Effect of Early Sprays on Control of Powdery Mildew Fruit Russet on Apples

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ABSTRACT

Daines, R., Weber, D. J., Bunderson, E. D., and Roper, T. 1984. Effect of early sprays on control of powdery mildew fruit russet on apples. Plant Disease 68:326-328.

Powdery mildew fruit infections of apple occur during the pink stage of blossom development and can be prevented by use of an effective fungicide. Etaconazole and dinocap were the most effective fungicides tested in controlling mildew fruit russet. Wettable sulfur and benomyl (in that order) were less effective. Morphological changes in infected flower buds were also noted.

During the last 4 yr, we have conducted field trials to determine the minimum spray program necessary to provide satisfactory control of powdery mildew (*Podosphaera leucotricha* (Ell. & Ev.) Salm.) on very susceptible apple cultivars (Jonathan and Rome Beauty) in the arid environment of Utah. In 1980, powdery mildew russet on Jonathan apples (Fig. 1) was greater when one of two spray applications applied during the pink stage of bloom was omitted. The amount of fruit russet was not reduced ($P = 0.01$) by additional postbloom (petal fall) or cover spray applications compared with fungicide applications applied only during the pink stage. This indicated that powdery mildew fruit infections occurred before the petal fall application, but the exact times were not defined. Further tests were conducted to determine the period when powdery mildew fruit russet infection occurred and to evaluate four fungicides for control of this disease.

MATERIALS AND METHODS

Tests were conducted on 25-yr-old Rome Beauty and 9-yr-old Jonathan trees. Each treatment was applied to four Rome Beauty and five Jonathan trees that had been selected randomly from larger blocks of trees. Four or five unsprayed trees of each cultivar were used as controls. The fungicides were etaconazole (Vangard), benomyl (Benlate), dinocap (Karathane), and wettable sulfur. These fungicides were used at the following rates in each 3.785 hml of water: etaconazole, 1, and benomyl, 1.13 hg; dinocap, 1.7 hml; and wettable sulfur, 2.72 kg. Chemical sprays were applied by hand to runoff, using single-nozzle guns at 400 lb of pressure. Sprays were applied in the pink stage when blossom clusters were separating, at petal fall, and at about 2-wk intervals during the cover spray period. Russeting on the fruit was assessed at harvest on 100–200 apples per tree.

In 1980, the pink period was marked by showers and higher than normal humidity. Because of prolonged cool weather, two sprays during the pink stage were applied to the trees in all treatments except treatment 2 (Fig. 1), where the first spray during the pink stage was omitted. The first chemical application was made while the flower buds were still in a tight cluster. The second spray in the pink stage was applied 7 days later, when the flower buds in the cluster were separated and an occasional king bud was open.

The pink stage of bloom in 1981 was shorter than in 1980 and only one spray was applied during the 1981 period (Fig. 1).

In 1982, one spray application during the pink stage was made on both Jonathan (Table 1) and Rome Beauty trees (Fig. 1). It was applied when about one-half of the Rome Beauty and most of the Jonathan flower bud clusters were separated. There were no blooms showing, but the king buds were swelling. Benomyl was used in all applications designed to determine the time of powdery mildew infection that subsequently caused fruit russet. There were seven treatments, including one that received all applications, including pink, bloom, petal fall, and five cover sprays. The remaining treatments in the series were varied by starting the fungicide application on an additional treatment on each succeeding spray date. Once started, fungicide applications were continued until the fifth cover spray was applied.

Cool showery weather during the spring of 1983 prolonged the period between early pink and full bloom from an average of 14 days for the previous years of this experiment to 27 days. During this year, the experiment was limited to the Jonathan cultivar and consisted of applications of etaconazole, benomyl, and wettable sulfur during the pink, bloom, petal fall, and first cover period. During the pink period, each fungicide was applied at 1) both the early and late pink periods, and 2) at the early pink period only. Etaconazole and benomyl were also applied only at the late pink period. Trees sprayed with wettable sulfur in the pink stage received additional applications of benomyl in the petal fall and first cover spray periods. Additional treatments received benomyl beginning 1) in full bloom and 2) at petal

Table 1. The effect of various fungicide treatments on incidence of fruit russet on Jonathan fruit in 1982

Fungicides	Applications	Percent fruit russet
Check	Not sprayed	49 b[z]
Benomyl	Third and fifth covers	52 b
Benomyl	Second, third, and fifth covers	43 b
Benomyl	First through third, and fifth covers	48 b
Benomyl	Petal fall, first through third, and fifth covers	49 b
Benomyl	Bloom, petal fall, first through third, and fifth covers	47 b
Benomyl	Pink, bloom, petal fall, first through third, and fifth covers	14 a
Etaconazole	Pink, petal fall, first through third, and fifth covers	9 a
Wettable sulfur	Pink, petal fall	
Benomyl	First through third, and fifth covers	12 a
Wettable sulfur	Pink, petal fall	
Etaconazole	First through third, and fifth covers	8 a
Benomyl	Pink, petal fall, first cover	14 a
Etaconazole	Pink, petal fall, first cover	5 a
Wettable sulfur	Pink, petal fall	
Benomyl	First cover	10 a
Wettable sulfur	Pink, petal fall	
Etaconazole	First cover	9 a

[z] Treatments followed by the same letter do not differ ($P = 0.01$) according to Duncan's multiple range test.

Accepted for publication 24 October 1983.

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fall. The early pink spray was applied when the fruit buds were in a tight cluster with about 50% of the buds showing pink. The late pink application occurred 17 days later, when 15% of the king buds were open.

RESULTS

In 1980, when the first pink stage spray was omitted (Fig. 1), fruit infections were significantly increased over treatments receiving two pink stage applications, regardless of the fungicide used. The percentage of fruit russeting that resulted when etaconazole or dinocap was applied only during the pink stage (treatments 1, 3, and 4) was equivalent to that resulting from treatments receiving the same fungicides in a full program (two pink, petal fall, and up to five cover sprays), indicating that fruit infections occur early in, and continue through, the pink stage.

In 1981, fruit from Jonathan trees treated with etaconazole, wettable sulfur, and dinocap had fewer powdery mildew fruit infections compared with those treated with benomyl (Fig. 1) ($P = 0.01$). Fruit from Rome Beauty trees (1981) treated with dinocap, and especially etaconazole, had less russet ($P = 0.01$) than fruit from benomyl-treated trees.

In 1982, no treatment had fewer russeted fruit than the unsprayed check (Table 1) at $P = 0.01$, except the treatment receiving the fungicide application during the pink stage of bloom. The amount of russeting on benomyl-treated trees that received one application during the pink stage was not statistically ($P = 0.01$) different from the amount of russeting that occurred on trees where etaconazole or wettable sulfur was used during the pink period. However, trees treated with benomyl tended to have higher percentages of diseased fruit than those treated with wettable sulfur, which in turn had a higher percentage of diseased fruit than those treated with etaconazole in the pink stage.

On Rome Beauty fruits in 1982 (Fig. 1), powdery mildew fruit russet data were divided statistically into three groups ($P = 0.01$). The first group, which received etaconazole in the pink stage, had significantly less powdery mildew fruit russet than the groups receiving wettable sulfur or benomyl used in the same schedules. However, wettable sulfur- and benomyl-treated trees had significantly less mildew russet than the unsprayed check trees.

In 1983 (Table 2), powdery mildew fruit russet was controlled by sprays applied in the pink stage. Control provided by applications begun in the bloom or petal fall stages failed to provide protection against mildew fruit russet ($P = 0.01$). Fruit from trees receiving two applications during the pink stage had less mildew than trees receiving only one. Trees that received

Table 2. Effect of various fungicide treatments on incidence of fruit russet on Jonathan fruit in 1983

Fungicides	Applications	Percent fruit russet
Etaconazole	Early and late pink, petal fall, and first cover	1.0 a[z]
Wettable sulfur and benomyl	Early and late pink Petal fall and first cover	4.3 ab
Benomyl	Early and late pink, petal fall, and first cover	11.3 ab
Etaconazole	Early pink, petal fall, and first cover	5.3 ab
Wettable sulfur and benomyl	Early pink Petal fall and first cover	13.8 b
Benomyl	Early pink, petal fall, and first cover	15.5 b
Etaconazole	Late pink, petal fall, and first cover	10.0 ab
Benomyl	Late pink, petal fall, and first cover	30.0 c
Benomyl	Bloom, petal fall, and first cover	48.0 d
Benomyl	Petal fall and first cover	45.5 d
Check	Not sprayed	50.3 d

[z]Treatments followed by the same letter did not differ ($P = 0.01$) according to Duncan's multiple range test.

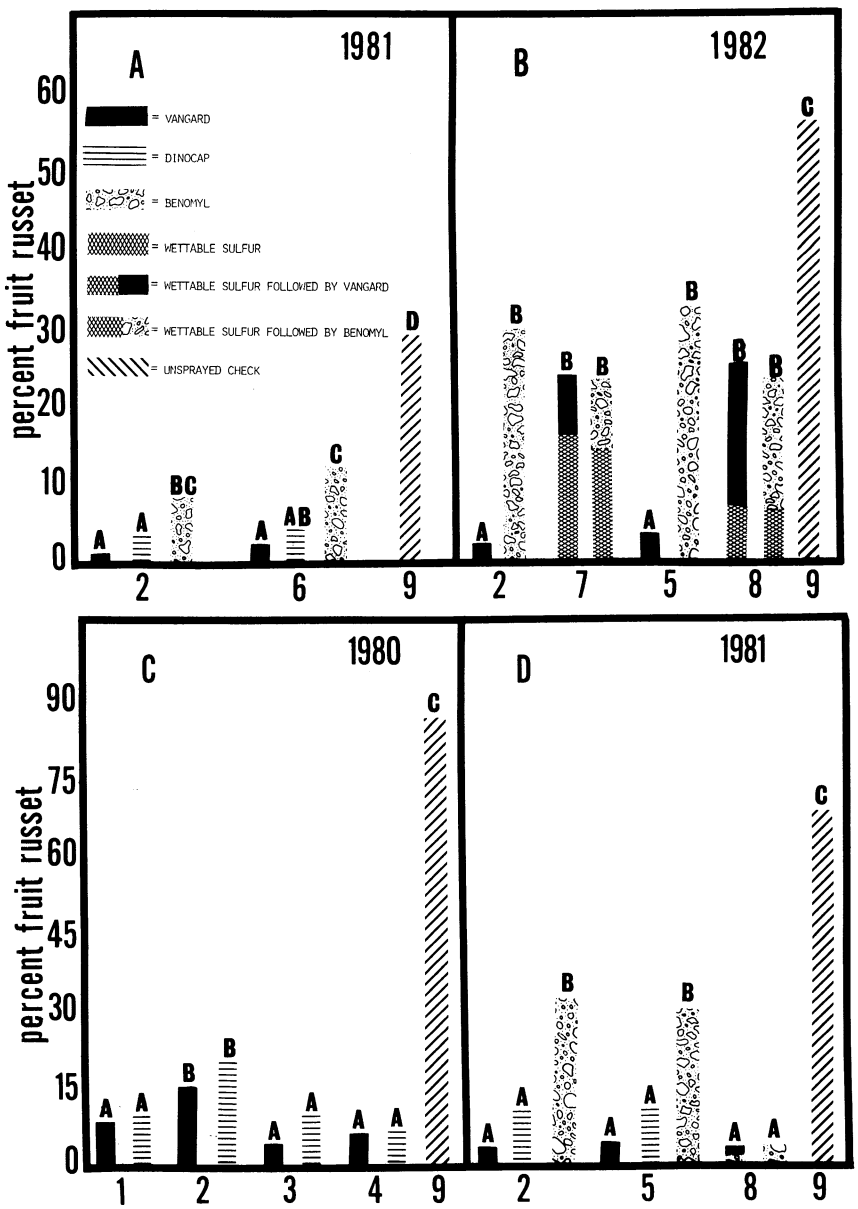

Fig. 1. Effect of fungicides and schedules on the control of powdery mildew russet development on **(A)** Rome Beauty fruit, 1981 data; **(B)** Rome Beauty fruit, 1982 data; **(C)** Jonathan fruit, 1980 data; and **(D)** Jonathan fruit, 1981 data. 1 = Two pink applications only; 2 = one pink, petal fall and first cover; 3 = two pinks, petal fall and first cover; 4 = two pinks, petal fall and five covers; 5 = one pink, petal fall and the first, third, and fifth covers; 6 = one pink, petal fall and five covers; 7 = wettable sulfur at the pink and petal fall, then etaconazole or benomyl at the first cover; 8 = wettable sulfur at pink and petal fall, then etaconazole or benomyl at the first, third, and fifth covers; and 9 = unsprayed check. Treatments followed by the same letter do not differ ($P = 0.01$) according to Duncan's multiple range test.

only the early pink stage application produced more russet-free fruit than trees that received only the late pink stage application. Of the fungicides used, etaconazole provided the most effective protection against mildew russet ($P = 0.01$). Although the percentage of diseased fruits varied considerably between those produced on trees receiving one or two pink stage applications, the differences between those sprayed twice during the pink stage and those sprayed only once in the early pink stage were not significant ($P = 0.01$). However, trees sprayed with benomyl in the early pink stage showed significantly ($P = 0.01$) less mildew fruit russet than trees receiving the same fungicide in the late pink stage.

Observations of flower buds revealed several morphological differences between infected and uninfected flower clusters. No attempt was made to explore cause-and-effect relationships between the powdery mildew fungus and abherrant flower parts.

DISCUSSION

The period when Jonathan and Rome Beauty apple fruits were susceptible to powdery mildew infection was during the pink stage of blossom development; protection against such infections can be achieved by use of an effective fungicide during that period. Yoder and Hickey (3) also found that early sprays were important for reduction of fruit russeting. Even a bloom spray using benomyl when 75% of the blossoms were open was of no value in reducing fruit infections in Jonathan apples in our 1982 and 1983 experiments.

Of the fungicides used, etaconazole and dinocap were most effective in preventing powdery mildew fruit russet. They were followed, where comparisons could be made, by the wettable sulfur and benomyl treatments. Dinocap performed very well in protecting Jonathan fruit (Fig. 1) during a prolonged cool period where two pink stage applications were employed.

In the 1982 experiments, neither the wettable sulfur treatment nor the benomyl treatment satisfactorily controlled powdery mildew russet on Rome Beauty apples (Fig. 1), yet they protected Jonathan fruit from mildew damage (Table 1). The pink stage spray was applied to the two cultivars on the same day. This application was proceeded by a light misty rain. The Rome Beauty trees were large, with their limbs meeting or nearly so in the row. These trees were not pruned during the winter of 1981–1982. The Jonathan trees were small, well separated in the row, and had been heavily pruned during the previous dormant season. In addition, the Jonathan block was separate from other plantings, whereas the experimental Rome Beauty trees were in the center of a large block of trees. This allowed better air circulation in the Jonathan than in the Rome Beauty planting. Less efficient air circulation may have increased the initial inoculum and the microhumidity around the Rome Beauty flower clusters and perhaps increased and/or extended the infection period. Powdery mildew fruit russet was more prevalent on the unsprayed Rome Beauty trees and on those sprayed with wettable sulfur or benomyl than it was on the Jonathan trees that received similar treatments. Under these conditions, etaconazole provided excellent protection against fruit injury from powdery mildew in both the Rome Beauty and Jonathan blocks. Although treatment with all three fungicides decreased spore germination (1,2), etaconazole appeared to be more effective than wettable sulfur or benomyl against the fungus mycelium. In this test (with Rome Beauty), etaconazole provided superior protection ($P = 0.01$) compared with spray combinations of wettable sulfur or benomyl. Wettable sulfur sprays provided more protection ($P = 0.05$) than benomyl treatments.

In apple trees in the early pink stage, terminals with mildewed leaves were abundant. Some infected pink bud clusters were smaller and appeared to develop more slowly than uninfected clusters. Observations during bloom revealed that infected buds had opened but were much altered in size and color. The most noticeable deviations were small ivory-colored petals about the size of sepals. Another deviation from normal flowers was a marked shortening of the filaments, which resulted in the anthers remaining closely appressed in the center of the flower. The anthers appeared not to dehisce. Sepals and styles were also shorter than normal. These blossoms did not set fruit. Apparently, all floral parts, when in the bud, may be damaged by powdery mildew. In normally developing flower buds, the outer surface of the floral tubes may remain susceptible to infection during the pink bud stage but lose this susceptibility by the bloom stage.

Where apple fruits are grown for the fresh fruit market and on cultivars very susceptible to powdery mildew fruit russet, adequate protection against infection should be provided during the entire pink period. In areas with normally arid climates, such as Utah, when the pink period is extended by cool humid weather, two effective fungicide applications about 1 wk to 10 days apart should be used. When the pink period is shortened by warm weather, one pink stage application usually provides good protection.

ACKNOWLEDGMENTS

This research was supported in part by Ciba-Geigy Corporation and by Brigham Young University, Provo, UT.

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