Sprayer Type and Pruning Affect the Incidence of Blueberry Fruit Rots

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Additional index words. Alternaria sp., anthracnose, Botrytis cinerea, Colletotrichum acutatum, Rizopus sp., Vaccinium corymbosum

Abstract. Highbush blueberries (Vaccinium corymbosum L.) in Michigan are treated annually with fungicides to control fruit rots caused by Colletotrichum acutatum 1.H. Simmonds, Alternaria sp., and Botrytis cinerea Pers.:Fr. Control with recommended fungicide programs is often inadequate. The goal of this study was to compare the effects of two spray treatments and three levels of pruning severity on fruit rot levels in mature ‘Jersey’ bushes. Two spray treatments were tested for 3 years: 1) recommended fungicide rates applied with a conventional airblast sprayer; 2) 67% of recommended fungicide rates applied with a multifan/Nozzle, above-row sprayer. Pruning treatments included light and heavy pruning (compared for 1 year), and light, moderate, and heavy pruning (compared for 3 years). Fruit rot incidence was determined after incubating individual fruit at 100% relative humidity and 21 °C for 7 to 11 days, and after exposing 0.24-L plastic clamshell containers of fruit to simulated commercial handling. The above-row sprayer provided fruit rot control at least equivalent to the airblast sprayer even though less chemical was applied. Anthracnose rot in berries from the top of the bush canopy were reduced by pruning, but those in the bottom of the bush, and levels of other diseases were not consistently affected. Pruning also reduced yields, although the study was too short in duration to determine the long-term impact on production.

Several fruit-rotting fungi cause significant losses in highbush blueberries. In Michigan, the most serious fruit diseases are caused by Colletotrichum acutatum (anthracnose fruit rot or ripe rot), Alternaria sp. (Alternaria rot), and, to a lesser extent, Botrytis cinerea (Ramsdell, 1989; Schilder, unpublished data). Anthracnose infections may occur anytime between bloom and harvest (Hartung et al., 1981), whereas most Alternaria infections appear to occur later in the season (Bristow and Windom, 1998). Colletotrichum acutatum, Alternaria sp., and Botrytis sp. can also infect fruit after harvest (Ceponis and Cappellini, 1987; Cline, 1996). Fungicides applied to control fruit rots account for over half of the crop protection chemicals applied annually to Michigan blueberries (U.S. Dept. of Agriculture, National Agricultural Statistics Service, 1998). Even when fungicide recommendations are followed, losses from fruit rots can be significant, emphasizing the need for improved control methods.

In Michigan, fungicides are applied to commercial blueberries with fixed-wing aircraft and various ground equipment. The primary fungicide used to control blueberry fruit rots is captan (N-Trichloromethylthiophio-4-cyclohexene-1,2-dicarboximide), a nontoxic protectant that needs to be applied uniformly throughout the canopy for greatest benefit. Application equipment characteristics and operation can affect fungicide efficiency by altering deposition patterns. Equipment that can treat large areas quickly (high field capacity) provides the flexibility necessary to treat large areas when conditions are optimal.

Airblast sprayers that propel spray up and through bushes are used by many Michigan growers. Cannon sprayers that project spray across the tops of several blueberry rows are also popular because the field capacity is high, and, since fewer passes through the field are required, the potential for mechanical damage to developing fruit is minimized. An above-row sprayer recently developed by researchers at Michigan State Univ. (MSU) shows promise because multiple fans and atomizers provide uniform droplet size and the machine has a relatively high field capacity. Canopy management by pruning may also aid in the control of fruit rots, since fruit-rotting pathogens are known to overwinter in infected twigs, and need high relative humidity and free moisture for infection and sporulation (Caruso and Ramsdell, 1995). The goal of this project, therefore, was to determine if fungicide rates could be reduced by utilizing the above-row sprayer or by modifying the bush architecture through pruning.

Materials and Methods

The study site was a 40-year-old commercial planting of ‘Jersey’ bushes in Muskegon, Mich. Bushes were 1.2 m apart in north-to-south oriented rows spaced 3 m apart (2690 bushes/ha). Two spray treatments were imposed in 1995, 1996, and 1997: 1) recommended fungicide rates applied with an conventional airblast sprayer, and 2) 67% of the recommended fungicide rates applied with an experimental above-row sprayer. Except for the difference in fungicide rates, sprays were applied by the grower according to commercial recommendations for Michigan blueberries (Johnson et al., 1995) (Table 1). The airblast sprayer was an Agtec (Ag-Chem, Minnetonka, Minn.) three-point hitch mounted unit that delivered 187 L·ha⁻¹ spray volume at a nozzle pressure of 1.0 kPa. The sprayer was driven over alternate row middles at 1.5 m·s⁻¹, and had an estimated field capacity of 3.2 ha·h⁻¹. The above-row sprayer was constructed by agricultural engineers at MSU, and was similar to machines marketed by Ledebuhr Industries (Bath, Mich.). The sprayer boom covered four rows (two nozzle-fan units per row), and delivered a spray volume of 93 L·ha⁻¹ at a nozzle pressure of 1.2 kPa. The above-row sprayer was driven through every fourth row middle at 1.52 m·s⁻¹, giving a field capacity of 6.7 ha·h⁻¹. The nozzle/fan assemblies were positioned ≈1 m apart along the boom, and were oriented at roughly 8 o’clock and 4 o’clock positions ≈1 m above the plants. Both fans were angled at 20° toward the center of the row, the front fan being angled forward, the back one rearward. The sprayer plots were five rows wide, 135 bushes long, and replicated twice. In 1998, the entire study area was treated with an airblast sprayer at recommended fungicide rates (Table 1).

Three pruning severity treatments (light, moderate, heavy) were assigned to plots in Mar. 1995. At that time, 20% of the largest canes were removed from bushes in the heavy pruning plots, and other plots were not pruned. Thus, only two pruning severities were compared in 1995. In Mar. 1996, 20% of the largest
Table 1. Fungicide† application times and rates for the airblast and above-row spray treatments applied to 'Jersey' blueberries in Muskegon, Mich.

| Growth stage | 1995 | 1996 | 1997 | 1998 |
|--------------|------|------|------|------|
| Green tip    | Triforine; 0.015, 0.01† | Triforine; 0.015, 0.01 | Benomyl; 0.23, 0.15 | Chlorothalonil; 1.68 |
| Pink bud     | Benomyl; 0.23, 0.15 | Captan; 0.9, 0.6 | Benomyl; 0.23, 0.15 | Chlorothalonil; 1.68 |
| Bloom        | Captan; 0.9, 0.6 | Triforine; 0.01, 0.007 | Benomyl; 0.23, 0.15 | Ziram; 1.68 |
| Petal fall   | Captan; 0.9, 0.6 | Benomyl; 0.23, 0.15 | Benomyl; 0.23, 0.15 | Fosetyl-Al; 2.24 |
| Green fruit  | Captan; 0.9, 0.6 | Benomyl; 0.23, 0.15 | Benomyl; 0.23, 0.15 | Fosetyl-Al; 2.24 |
| Green fruit  | Captan; 0.9, 0.6 | Benomyl; 0.23, 0.15 | Benomyl; 0.23, 0.15 | Fosetyl-Al; 2.24 |

†Commercial products used: benomyl [1-(butylcarbamoyl)-2-benzimidazolcarbamate] (Benlate® 50 WP, DuPont Inc.); captan (Captec® 4 FL, Micro-Flow Co); chlorothalonil (tetrachloroisophthalonitrile) (Bravo® Weather Stick, Zeneca); fosetyl-Al [aluminum tris (O-ethyl phosphate)] (Aliette® WDG, Rhone-Poulenc); triforine [N,N’-1,4-piperazine-1-yl-bis(2,2,2-trichloroethylidene)]-bis-[formamide] (Funginex® 18.2 EC, Ciba-Geigy); ziram (zinc dimethylthiocarbamate) (Ziram® 76DF, Elf Atochem).

Table 2. Effect of pruning on the percentage of canes with different base diameters (cm) in 'Jersey' bushes in Muskegon, Mich.

| Pruning treatment | Total number of canes | <0.6 | 0.6–1.3 | 1.4–1.9 | 2.0–2.5 | >2.5 |
|-------------------|-----------------------|------|---------|---------|--------|------|
| Light             | 41.9 a†               | 36 a | 41      | 14 a    | 7      | 1    |
| Moderate          | 37.4 ab               | 46 b | 40      | 11 ab   | 3      | 0    |
| Heavy             | 34.9 b                | 42 ab| 43      | 9 b     | 5      | 1    |
| Light             | 58.5                  | 17 a | 58      | 14 a    | 9 a    | 2    |
| Moderate          | 58.8                  | 26 b | 58      | 12 ab   | 4 b    | 0    |
| Heavy             | 70.0                  | 25 b | 65      | 8 b     | 1 c    | 0    |
| Light             | 20.1                  | 4    | 47      | 29      | 17 a   | 2    |
| Moderate          | 21.3                  | 9    | 56      | 24      | 10 ab  | 1    |
| Heavy             | 19.4                  | 8    | 62      | 24      | 6 b    | 0    |

†Mean separation within columns and years by LSD, P ≤ 0.05. If no letters, the F-test was nonsignificant.

Table 3. Effect of pruning treatments on yield of 'Jersey' blueberries in Muskegon, Mich., 1995 to 1998.

| Pruning treatment | Yield (kg/bush) |
|-------------------|-----------------|
| Light             | 4.0 a†          |
| Moderate          | 3.9 b           |
| Heavy             | 3.6             |

†Mean separation within columns and years by LSD, P ≤ 0.05. If no letters, the F-test was nonsignificant.
Yields and berry weights were not significantly affected by the spray treatments or the interaction of the spray and pruning treatments (data not shown).

The inadvertent pruning by the grower’s crew in Winter 1998 reduced total cane numbers from the previous year, and greatly reduced the number of small-diameter canes. Our selective pruning later in 1998 reestablished some treatment differences. Although all plots contained the same number of canes, the lightly pruned plots contained greater percentages in the large-size categories. The optimum number and age distribution of canes in ‘Jersey’ bushes has not been clearly defined; however, based on commercial standards, the lightly pruned plots were considered in need of pruning by the 1996 and 1997 seasons, whereas the canopy densities in the moderate and heavily pruned plots were considered acceptable. In 1998, all bushes were properly pruned by commercial standards.

The reduction in 1996 and 1997 yields due to pruning was expected because large, productive canes were removed. In 1996, bushes in the moderately and heavily pruned plots contained ≈10% and 20% fewer canes, respectively, than those in the lightly pruned plots, and these differences were all in the larger size categories (>1.3 cm). Overtime, bushes would be expected to respond to moderate and heavy pruning by producing more vigorous, productive canes in the intermediate-size categories, which would compensate for heavier pruning. By 1996 and 1997, moderate and heavy pruning had stimulated the growth of more canes in the smallest-size class. However, the study was not conducted long enough for these canes to become productive. Overall yields in 1996 were low because of reduced flower bud production and winter injury. Although pruning often increases berry weight in ‘Jersey’ (Siefker and Hancock, 1987), average berry weight was not consistently affected by pruning in this study. Overall yields during the study were only low to moderate compared with those in Siefker and Hancock’s (1987) study, so berry weight and yield were probably limited by heavy cropping stress.

**Fruit rot.** Fruit fungal infections were assessed by incubating fruit from two harvests in 1995, 1996, and 1997, and from one harvest in 1998, and by simulating short- and long-term commercial handling conditions with fruit from two harvests in 1997, and one harvest in 1998. Anthracnose was the primary fruit rot in 1995, 1996, and 1998, whereas Botrytis rot was most prevalent in 1997 (Fig. 1). However, levels of each pathogen varied considerably between years and between harvests in the same year (Fig. 1). Anthracnose rot was consistently higher in fruit from the bottoms than from the tops of bushes, when compared by a paired t test. Means from incubation tests were 22.8% and 34.4% for the top and bottom fruit, respectively (P ≤ 0.001), and means for simulated storage tests were 3.7% and 7.6% for top and bottom fruit (P ≤ 0.01). Botrytis and Alternaria rot levels did not differ significantly between the top and bottom of the bush.
Moderate or heavy pruning significantly reduced anthracnose levels in berries from the tops of bushes in five of seven incubation tests and three of six simulated commercial storage tests (Fig. 2). Data from tests where pruning did not significantly affect anthracnose levels are not shown. In the commercial tests, rot levels were lower in moderately pruned than lightly pruned plots in each case, and, in one case, moderate pruning also resulted in lower rot levels than did heavy pruning (Fig. 2).

Pruning could potentially reduce fruit rots by removing diseased wood that is a source of inoculum, or by opening the canopy to hasten drying and/or improve spray penetration (Cooley et al., 1997). Pruning probably reduced anthracnose rot by removing infected wood (Ramsdell, 1992), which is the primary source of anthracnose inoculum (Hartung et al., 1981). If the benefits of pruning were associated with enhanced drying or improved spray penetration, pruning would also be expected to reduce the levels of Alternaria or Botrytis rot, which was not the case in this study.

Why pruning often reduced anthracnose levels in the top but not the bottom of bushes is not clear. Perhaps this observation reflects spacial differences in anthracnose inoculum levels. Fruit in the bottom interior of the canopy had higher levels of anthracnose and may have been exposed to higher spore numbers if those discharged from infected tissue in the top of the canopy migrated downward. Spore numbers may have been so high in the bottom of the canopy that modest reductions due to pruning were not sufficient to reduce fruit infections. Pruning also opens the canopy and should reduce drying times and canopy moisture levels. Perhaps moisture levels in the bottom of the canopy were not reduced sufficiently by pruning to affect infection levels.

The spray treatments occasionally affected levels of specific pathogens in specific tests (Table 4), but overall, the spray treatments had similar effects on rot levels. Levels of each fruit rot in berries from both positions in the current study did not generally reflect these deposition patterns. The spray deposition patterns of these sprayers were studied in the same pruning plots in a companion study (Van Ee et al., 2000). The above-row sprayer often provided better coverage on card targets placed in the top of the canopy, whereas coverage in the bottom of bushes was often better with the airblast sprayer. Fruit rot levels in the tops and bottoms of the bushes in the current study did not generally reflect these deposition patterns.

The incubation procedure appeared to be a more rigorous test for the presence of fungi than simulations of commercial handling conditions. Berries from the first and second harvests in 1997 and the second harvest in 1998 were subjected to both tests. Mean rot levels across all treatments and positions in the canopy were higher for incubation tests (33.8% anthracnose, 7.0% Alternaria, 27.2% Botrytis) than following short-term (6.2% anthracnose, 1.4% Alternaria, 0.4% Botrytis) or longer-term (5.2% anthracnose, 0.9% Alternaria, 0.5% Botrytis) commercial handling simulations. Rot levels could have been increased by prolonging incubation at 19 °C. The duration of the commercial storage period did not consistently affect rot levels, but the short- and long-term storage regimes differed only in the length of time at 2 °C. In these tests, rotting may have resulted from latent infections or infections occurring during incubation or storage. Colletotrichum acutatum and Alternaria sp. may infect blueberries after harvest, if the surfaces of sorting equipment are wet and contaminated with spores (Cline, 1996).

In conclusion, this study demonstrated that the above-row sprayer could allow growers to reduce recommended fungicide rates by one-third without increasing the incidence of fruit rots. An added advantage of this sprayer is a greater swath width (four rows) so that more acreage can be treated in less time, providing greater flexibility when conditions are optimal. From a commercial standpoint, the pruning treatments yielded conflicting results. Pruning often reduced anthracnose rot, but also reduced yields in two seasons. Note again that the long-term effects of these pruning treatments could not be determined as the study only lasted 3 years and was confounded by the inadvertent pruning of all plots in 1998.

**Table 4. Instances of significant spray treatment effects on fruit rot levels (percentages of berries infected) in the top and bottom of ‘Jersey’ blueberry bushes in Muskegon, Mich. Levels of each rot organism in berries from the top and bottom positions were compared 17 times over years and harvests using different evaluation methods. Data from nonsignificant comparisons not reported.**

| Year | Test   | Harvest | Location | Berries infected (%) | Airblast | Above-row |
|------|--------|---------|----------|----------------------|----------|-----------|
| 1995 | Incubation | 1 | Top      | 8.3 A' | 3.4 B          |
| 1995 | Incubation | 1 | bottom   | 11.7 a | 4.4 b          |
| 1998 | Storage (14d) | 2 | Top      | 12.0 a | 6.8 b          |
| 1998 | Storage (7d) | 2 | bottom   | 1.6 a  | 0.9 b          |
| 1998 | Incubation | 2 | Top      | 0.4 a  | 0.8 b          |

Mean separation within rows by LSD, P ≤ 0.05 (lower-case letters) or ≤ 0.01 (upper-case letters).

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