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Michael L. Avery
USDA/APHIS/Denver Wildlife Research Center, michael.l.avery@aphis.usda.gov

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MICHAEL L. AVERY, USDA/APHIS/Denver Wildlife Research Center, 2820 E. University Ave., Gainesville, Honda 32601

ABSTRACT: Methyl anthranilate (MA) is a grape-flavored food additive that is aversive to birds. Previous studies had indicated that anthranilates can deter frugivorous birds but that anthranilates are phytotoxic. In this study, I tested the bird repellency to 2 MA formulations on blueberry plants in a large flight pen. Neither MA formulation protected the blueberries from damage by cedar waxwings (*Bombycilla cedrorum*) or European starlings (*Sturnus vulgaris*). The encapsulated formulation, however, was nonphytotoxic. Due to the on-going need for safe bird deterrent compounds, further development and testing of MA as a bird repellent on fruit is warranted. The most fruitful and cost-effective approach, however, might be to integrate MA use with other bird deterrent methods to lower the attractiveness of the cultivated fruit relative to available alternate foods.

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INTRODUCTION

The bird repellent effects of methyl anthranilate (MA), dimethyl anthranilate (DMA), and related compounds have been known for over 30 years (Kare 1961). Despite this knowledge, relatively little was done to develop for practical use the bird repellency of MA and DMA until the early 1980's when DMA was investigated as a possible bird repellent feed additive to discourage European starlings (*Sturnus vulgaris*) and other species at feedlots (Mason et al. 1985, Glahn et al. 1989). Since then, various studies have addressed the potential for other uses such as to deter grazing waterfowl (Cummings et al. 1991), to reduce bird use of standing water (Dolbeer et al. 1991, Avery et al. 1992), and to protect fruit crops (Askham and Fellman 1989, Avery et al. 1989).

Several factors provide incentive for the development of MA as a bird repellent on fruit:

(1) With the withdrawal of methiocarb as a bird repel lent (Tobin and Dolbeer 1987, Avery and Decker 1992), growers have no effective means to control bird damage,
(2) There is substantial bird damage to cherries, grapes, and blueberries throughout the country (Besser 1985, Strik 1990, Avery et al. 1991),
(3) Methyl anthranilate has been an effective bird repellent in other contexts (e.g., Mason et al. 1989, Mason et al. 1991), and
(4) Methyl anthranilate is used as a food additive and presumably is safe for human consumption.

Initially, our investigation (Avery et al. 1989) of MA as a bird repellent on fruit focused on determining: (1) the effective repellent MA concentration on fruit, and (2) the effects of the chemical on the plant. Our results from feeding trials with individually caged waxwings (Avery et al. 1992) showed that berry consumption was reduced 43%, 75%, and 86% by MA applications of 0.25% (g/g), 0.5% (g/g), and 1.0% (g/g), respectively (Fig. 1). We also noted, however, that even though the birds did not eat many MA-treated berries, they persisted in testing them so that the total number of berries handled was reduced only 14% by the MA treatments. Moreover, when we applied an encapsulated MA formulation to blueberry plants in the field, we observed substantial foliar burn with each of the rates tested (Avery et al. 1989, Fig. 2). Similar phytotoxicity was obtained in a more limited bioassay with grape leaves.

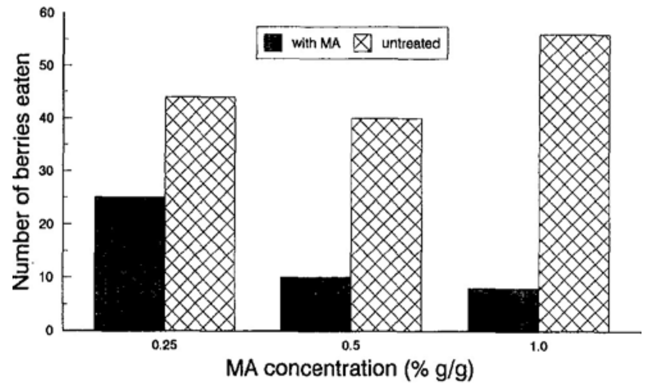

Figure 1. Consumption by captive cedar waxwings of MA-treated and untreated blueberries.

Meanwhile, Askham and Fellman (1989) evaluated DMA in cage and field trials. Their results were similar to ours in that captive starlings reduced consumption of DMA-treated grapes and that foliar burn occurred in field applications to cherry trees. Based on a limited field evaluation, they concluded that damage to cherries was reduced from 9.8% prespray to 6.4% and 3.5% after application of 4% and 8% DMA solutions, respectively.

Since our initial tests, new formulations have become available. In this paper, I describe results of more recent tests using some of these newer MA formulations on blueberries, and discuss possible avenues for additional investigation.

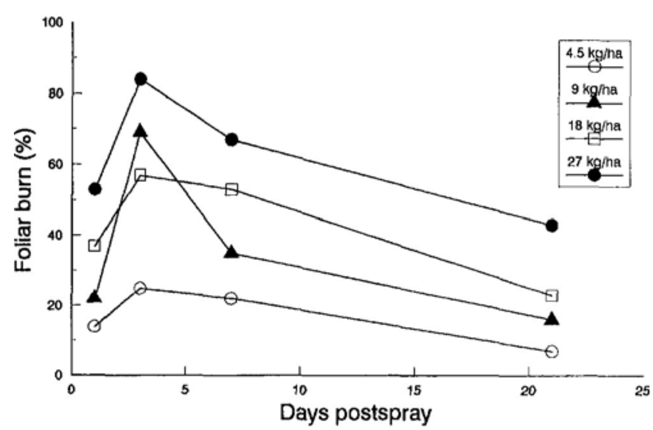

Figure 2. Estimated foliar burn to blueberry plants following MA applications at various rates.

METHODS

General

In 1989 we established 3 blueberry plots within the 0.2 ha flight pen at the Florida Field Station. Two plots (5 x 5 m) each contained 25 plants of mixed early-ripening highbush varieties obtained from the University of Florida Horticulture Unit. These plots were 15 m apart. A third plot (triangular, 3 x 3 x 5 m) was planted in the northwest corner of the flight pen, 40-50 m from the highbush plots. This plot contained later-ripening lowbush varieties also obtained from the Horticulture Unit. Due to the mixture of varieties, berry size, and berry crop, ripening times varied among bushes within plots and between plots.

Experiment 1

On 10 April 1990,1 applied MA to the east highbush plot at the rate of 18 kg/ha (16 lb/ac). I did not use a higher rate because of potential phytotoxicity. The MA was in a formulation of poly vinyl alcohol at a concentration of 10% (g/g). The formulation was mixed with water for application with a hand-pumped sprayer. The sprayer was equipped with a stainless steel 8002 evenflow nozzle and the operator sprayed the bushes repeatedly while walking quickly around the plot. The other highbush plot was unsprayed and served as a control. The lowbush plot had only unripe fruit at this lime.

In each plot, I marked 15 branches with aluminum tags and counted all berries distal to the tags. The number of berries remaining 24 h and 48 h postspray were recorded as a measure of bird damage. Foliage was examined 24 h and 48 h postspray in the sprayed plot to record the frequency of foliar burning.

Five cedar waxwings were released into the flight pen within 30 min of MA application. These birds were trapped in nearby blueberry fields and had been group-housed for 3 wk at the Florida Field Station with free access to water and banana mash (Denslow et al. 1987).

The birds were observed from a blind 35 m away for 40 min following their release into the flight pen. Plot use and berry consumption were recorded. After 48 h, the first group of birds was freed. Then the treated plot was resprayed, new sets of fruit-bearing branches were marked, 5 new cedar waxwings were introduced, and the entire trial was repeated.

Experiment 2

On 23 May 1990, a second test was conducted with a MA formulation supplied by Wheatec Co. (Wheaton, IL). This formulation contained 11 % (g/g) MA in a biodegradable starch matrix. The MA-starch formulation was mixed with a small amount of commercially available sticker and water before being sprayed on the west highbush plot at a rate of 9 kg/ha (8 lb/ac). The rate was selected in an attempt to avoid a phytotoxic reaction.

Ten branches were marked with aluminum tags on the treated plot and on the unsprayed control plot which consisted of small-fruited blueberry bushes planted in the northwest corner of the flight pen. Berries remaining on marked branches were counted 24, 48, and 72 h postspray. By this time, there were no berries in the east highbush plot, the one treated in Experiment 1.

Immediately after treatment, 10 European starlings were released into the flight pen. These birds had been trapped locally and held in captivity approximately 8 months. Four days prior to the test they were taken from their holding cage and put into a 3 x 10 x 2m enclosure within the flight pen, where they were fed fresh blueberries as well as their normal maintenance diet of Flint River Mills F-R-M(R) Game Bird Starter.

RESULTS

Experiment 1

The first group of cedar waxwings began feeding in the sprayed plot within 25 min of their introduction, and displayed no evidence of discomfort or unusual behavior. Of the 15 berries observed plucked from the treated bushes, 13 were swallowed and 2 were dropped. After 48 h, 43% of the berries in the sprayed plot were gone compared to 17% in the unsprayed plot (Table 1).

The second group of waxwings was slower to begin feeding and a check of the bushes indicated that they had not used either plot 3 h postspray. After 24 h, only 30 berries had been removed from the 2 plots combined (Table 1). Ultimately, this group of birds removed 20% of the berries from marked branches in the treated plot, compared to 10% in the unsprayed plot.

The day after the second spray application, substantial foliar burn was detected on bushes throughout the treated plot. Of the leaves on the marked branches, over 90% displayed some, often major, damage. No such damage was recorded in the unsprayed plot.

Experiment 2

Test birds ultimately removed 10% of the berries from the control plot and 43% of the fruit in the sprayed plot (Table 2). There was no indication of foliar burning on any of the treated bushes.

Table 1. Berry removal by cedar waxwings from unsprayed blueberry bushes and from bushes sprayed with methyl anthranilate at a rate of 16 lb/ac.

Test Treatment	Group	Initial count	Berries remaining after 24 h	48 h	Loss
Sprayed	1	318	212	180	43%
	2	236	227	188	20%
Unsprayed	1	219	219	181	17%
	2	244	223	219	10%

Table 2. Berry removal by starlings from unsprayed blueberry bushes and from bushes sprayed with MA at the rate of 8 1b/ac.

Plot	Initial count	No. of berries remaining after 24 h	48 h	72 h	Loss
Sprayed	86	69	59	49	43%
Unsprayed	181	168	164	163	10%

DISCUSSION

The results from Experiment 1 corroborate earlier findings (Avery et al. 1989) that MA is phytotoxic to blueberry plants. The poly vinyl alcohol formulation may have inhibited MA phytotoxicity because the foliar burn did not appear until the morning after the second application. Rain showers during the night following the initial spray may have washed off some of the material and thus delayed the onset of the leaf damage.

In Experiment 1, I did not observe the second group of waxwings feeding on the berries, but the actions of the first group demonstrated that this MA formulation, even when freshly applied, was not deterrent to the birds. This finding is in contrast to previous results (Avery et al. 1992) that showed MA to be repellent to caged cedar waxwings (Fig. 1).

In Experiment 2, a different species of bird was used, the application rate was lower, and the formulation was different, but as in Experiment 1, there was no evidence of any repellent effect. At the 9 kg/ha (8 lb/ac) application rate, however, the starch matrix formulation was not phytotoxic.

The complete lack of repellency in these experiments is puzzling. Because waxwings and starlings are known to be sensitive to MA, some repellent effect was expected. Contrary to expectations, however, each species preferentially damaged the treated fruit.

MANAGEMENT IMPLICATIONS

The lack of an effective bird repellent for use on fruit crops, and the successful deterrence of birds with MA in other contexts (e.g., Mason et al. 1989, Mason et al. 1991), provide incentive for the development of MA for bird control applications in fruit. The results obtained by Askham and Fellman (1989) with DMA were similar to our earlier study with MA (Avery et al. 1992) in that (1) captive frugivores were deterred from feeding on fresh fruit treated with anthranilates, and (2) anthranilates can be phytotoxic when applied in the field. The starch matrix formulation tested in Experiment 2 seemed to solve the phytotoxicity problem.

But there is still doubt that MA can be an effective deterrent to free-flying frugivores. Askham and Fellman (1989) noted reduced bird damage following DMA treatments in the field, but I did not obtain similar responses in flight pen trials. Possible reasons for this disparity include differences in the chemical formulation, different bird species, and greater behavioral options in the field than in the flight pen. Because flight pen evaluations do not replicate all aspects of field uses, inferences about performance in the field must be drawn cautiously. Nevertheless, until positive results arc forthcoming in controlled experiments, full-scale field trials seem premature.

Even if MA effectively deters frugivorous birds, two important considerations remain. First, the strong taste and odor of MA could seriously degrade the appeal of the fruit for consumers. Askham and Fellman (1989) reported no taste effect due to DMA treatment of cherries. Hours after applying MA in this study, however, I ate blueberries from treated bushes and they tasted like grapes. Post-harvest washing to remove all traces of the repellent could add additional cost to the packing operation.

Also, the cost-effectiveness of anthranilate applications must be considered. We estimated from caged feeding trials (Avery et al. 1992) that a treatment rate of 0.5% (g/g) MA on blueberries reduced cedar waxwing consumption by 75%. How much MA has to be applied in the field to achieve the desired 0.5% concentration on the fruit? If we assume an average blueberry yield of 5400 kg/ha (Hancock and Draper 1989) and also assume that about one half of what is sprayed actually gets on the fruit, then approximately 54 kg MA/ha would be needed to obtain 0.5% MA concentration on the fruit. At a cost of $7.50/kg MA (Mason et al. 1991), this equals $405/ha per application.

Under what circumstances can a grower expect to profit by applying MA at $405/ha? Cost effectiveness depends on 3 factors:

(1) the value of the crop,
(2) the effectiveness of the MA application, and
(3) the level of damage without the MA application.

As crop value and the level of anticipated damage increase, so does the cost-effectiveness of MA use (Table 3).

The cost-effectiveness of MA can be increased considerably by relaxing the requirement that the entire field be treated. Selective application of the repellent will reduce wastage and focus the chemical on parts of the field or portions of the bushes where the bird problem is most acute. Furthermore, the effectiveness of MA might be increased by combining the repellent with other crop protection methods.

In addition, lowering the attractiveness of the cultivated fruit relative to the available alternate foods will increase the effectiveness of the repellent. The appeal of cultivated fruit to birds such as starlings and American robins (*Turdus migratorius*) may be reduced by altering the sugar composition of the fruit (Brugger and Nelms 1991). Also, the relative value of cultivated blueberries may be reduced by providing

Table 3. Estimated net savings ($/ha) from full-field application of methyl anthranilate, assuming that the cost of application is $450/ha and that the application reduces bird damage by 75%.

Anticipated level of damage without MA (%)	Value of the crop ($/ha) $600	$1200	$2400	$4800
20	-360	-270	- 90	270
40	-270	- 90	270	990
60	-180	90	630	1710
80	- 90	270	990	2430
100	0	900	1350	3150

birds with a more attractive alternate. Laboratory and field data (Nelms et al. 1990) suggest that cedar waxwings prefer the small berries of native blueberry varieties to the large-fruited cultivars. This preference could be enhanced and cost-effectiveness increased by selective application of MA to the large-berried cultivars.

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