Effects of Fungicides that Inhibit Ergosterol Biosynthesis on Apple Powdery Mildew Control, Yield, and Fruit Growth Factors

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ABSTRACT

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The effects of triadimefon, etaconazole, and dinocap on apple powdery mildew control, fruit set, size, shape, percent floral buds, and yield were studied on mature cultivar Newtown apple trees on seedling rootstock in four successive years. Treatments were applied to the same 0.2-ha blocks each year at 561 L/ha at 1-cm green, pink, petal fall, and first cover. Triadimefon, etaconazole, and dinocap rates were 0.14, 0.10, and 0.55 kg a.i./ha, respectively. Triadimefon and etaconazole reduced leaf and bud mildew infection more than either dinocap or check treatments. None of the mildewcides affected percent floral buds or fruit set, size, or shape. Yields of trees treated with etaconazole and dinocap were not different from each other but were greater than yield of triadimefon or check trees.

Triadimefon, an ergosterol biosynthesis inhibitor (EBI) fungicide, has been used commercially in the Pacific Northwest since 1982 to control apple powdery mildew, caused by *Podosphaera leucotricha* (Ell. & Ev.) Salm. Triadimefon was reported to increase apple fruit set (16), but high rates reduced fruit length/diameter ratios (15). Kolbe (7,8) reported increased yield and fruit numbers when apple powdery mildew was controlled with triadimefon. Triadimefon retarded growth of tomato and cotton plants because of inhibition of gibberellin biosynthesis (1). Another EBI fungicide, etaconazole, retarded shoot growth and altered size and coloration of apple leaves (6), suppressed return bloom (9), and increased yield (11).

The objectives of this study were to evaluate the effects of triadimefon and etaconazole on control of apple powdery mildew on leaves and buds and to determine the effects of these fungicides on fruit set, percent floral buds, fruit weight and shape, and yield. These responses were studied on large, commercially managed plots of mature apple trees over a 4-yr period. An abstract of this study has been published (12).

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MATERIALS AND METHODS

A 0.8-ha block of mature apple (*Malus sylvestris* Mill. 'Newtown') on seedling rootstock was selected for the study. For several years before the experiment, cultural and pest management practices were applied uniformly to all trees in the block.

Fungicide treatments included triadimefon (Bayleton 50WP), etaconazole (Vangard 10WP), and dinocap (Karathane LC) at 0.14, 0.10, and 0.55 kg a.i./ha, respectively. Dinocap was included because it has been used commercially for mildew control for many years and is not an EBI fungicide. Dodine (Cyprex 65WP) at 2.2 kg/ha was applied for apple scab control on plots treated with triadimefon and dinocap and control plots, which received no mildewcide. Each fungicide was applied to two 0.1-ha plots, each plot consisting of 10 60-yr-old trees. The same fungicides were applied to the same trees each year. Tree height was 6–7 m, and tree spacing was 10 × 10 m. Fungicides were applied each year from 1981 through 1984 at the 1-cm-green-tip, pink, petal-fall, and first-cover stages. The last sprays were applied on about 1 June each year. Fungicides were applied with an air-blast sprayer (Orchard Master MD 32-5, Mitchell Manuf. Co., Wilsonville, OR) calibrated to deliver 561 L/ha. Cultural practices and insect and weed control were done uniformly to all trees according to commercial recommendations (10).

Powdery mildew infection of foliage was evaluated on all leaves of 10 shoots per tree, eight trees per treatment, in early July 1981–1984 when terminal growth ceased. Leaves were assessed as diseased or healthy. Percent terminal buds infected with powdery mildew was determined in January 1982–1985 by evaluating 100 buds per tree on six trees per treatment according to visual criteria for infection (4,13). When less than the total number of trees in each plot were evaluated, trees on plot borders were not used for observations.

Measurements of fruit set and floral bud ratios were done using standard procedures of the WRCC-17 fruit-set regional committee (E. A. Mielke and P. B. Lombard, *personal communication*). Fruit set was determined by counting flower clusters on limbs 4–10 cm in diameter, two limbs per tree, during early bloom in April 1982–1984, and the fruits on each limb were counted in late June after natural drop ceased. Counts for fruit-set calculations were made on all 20 trees in each fungicide treatment.

The ratio of floral buds to vegetative buds was determined by counting the flower clusters and vegetative growing points on two limbs per tree in mid-April 1984 and 1985. Counts were made on all trees, and percent floral buds as related to total growing points was calculated.

In late September 1982–1984, just before harvest, average fruit weight and shape (length/diameter ratio) of 25 fruits per tree were measured on seven trees per treatment. Total yield of each tree was determined at harvest on 20, 16, 4, and 3 October in 1981, 1982, 1983, and 1984, respectively.

Data were analyzed with two-way analysis of variance using fungicides as treatments and years as blocks. Treatment means were separated with Duncan's new multiple range test.

RESULTS

All fungicide treatments significantly ($P = 0.05$) reduced foliar mildew. Triadimefon was most effective and dinocap was least effective (Table 1). Similarly, all fungicides significantly ($P = 0.05$) reduced the percentage of terminal buds infected by mildew (Table 1). Control of bud infection was no different with triadimefon than with etaconazole. Although fungicide applications were not made after 1 June, bud infection was reduced 57% with triadimefon and 47% with etaconazole. Scab infection was controlled with dodine in the triadimefon, dinocap, and check trees, and etaconozole provided both scab and mildew control. Leaf and fruit scab remained lower than

Table 1. Effects of triadimefon, etaconazole, and dinocap on powdery mildew incidence, fruit set, floral bud ratio, fruit weight and shape, and yield of Newtown apple

Treatment	Rate (kg a.i./ha)	Mildew infection (%)		Fruit set[w] (%)	Floral buds[x] (%)	Fruit size (g)[y]	Fruit shape (L/D)[y]	Yield (kg/tree)
		Leaves	Buds					
Triadimefon	0.14	9 a[z]	20 a	24 a	43 a	177 a	0.89 a	430 a
Etaconazole	0.10	15 b	25 a	30 a	49 a	181 a	0.90 a	479 b
Dinocap	0.55	21 c	37 b	25 a	44 a	177 a	0.90 a	470 b
Check	···	29 d	47 c	27 a	48 a	185 a	0.91 a	416 a

[w] Fruit set determined on two limbs per tree, 20 trees per treatment. Blossom counts made in April and fruit counts made in late June 1982–1984.

[x] Percentage of total growing points that were floral buds, counted on two limbs per tree, 20 trees per treatment, in April 1984 and 1985.

[y] Average weight per fruit or length/diameter of 25 fruits per tree, seven trees per treatment, in late September 1982–1984.

[z] Numbers followed by the same letter within columns are not significantly different at $P = 0.05$ according to Duncan's new multiple range test.

1% in all 4 yr.

None of the fungicides significantly ($P = 0.05$) affected fruit set, weight, or shape (Table 1). Also, no shift in the percentage of total growing points that were floral buds was observed with any fungicide treatment (Table 1).

Average yields ranged from 416 to 479 kg/tree (Table 1). Yields of trees treated with etaconazole and dinocap were not significantly different ($P = 0.05$) from each other but were greater than yields of control trees or trees treated with triadimefon. Differences in yield were not observed until the third year of the study.

DISCUSSION

Triadimefon and etaconazole provided better control of leaf and bud mildew than dinocap, which had been used routinely in the Pacific Northwest for many years. This agrees with a previous report (14). The number of infected terminal buds was reduced 47–57%, even though the last of the four annual mildewcide applications was made on about 1 June. Butt (3) found that the best protection of terminal buds resulted from mildewcides applied before early July, although terminal bud infections can occur throughout the growing season (2).

Triadimefon and etaconazole did not significantly ($P = 0.05$) affect fruit set, percent floral buds, or fruit weight and shape. Strydom and Honeyborne (16) reported that five applications of triadimefon at 0.14 kg/ha in 1,400–2,000 L of water increased fruit set of Delicious apple. Etaconozole applied as a dilute spray in a season-long program suppressed return bloom of Delicious apple (9). In a previous experiment, triadimefon altered fruit shape (15), but the application rate per hectare was twice that used in this study, and 10 applications were made during the season (15). Thus, differences in effect on fruit set, bloom, and shape may be related to other factors such as cultivar, spray volume, geographic area, tree age, and rootstock.

Although yields of etaconazole- and dinocap-treated trees were higher than yields of control trees, the yield increase with triadimefon was not significant ($P = 0.05$). Etaconazole treatments had a higher floral bud ratio and fruit set than other fungicides, but differences were not statistically significant when considered separately. Similarly, triadimefon-sprayed trees had the lowest floral bud ratio, fruit set, and fruit size of all trees that received fungicides, but differences among treatments for variables were not significant. The observed yield effects may be related to the net effect of several subtle changes in these tree performance factors. However, Kolbe (7,8) reported that use of triadimefon in a mildew control program increased yield by increasing the number of fruits per tree. Ingram (5) showed that yields of trees sprayed with dinocap increased in the third and fourth year of the study, and Roper et al (11) reported increased yields with etaconazole. Although dinocap and triadimefon are registered by the Environmental Protection Agency for control of apple powdery mildew, the manufacturer of etaconazole is not seeking registration.

Although short-term disease control data are essential for development of new fungicides, these results emphasize the importance of measuring the effects of new fungicides on tree performance factors, particularly yield, in long-term studies.

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