 28 plots of apple trees in seven commercial orchards.

Treatment	No. AMF captured per plot*	Fruit injury per plot (%)
Wooden PTS	21.8	0.003
Sugar/flour PTS	25.8	0.016
Sticky Spheres	33.2	0.006
Insecticide Sprays	21.7	0.011

vidual PTS of each type from each orchard and returned them to the laboratory for testing. We directly assessed the residual fly-killing power of each PTS type by exposing 20 AMF to each sphere type from each orchard. Each sphere was tested twice: immediately upon return from the field (with no supplemental feeding stimulant), and again after application of a 20% sucrose solution to stimulate fly feeding. Fly residence time on spheres and fly condition (alive or dead) 72 hours post-exposure were recorded for each fly. In all, we tested 2240 AMF (individually) on a total of 224 PTS.

Table 2. Percentage of PTS receiving greater than 20% damage by rodent feeding, based on visual inspection (bi-weekly) of 180 spheres of each type.

Weeks of field exposure	Spheres damaged by rodent feeding (%)*	
	Wooden PTS	Sugar/flour PTS
2	7.0	2.0
4	14.7	14.0
6	20.5	35.4
All sugar/wax caps and sugar/flour spheres replaced at mid-season.		
2	27.1	26.6
4	29.6	37.5
6	31.4	43.7

* Loss of 20% or more surface area (sugar/flour PTS) or mass (sugar/wax caps).

Results

Treatment Effectiveness. Comparisons of AMF captures on unbaited monitoring spheres on interior trees of each plot (Table 1) show that the number of AMF that penetrated into plots surrounded by wooden PTS was no greater than the number that penetrated into plots that received two to three insecticide sprays. Although differences were slight, wooden PTS actually numerically outperformed both sugar/flour PTS and sticky spheres. Fruit damage levels between plots were very difficult to compare and were not particularly reliable for this trial, given the near total lack of AMF damage in any plot. Even so, wooden PTS performed as well as or better than any other treatment.

Structural Integrity. In order for spheres to maintain effectiveness throughout a field season, they must be somewhat resistant to naturally damaging in-orchard influences, particularly rodents and mold. Results from this trial clearly indicated that no advantage in combating these influences was gained by altering sphere color from red to black. Therefore, all results focus only on structural integrity of wooden PTS versus sugar/flour PTS (pooled data from red and black spheres).

Through the years of development of PTS, feeding by rodents on spheres has been a significant obstacle to large-scale implementation. After only 4 weeks of field exposure (Table 2), 14.7% of caps atop wooden PTS had lost 20% or more of their mass to rodent feeding. Similarly, after the same period, 14% of sugar/flour spheres had lost 20% or more of their surface area to rodent consumption. Destruction of both sugar/wax caps (wooden PTS) and sugar/flour PTS by rodents increased in intensity as the season progressed, reaching 20.5% and 35.4% rodent damage, respectively, after 6 weeks of field exposure. After 6 weeks of exposure, all sugar/flour spheres and all caps atop wooden spheres were replaced. Unfortunately, the trend of rodent feeding established in the first half of the season continued until trap removal after 6 additional weeks of exposure. During this interval, 31.4% of caps on wooden PTS lost 20% or more of their mass to rodents, faring only slightly better than sugar/flour PTS (43.7% losing 20% or more surface area).

Table 3. Percentage of PTS exhibiting growth of mold on the sphere surface, based on visual inspection (bi-weekly) of 180 spheres of each type. Rainfall was sampled hourly at four regional sites: Deerfield, Belchertown, Sterling, and Northboro.

		Spheres with mold growth (%)	
Weeks of field exposure	Mean rainfall (inches) per 2-week period	Wooden PTS	Sugar/Flour PTS
2	0.47	0.0	0.0
4	3.60	1.2	32.7
6	3.00	1.3	61.0
All sugar/wax caps and sugar/flour spheres replaced at mid-season.			
2	0.71	0.0	2.9
4	1.13	13.2	12.8
6	1.32	13.6	26.2

Growth of mold on spheres (Table 3) was found to occur more commonly on sugar/flour PTS than on wooden PTS. This was a logical finding, given that the entire bodies of sugar/flour spheres were constructed of food products (with a small dose of preservative), all of which were subject to mold growth. Through mid-season (six weeks), very few wooden PTS exhibited significant mold growth (1.3%). In fact, only 13.6% of wooden PTS in place through the entire 12-week trial had any mold present on the sphere surface. For sugar/flour PTS, a great number of spheres exhibited mold growth through 4 weeks (32.7%) and 6 weeks (61.0%) of field exposure, at which point all spheres were replaced. In the second 6-week interval, fewer (26.2%) sugar/flour PTS developed mold, likely owing to greatly reduced rainfall and humidity in the second half of the season (Table 3).

Residual Toxicity. After 6 weeks of field exposure (Table 4), neither wooden PTS nor sugar/flour PTS provided an acceptable level of AMF mortality (30.7% and 26.5% kill, respectively) prior to addition of feeding stimulant. The implications of these data are humbling, suggesting that after 6 weeks of field exposure, PTS of either type were lethal to less than one-third of arriving flies. Upon re-treatment of spheres with feeding stimulant, mortality of AMF after exposure to wooden PTS was very good (75.7%). However, sugar/flour spheres had apparently lost a substantial amount of toxicant (possibly lost to heavy rainfall in the first half of the season), still yielding an unacceptable level of AMF control (44.6%).

As mentioned in the previous sections, we replaced all sugar/flour PTS at the mid-point of the season; wooden spheres were left in place for the balance of the 12-week season and only the sugar/wax caps were replaced. After an additional 6 weeks of field exposure (Table 5), performance of wooden PTS was nearly identical to performance at mid-season: 41.4% kill of exposed AMF prior to re-treatment with

Table 4. Mortality of AMF after exposure to PTS. All PTS were retrieved from commercial orchards at the mid-point of the season (six weeks field exposure). AMF were exposed (individually) to each treatment and allowed to forage freely for up to ten minutes.

	AMF mortality (%) 72 hours after exposure to:		
Treatment	Wooden PTS	Sugar/Flour PTS	Control
No sugar applied prior to fly exposure	30.7	26.5	2.1
20% sugar solution applied prior to fly exposure	75.7	44.6	0.0

Table 5. Mortality of AMF after exposure to PTS. All PTS were retrieved from commercial orchards at the end of the season (six weeks field exposure for starch/flour PTS, twelve weeks field exposure for wooden PTS). AMF were exposed (individually) to each treatment and allowed to forage freely for up to ten minutes.

	AMF mortality (%) 72 hours after exposure to:		
Treatment	Wooden PTS	Sugar/Flour PTS	Control
No sugar applied prior to fly exposure	41.4	45.7	0.0
20% sugar solution applied prior to fly exposure	75.0	67.0	3.0

sugar. Performance of sugar/flour PTS in this interval was slightly better than in the initial 6-week trial, yielding 45.7% kill prior to re-treatment with sugar. After spheres received sugar treatment, wooden PTS rebounded to 75.0% effectiveness, again outperforming sugar/flour PTS (67.0% kill of exposed AMF). Taken together, it is quite clear that sugar/flour PTS are prone to lose toxicity over time (particularly under heavy rainfall), while wooden PTS can retain a high level of toxicity for a longer period under relatively adverse field conditions.

Conclusions

If we focus on field performance of this season's PTS and gauge their promise only on the basis of monitoring sphere captures and fruit damage, both wooden PTS and sugar/flour PTS appear to be highly effective in controlling AMF. In fact, this is the first season in which any PTS has outperformed (numerically, though not statistically) sticky spheres or insecticide sprays in an extended field trial. Although these data are encouraging, we believe that they are also somewhat deceiving, given the statewide dearth of AMF this season.

In this study, it is much more revealing to focus on the field/laboratory aspect of residual toxicity, bearing in mind that our goal is to develop a PTS that provides 80%-90% kill of arriving AMF without manual re-treatment with feeding stimulant. In this context, neither PTS type approached optimal efficacy. However, this study provided key information to aid in further development of PTS. It appears that as the season progresses, wooden PTS fitted with sugar/wax caps do not retain enough sugar to stimulate consistent fly feeding after 4 to 5 inches of rainfall. After re-treatment with sugar, wooden PTS return to their original toxicity. Sugar/flour PTS, on the other hand, appear to actually lose toxicant under field conditions, meaning that the spheres are inherently less effective against AMF in mid- to late-season (the period of greatest AMF risk).

Given these data, the focus of our research has shifted markedly toward further development of wooden PTS that can endure a full northeastern growing season, fitted with sugar/wax caps designed to be replaced once during the season (see following article). Overall, we are encouraged by the results of this commercial-orchard field trial, and remain optimistic about the potential of PTS technology for control of AMF.

Acknowledgments

We are very grateful to the seven growers who allowed us to deploy traps in their orchards: Dave Chandler, Aaron and Dana Clark, Tony Lincoln, Wayne Rice, Dave Shearer, Joe Sincuk, and Mo Tougas. Sugar/flour PTS were provided by FruitSpheres Inc. in conjunction with Robert Behle of the USDA NCAUR facility in Peoria, IL. This project was supported by state and federal IPM funds, along with grants from the Massachusetts Society for Promoting Agriculture and the US EPA IR-4 Program.

* * * * *