Apple Scab Control with Bitertanol as Influenced by Adjuvant Addition

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ABSTRACT

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In greenhouse studies, lesion development and conidial production were used to evaluate the curative control of apple scab with bitertanol alone and combined with the adjuvant Agridex. Bitertanol at 62.5 and 125 μg/ml combined with the adjuvant at 250, 500, and 1,000 μl/L prevented most lesion development when applied 24–72 hr after inoculation, but when applied 120 hr after inoculation, chlorotic scab lesions were apparent. Because of a higher number of chlorotic lesions, bitertanol alone provided less disease control than when combined with the adjuvant. The adjuvant at 500 and 1,000 μl/L with bitertanol did not improve disease control or inhibition of conidial production over that at 250 μl/L. All curative treatments of bitertanol, either alone or combined with the adjuvant, provided nearly complete inhibition of conidial production. Bitertanol at 62.5 μg/ml plus adjuvant at 250 μl/L (applied 24–120 hr before inoculation) provided less disease control than metiram at 1,200 μg/ml. Addition of 600 μg/ml metiram to bitertanol plus adjuvant was highly effective in protecting trees from scab infection for 72 hr.

The sterol-inhibiting fungicide bitertanol was introduced in 1978 as an experimental compound for control of several diseases including apple scab (1). Initial research with bitertanol indicated it had curative control properties, which included both after-infection and presymptom control activity as defined by Szkolnik (7). When applied after onset of infection and before symptoms were visible, lesions either did not develop or they were chlorotic and conidial production was inhibited (2,3,6,8). In these initial studies, bitertanol was tested at rates of 300–500 μg/ml (3,6,8). More recent studies indicate rates of 125–250 μg/ml were adequate for use in the field (2,9). Also, an adjuvant was noted to improve the activity of bitertanol for apple scab control (2), but the optimum concentration for this adjuvant and whether the rate of bitertanol could be reduced when combined with the adjuvant were not determined.

This study was undertaken to establish the effectiveness of lower rates of bitertanol for curative and protective control of apple scab and to assess the influence of an adjuvant on its effectiveness.

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MATERIALS AND METHODS

All experiments were conducted with ungrafted MM109 apple trees in 175-mm-diameter pots containing 2 L of soil. Each tree had two to five actively growing shoots. Bitertanol (Baycor 25W) was tested alone and in combination with the adjuvant Agridex (principal functioning agents: paraffin base petroleum oil, polyoxyethylated polyol fatty acid ester, and polyol fatty acid ester constituents). Both chemicals were obtained from Bayer South Africa, P.O. Box 1366, Johannesburg, 2000. Other fungicides included for comparison in the tests were metiram (Polyram Combi 80W, BASF, P.O. Box 11337, Johannesburg, 2000), CGA-71818 (Topas 5W, Ciba-Geigy, P.O. Box 92, Isando, 1600), and mancozeb (Dithane M-45 80W, Rohm and Haas, P.O. Box 2356, Primrose, 1416).

To evaluate the curative action of bitertanol and bitertanol-adjuvant combinations, trees were inoculated with conidial suspensions of *Venturia inaequalis* (Cke.) Wint. (5) and exposed to wet periods of 24, 48, and 72 hr at 15 C. Wetting was maintained by an overhead irrigation system operating 20 sec every 30 min. It delivered about 8 mm water every 24 hr. Treatments were applied after trees had been in the inoculation chamber for 24, 48, 72, and 120 hr. Trees sprayed 120 hr after inoculation were exposed to a 72-hr wet period followed by a 48-hr dry period at 15 C. After removal from the inoculation chamber, trees were allowed to dry, then sprayed with suspensions of bitertanol and bitertanol-adjuvant combinations until runoff, allowed to dry, and incubated at about 20 C for 2–3 wk. All treatments were replicated 12 times and unsprayed trees were maintained at all time intervals.

The level of infection was determined for each of seven leaves per shoot as described by Schwabe (5). The percentage of scab development per single-tree-replicate was calculated by the method of Kremer and Unterstenhöfer (4). To evaluate conidial production, seven leaves were picked from each shoot. Leaves from each set of three trees were pooled, weighed, suspended in 250 ml water, and shaken for 1 min to suspend conidia. The number of conidia per milliliter of suspension was determined with a hemacytometer and counts were adjusted to give the number of conidia per 10 g of leaf tissue.

To evaluate the protective action of bitertanol, trees were sprayed 4, 24, 48, 72, 96, and 120 hr before inoculation. Before inoculation, trees were placed outside the greenhouse and exposed to natural conditions. No rain was recorded during this period. The number of leaves that unfolded per shoot between spraying and inoculation was recorded. After inoculation, trees were given a 48-hr wet period at 15 C. Disease development was assessed after 2–3 wk of incubation in a greenhouse at 20 C as indicated in the curative study, except the production of conidia was not determined. The rate of artificial precipitation in the moist chamber was about 8 mm of water per 24 hr. All treatments were replicated 12 times.

Percent disease control was based on the difference in disease incidence between the control and each fungicide treatment. Differences were divided by disease incidence in the control and multiplied by 100. Percent reduction in numbers of conidia produced per 10 g of tissue was computed in a similar way.

RESULTS

The effect of adjuvant concentration on control of scab with bitertanol was tested in two experiments. In the first experiment, bitertanol at 125 μg/ml provided 89.2–96.5% control of scab when applied 24–72 hr after inoculation and 36.8% control when applied 120 hr after inoculation (Fig. 1A). When the adjuvant at 250, 500, and 1,000 μl/L was added to 125 μg/ml bitertanol, the level of control was 98.3–100% when applications were made 24–72 hr after inoculation. At 120 hr after inoculation, scab control increased from 36.8 to 83.4%

as the concentration of the adjuvant was increased from 0 to 1,000 μl/L. Conidial production was reduced to 97–100% of the control by all the treatments.

In the second experiment, bitertanol at 62.5 μg/ml provided about 58% control when applied 24–48 hr after inoculation, 39% when applied 72 hr after inoculation, and 14% when applied 120 hr after inoculation (Fig. 1B). When the adjuvant was added to this rate of bitertanol, disease control was increased at all time intervals. Disease was reduced to 81–90% of the control at time intervals of 24–72 hr and to 39–51% of the control at 120 hr after inoculation. Although disease control in this experiment varied from 14 to 98%, conidial production was reduced to 95–100% of the control by all treatments (Fig. 1C).

The effectiveness of bitertanol for scab control at concentrations of 31.25, 37.5, and 62.5 μg/ml was tested in two experiments. The adjuvant was included at 500 and 250 μl/L in the first and second experiment, respectively. In both experiments, control with 62.5 μg/ml bitertanol was usually higher than with 31.25 and 37.5 μg/ml at each time interval (Fig. 2A,B). Although disease control in the second experiment varied from 4.8 to 99%, conidial production was reduced to 98–100% of the control by all treatments (Fig. 2C).

To study the protective action of bitertanol, metiram was chosen as a standard for comparison (Fig. 3). Metiram gave 93.4–99.5% control when applied 4–48 hr before inoculation, 73.1–78.2% when applied 72–96 hr before inoculation, and 37% when applied 120 hr before inoculation. Scab control with 62.5 μg/ml bitertanol combined with 250 and 1,000 μl/L adjuvant was less than that with metiram, particularly when applied 24–120 hr before inoculation. At 24, 48, and 72 hr before inoculation, mixtures of metiram, bitertanol and adjuvant and mancozeb plus CGA-71818 gave better scab control than bitertanol plus adjuvant. Disease control with mixtures decreased when sprays were applied 96 and 120 hr before inoculation. Lesions that developed on leaves treated with protective sprays of bitertanol showed typical sporulation for the scab fungus. During the 120-hr period between spraying and inoculation, an average of 4.4 leaves unfolded per shoot. Growth-regulating or other phytotoxic effects were not observed with any fungicide treatment.

DISCUSSION

Bitertanol at 150 and 300 (3), 300 (8), and 500 μg/ml (6) has shown curative activity against apple scab in the greenhouse. Our research confirms the curative activity of bitertanol against apple scab but at lower rates than reported previously. The curative activity of bitertanol is twofold: 1) it prevents

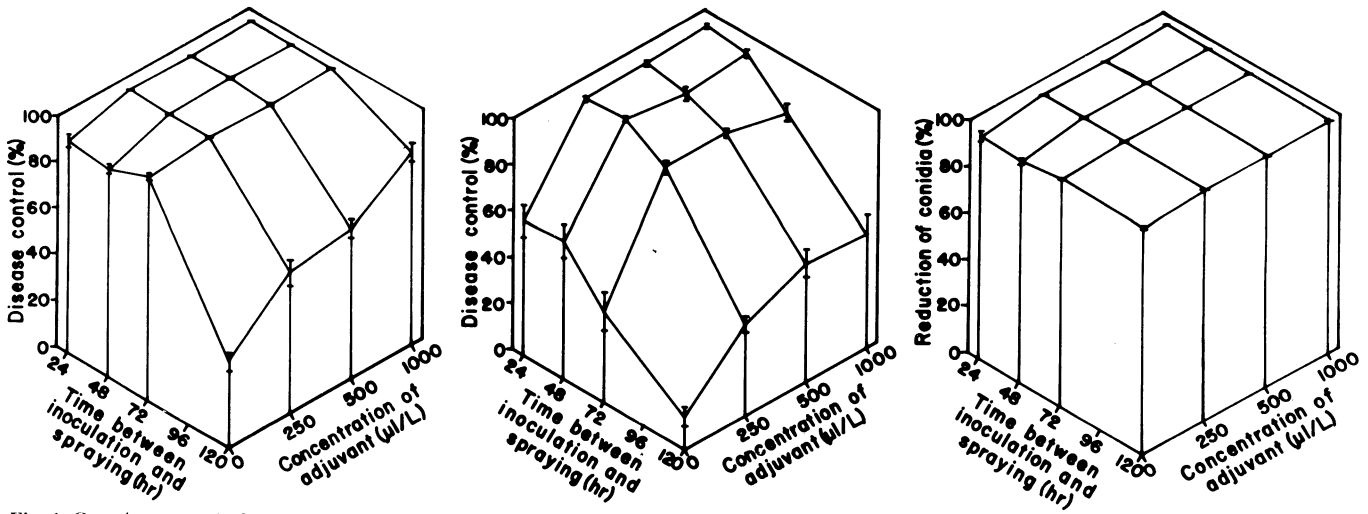

Fig. 1. Curative control of scab on leaves of potted apple trees of MM109 rootstock in the greenhouse by bitertanol with increasing concentrations of adjuvant Agridex applied at indicated times after inoculation. **(A)** Disease reduction with bitertanol at 125 μg/ml, **(B)** disease reduction with bitertanol at 62.5 μg/ml, and **(C)** reduction in numbers of conidia produced with bitertanol at 62.5 μg/ml.

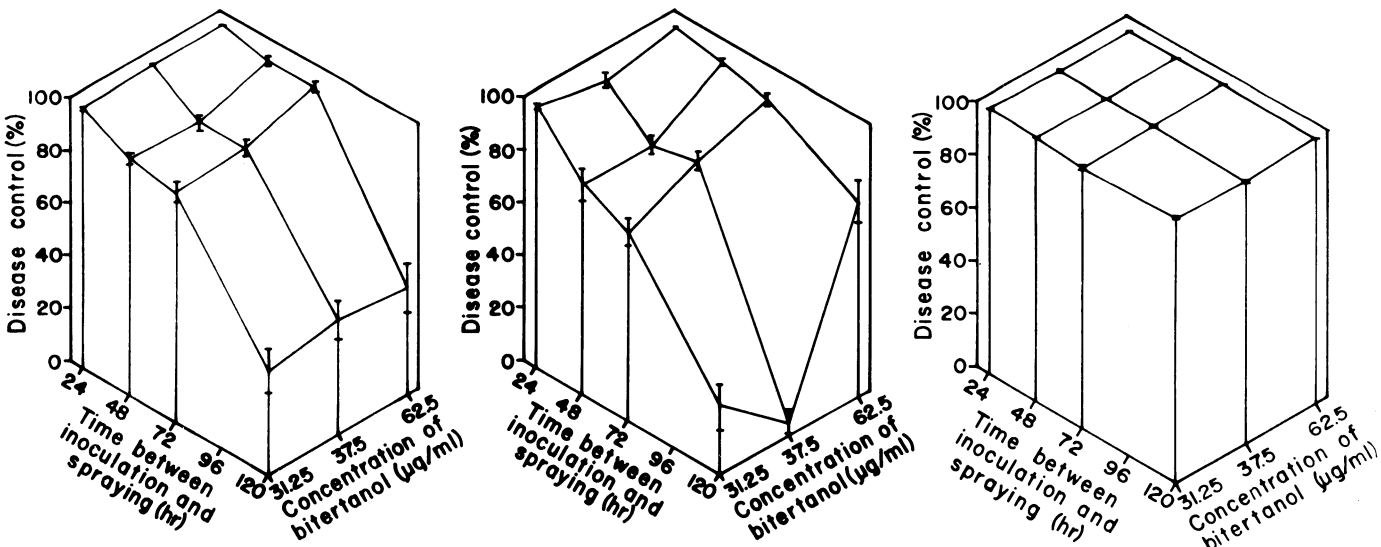

Fig. 2. Curative control of scab on leaves of potted apple trees of MM109 rootstock in the greenhouse by increasing concentrations of bitertanol applied at indicated times after inoculation. **(A)** Disease reduction with bitertanol plus adjuvant Agridex at 500 μl/L, **(B)** disease reduction with bitertanol plus adjuvant at 250 μl/L, and **(C)** reduction in numbers of conidia produced with bitertanol plus adjuvant at 250 μl/L.

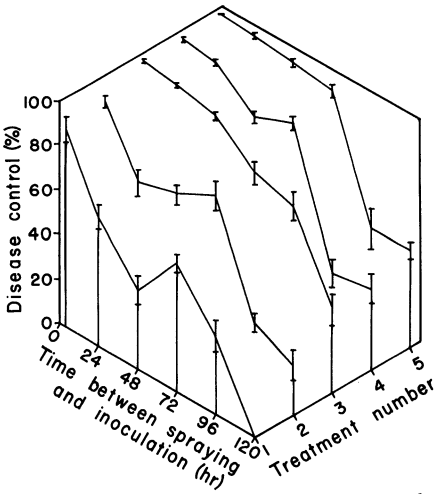

Fig. 3. Protective control of scab on leaves of potted apple trees of MM109 rootstock in the greenhouse with fungicides applied at indicated times before inoculation with conidia of *Venturia inaequalis*. 1 = Bitertanol at 62.5 μg/ml plus adjuvant Agridex at 250 μl/L, 2 = bitertanol at 62.5 μg/ml plus adjuvant at 1,000 μl/L, 3 = metiram at 1,200 μg/ml, 4 = bitertanol at 62.5 μg/ml, and 5 = CGA-71818 at 25 μg/ml plus mancozeb at 600 μg/ml.

establishment of lesions and 2) it inhibits conidial production. Bitertanol prevented conidial production more effectively than it prevented establishment of lesions. When we reduced the rate of bitertanol to 62.5 μg/ml, conidial production continued to be inhibited more effectively than lesion establishment.

The adjuvant improved the curative activity of bitertanol by increasing its efficiency in preventing development of visible lesions. Although concentrations of 250–1,000 μl/L of the adjuvant were tested, concentrations greater than 250 μl/L gave little or no improvement in curative activity except when used at the 120-hr time interval.

The method used in this study for evaluating the protective action is especially valuable in testing retention of a fungicide or a combination of chemicals. As a protective treatment, bitertanol plus adjuvant was not as effective as metiram. The inferior protective action of bitertanol was reported previously by Szkolnik (8). In our study, a mixture of bitertanol, adjuvant, and metiram provided better protection than bitertanol plus adjuvant. Mixtures of bitertanol with other conventional protective fungicides should be tested further. By combining the curative action of bitertanol with the protective action of a conventional fungicide, it may be possible to extend the application interval with mixtures, which may have the added advantage of reducing the chances for resistance developing to bitertanol if such a risk should exist.

Based on our results, we suggest bitertanol be tested at 125 μg/ml in field trials for apple scab control in spray treatments applied up to 120 hr after the beginning of wet periods favorable for scab infection. Because of the beneficial effect of the adjuvant on the control activity of bitertanol, it should be included when disease pressure is high or weather conditions are uncertain. Rates of 62.5 μg/ml bitertanol and 250 μl/L adjuvant, which were highly effective in this investigation, should be included in these trials.

In addition, a conventional protective fungicide should be mixed with bitertanol to improve the level of protection during infection periods that may develop a few days after application. Rates for protective fungicides selected for use in mixtures with bitertanol were selected arbitrarily and other rates should be tested. Finally, by using bitertanol at rates found effective in this investigation, effects on tree growth of the type observed with much higher rates (3) should be avoided.

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