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Potential Use of Sucrose as a Feeding Deterrent for Frugivorous Birds

Anne M. Socci¹,
Marvin P. Pritts, and
Mary Jo Kelly

ADDITIONAL KEY WORDS. blueberry, table sugar, *Vaccinium corymbosum*

SUMMARY. A mixed cultivar blueberry planting was treated with a concentrated sucrose solution before fruit ripening and after episodes of rain during the harvest season. Fruit losses due to birds were monitored throughout the season in this planting and in the same cultivar in a separate nontreated planting ≈ 200 m (650 ft.) away. Fruit loss to birds was $\approx 50\%$ greater in the nontreated planting over the first 3 weeks of harvest. In addition, bird activity was monitored between 0600 and 0700 HR on two occasions in each planting during the early harvest season. Bird activity was many times higher in the nontreated planting. These observations suggest that sucrose should be tested more widely for potential activity on bird feeding behavior.

Birds cause considerable losses in fruit plantings throughout the world. In 1989, 10% of the highbush blueberry crop was lost to birds (Avery et al., 1992), costing growers \$8.5 million. Birds cause losses for grape growers as well, estimated to be \$4.4 million in 1972 (Crace et al., 1976). Cherry growers also suffer losses from birds (Tobin et al., 1991). 'Fuji' apple growers lose considerable amounts of fruit to bird damage every year (E. Fallahi, personal communication).

Department of Fruit and Vegetable Science, Cornell University, Ithaca, NY 14853.

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Fruit that experience bird depredation consist mainly of simple sugars, such as fructose and glucose (Chapman et al., 1993; Gardiner et al., 1993; Kader et al., 1994; Kondo and Gemma, 1993; Ranwala et al., 1992; Shaw, 1988; Woodruff et al., 1960). Many frugivorous bird species lack the enzymes necessary to digest polysaccharides and other complex sugars (Brugger and Nelms, 1991; Martinez del Rio et al., 1988; Schuler, 1983) or cannot maintain a positive energy balance feeding on a high sucrose diet (Avery et al., 1995). When the former eat sucrose, they experience intestinal discomfort from fermentative diarrhea and develop a learned aversion to the food containing the sucrose (Martinez del Rio et al., 1988). Many birds show a clear preference for fruit containing hexose sugars, such as glucose and fructose (Avery et al., 1995; Schuler, 1983), and artificial feeding trials suggest a concentration threshold of $\approx 11\%$ sucrose for repellency (Brugger et al., 1993).

Darnell et al. (1994) suggest that blueberry fruit could be genetically engineered to produce sucrose to deter feeding. However, growers might be able to directly treat ripening fruit with sucrose to achieve the same effect. Sucrose is readily available, cheap, and safe to apply and consume.

Our objectives were to determine if sucrose sprays have potential as a bird feeding deterrent and, if so, to identify any negative consequences of treating with sucrose.

Materials and methods

Two blueberry plantings in Ithaca, N.Y., separated by ≈ 200 m (650 ft.) were selected for study. Both plantings contained a mixture of cultivars in five plant plots and were bordered on at least three sides by fences or trellises. Trees were abundant in the area, and both plantings were 300 m (1000 ft.) from the nearest highway. The smaller planting, consisting of 160 plants (two cultivars), was treated with a concentrated sucrose solution before fruit ripening and after each significant rain event for 3 weeks. The larger planting, containing 300 plants (20 cultivars), was not treated.

In each planting, two inflorescences in each of 15 bushes of 'Berkeley' were marked and the number of unripe fruit were counted. One fruit cluster was located in the top half of

the bush; the other was in the lower half. Twice weekly the number of fruit on each cluster was counted. Fruit that were damaged by birds but still attached to the cluster were removed and counted. Occasionally a berry was damaged by a Japanese beetle or other insect (independent of sucrose treatment); these fruit were removed, but were not counted as bird-damaged fruit.

The treated planting received the first application of sucrose on 10 July 1996 when the berries started to turn blue but before any bird feeding was evident. There were three significant rain events during the following 3 weeks that washed off the sucrose, so reapplications were made immediately following the rain events.

The sucrose solution was applied with a CO₂ backpack sprayer with a 8006 Tee-Jet flat-fan nozzle at 140 kPa (20 psi) using 400 L·ha⁻¹ (40 gal./acre). This volume wetted the bushes nearly to runoff. The sucrose solution consisted of granulated cane sugar at 1.3 kg·L⁻¹ water (10 lb. 13 oz./gal.), yielding ≈1.9 L of solution. The sugar was stirred into warm water, allowed to stand at room temperature for 1 to 2 d, then stirred again until the sugar completely dissolved. Olympic Spreader Sticker was added at 310 ppm to help retain sugar on the waxy fruit. (Preliminary work with three spreader-stickers showed that Olympic Spreader Sticker held the sugar on the fruit without leaving marks on the berry.)

On each of two mornings in each planting (18, 19, 23, and 24 July), between 0600 and 0700 HR, bird activity was monitored by recording the species and the number entering and existing a prescribed area over the observation period.

Results and discussion

The sucrose-treated planting experienced fewer losses to birds [22% by 29 July (Julian day 211)] than did the nontreated planting (43% by 29 July) for the first 3 weeks of the harvest season (Fig. 1). In addition, bird activity was low in the treated planting (an average of two birds in-out per hour), but high in the nontreated planting (an average of 69 birds in-out per hour). Major species in the plantings included starling (*Sturnus vulgaris* L.), robin (*Turdus migratorius* L.), and sparrow (*Passer domesticus* L.). Additional species observed in the nontreated field included cedar waxwing, gray catbird, goldfinch, mockingbird, kingbird, and house finch. Several days after the fourth rain event and the discontinuation of sugar applications, feeding increased markedly in the treated planting (Fig. 1). Although not definitive, the results suggest that the presence of sucrose was reducing bird activity and damage.

Fruit clusters lower on bushes experienced more bird depredation than upper clusters (Fig. 2), but the difference was highly significant only in the treated planting ($P < 0.01$ on day 211). The reason for the differ-

ence between upper and lower clusters is unclear. Perhaps less sugar stuck to the lower clusters as the spray was intercepted by upper clusters and leaves, or perhaps our resident bird species may feed more on lower clusters. Ground-feeding sparrows and finches may be less deterred by sucrose than starlings and robins which tend to feed on upper clusters. Berries on lower clusters ripen later than berries on upper clusters (Gough, 1994), and it is commonly observed that later-ripening blueberries experience less bird depredation. So, we do not attribute differences in feeding within the canopy to differences in the time of ripening.

It is unclear if the sucrose was acting as a taste deterrent in the planting or if the birds found the sticky leaves and branches discomforting. Clark and Mason (1993) suggest that it would be unrealistic to use foliarly applied sugar in a sufficient quantity to cause a learned aversion in starlings based on sucrose ingestion (threshold concentration in food of 11%). In our experiment, the high concentration on the outside of the fruit may have been sufficient to deter feeding, although the average sucrose concentration of an entire treated fruit would have been low. Regardless, activity was significantly less where sucrose was sprayed.

We neither observed any increase in fungal colonization or insect or mammal feeding in the treated planting nor could we detect any differences in fruit quality among the two treatments. Small, crystallized droplets of sugar were present on the fruit of the treated planting, but these droplets were removed easily with rain, overhead irrigation, or washing. Pickers may find it discomforting to harvest bushes covered with crystallized sugar. If sugar sprays are used to deter birds, then bushes may have to be washed via overhead irrigation before harvest.

Birds learn to associate certain foods with specific locations and establish a feeding pattern based on these locations. If birds learn that a particular location has poor forage or high disturbance, they will not include this location in their routine feeding pattern (Curtis et al., 1995). For this reason, taste deterrents must be in place at the time birds begin foraging in a fruit planting.

Fig. 1. Seasonal trend of fruit loss to birds during 1996 in a treated and nontreated field of 'Berkeley'.

It is difficult to properly replicate studies on avian feeding deterrents because birds are mobile and forage over a large area, and they cannot visually distinguish between small plots of treated and nontreated fruit. If one were to randomize taste deterrents within a field, birds would receive a confusing message (both positive and negative reinforcement) about the palatability of the food in that field. Since fruit must be sampled to determine palatability, treated fruit in a replicated trial would receive considerably more damage than an entire field treated with the taste deterrent. For this reason, we had to make our comparison between two separate fields, and the treatments could not be directly compared statistically. Although the fields were not equivalent in terms of cultivar mix and size, we can think of no compelling reason why one field would be inherently more or less attractive to birds than the other. The smaller planting had experienced intense bird depredation in previous years, and most gardeners will attest that birds have little problem locating ripe fruit on three or four bushes. (Our smaller planting contained 160 bushes.) Furthermore, when the sugar applications were discontinued, the field became more attractive to birds (Fig. 1), suggesting that birds could find the blueberries easily.

At our location, birds had a choice between treated and nontreated fruit. If all blueberries in a given location were to be treated, sucrose may be less of a deterrent because no alternative would be available other than blueberry avoidance. Sucrose sprays need to be evaluated over many locations and on large fields before firm conclusions about efficacy can be made.

We recognize that our single study has limitations. It was not replicated over years or locations, and the size of our plantings was small. However, potential benefits are large as sugar is cheap and easy to apply. The cost of materials per application was about \$100/ha (\$40/acre), and we made four applications per year. This \$400 cost was more than offset by a 50% reduction in losses that were attributed to birds and resulted in the equivalent of a 22% greater realized yield over the nontreated field by the end of July. We hope that other researchers and growers will examine the efficacy of sucrose applications under a wide range of environmental conditions.

Fig. 2. Seasonal trend of fruit loss to birds during 1996 in upper vs. lower portions of blueberry 'Berkeley' bushes treated (a) or not treated (b) with sucrose.

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Oxamyl Is an Effective Apple Fruit Thinner when Used Alone or when Combined with Other Thinners

Richard Marini

ADDITIONAL INDEX WORDS. Vydate, fruit set, *Malus domestica*, carbaryl, Accel, ethephon, NAA, oil, Tween 20

SUMMARY. In five experiments with 'Redchief Delicious' and one with 'Braeburn', oxamyl (Vydate 2L) was used alone or combined with other chemicals to thin apples. The thinning response to oxamyl depended on dose. In most cases, oxamyl at 600 mg·L⁻¹ and carbaryl at 900 mg·L⁻¹ thinned trees similarly, but the combination of oxamyl plus carbaryl was no more effective than either chemical alone. The combination of oxamyl plus NAA (2.5 to 5 mL·L⁻¹) was slightly more effective than either material alone. The thinning response to oxamyl and carbaryl was related to the concentration of superior oil added to the spray solution; for both chemicals, adding oil at 5 mg·L⁻¹ or Tween 20 at 1.25 mL·L⁻¹ gave equivalent thinning. Apples on trees sprayed with oxamyl plus oil had a dull finish. Adding Tween 20 at 1.25 mL·L⁻¹ improved the thinning activity of carbaryl (Sevin XLR-Plus) more than oxamyl. Similar thinning occurred whether oxamyl was applied when fruit diameter averaged 4 or 10 mm. On 'Braeburn' oxamyl, carbaryl, Accel, and NAA were mild thinners, but all combinations of oxamyl or carbaryl plus Accel or NAA overthinned the trees without improving fruit size. In general, oxamyl at 600 mg·L⁻¹ (2 pints of vydate 2L/100 gal.) and carbaryl thin apple trees similarly, and the efficacy of both chemicals is improved by adding a surfactant.

¹Department of Horticulture, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0327.

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Carbaryl (Sevin) is a carbamate insecticide commonly used for thinning apples; its major attributes are fairly consistent results, the thinning response does not depend on dose, overthinning is uncommon, and it is relatively inexpensive. Unfortunately, the most common formulation, Sevin 50W, is highly toxic to honey bees and mite predators (Pfeiffer et al., 1995). The new carbaryl formulation (Sevin XLR-Plus) is less toxic to beneficial arthropods (L. Williams, Rhone-Poulenc Ag. Co., personal communication). When used at the same concentration of active ingredient, the two carbaryl formulations thin similarly (R.E. Byers, personal communication). Oxamyl (Vydate 2L) is a carbamate insecticide that was first registered as an apple thinner in Virginia in 1994, followed by Pennsylvania in 1995, and West Virginia and New Jersey in 1996. Federal registration is expected in the near future (D. Gansky, Dupont Co., personal communication).

When applied to fruit with mean diameters of 4 to 14 mm, oxamyl and carbaryl thinned similarly (Byers et al., 1982; Marini, 1996). Oxamyl fits well into the Virginia integrated orchard management program. It is rated only moderately toxic to honey bees and the primary mite predator (*Stethorus punctum*), it is a moderately effective acaricide, and, if applied near petal fall, it controls the first generations of spotted tentiform leafminer and white apple leafhopper (Pfeiffer et al., 1995). When used for thinning, Sevin 50W, but not oxamyl, increased European red mite populations (Byers et al., 1982).

Because oxamyl registration for thinning apple is being extended to additional states, fruit specialists, county agents, consultants, and fruit growers need information on its efficacy. The purpose of this paper is to report results from several unrelated experiments conducted over several years and designed to obtain information concerning the thinning response to oxamyl, alone and in combination with surfactants and other thinning chemicals. In addition, a new formulation of Vydate (Vydate 2L) was evaluated, as Vydate 2EC was used in previous studies (Byers, 1978; Byers et al., 1982).

Materials and methods

EXPERIMENT 1: DOSE RESPONSE, OXAMYL ALONE. On 23 Apr. 1991, dur-