Postsymptom Activity of Ergosterol Inhibitors Against Apple Powdery Mildew

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ABSTRACT

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Ergosterol synthesis-inhibiting fungicides triadimefon, etaconazole, bitertanol, and triforine were compared with sulfur, dinocap, and benomyl for postsymptom activity against powdery mildew on McIntosh apple seedlings in the greenhouse. After a dilute spray to seedlings with abundantly sporulating mildew lesions, spore samples were taken at 1, 10, and 20 days using the transparent adhesive tape technique. Water and fungicide treatments greatly reduced the numbers of total and of newly formed nonwrinkled spores compared with unsprayed leaves. There was no reduction in the total number of spores between water- and fungicide-sprayed treatments at 1, 10, or 20 days after sprays except for a reduction with triforine in the 1-day count. Counts of apparently normal, nonwrinkled spores 1 day after spraying showed no significant difference among treatments except for a reduction by triforine compared with water; this difference was not evident 10 and 20 days after treatment. The greatest postsymptom reduction in the production of new viable spores was noted at 20 days, with significantly lower counts on leaves sprayed with triadimefon, etaconazole, or sulfur.

Pruning out mildewed parts of apple trees has been reported (1,2) to enhance the effectiveness of chemical control of apple powdery mildew, caused by *Podosphaera leucotricha* (Ell.& Everh.) Salm. Removal of mildewed leaves, shoots, and flowers reduces sources of secondary infection (6). Field observations have indicated that suppression of sporulation of the fungus is an important aspect of the action of benomyl (5), thiophanate-methyl (8), and bupirimate, triadimefon, and ditalimfos (4,9,12). Triadimefon and bupirimate reduced the need for pruning to protect trees from apple powdery mildew (7,10).

Several commercial fungicides and a dinitrophenolic compound were reported to suppress further sporulation of established *P. leucotricha* infection on seedlings in the greenhouse (12). Although the materials tested did not kill the fungus, two organophosphorus (pyrazophos and 0,0-diethyl phthalimidophosphonothioate) and two benzimidazole-type compounds (benomyl and-thiophanate-methyl) suppressed spore production for at least 18 days. In similar tests, bupirimate, pyrazophos, binapacryl, and ditalimfos were active fungicides (3).

This paper reports on the postsymptom (11) antisporulant activity of some ergosterol inhibitors and other fungicides against apple powdery mildew.

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MATERIALS AND METHODS

Nine pots, each containing five McIntosh apple seedlings, were used for each treatment in three experiments. Before spraying, leaves with abundantly sporulating mildew lesions were marked. The fungicides tested were benomyl (Benlate 50W), bitertanol (Baycor 50W), etaconazole (Vangard 10W), dinocap (Karathane 19.5WD), triadimefon (Bayleton 50W), triforine (Funginex 18.2EC), and sulfur 92WP.

Each fungicide was applied as a thorough dilute spray to the top and bottom of all leaves with a paint sprayer at 1.75 kg/cm^2. One liter of spray was used in each nine-pot treatment. Greenhouse conditions were favorable for production of powdery mildew spores. Spore samples were taken 1, 10, and 20 days after spraying, using a transparent adhesive tape technique (7). The adhesive side of the tape was touched to the mildew lesions on marked leaves, then removed and adhered to glass slides. The slides then were placed on moist paper toweling in covered plastic boxes that were stored at 6 C. On each sampling date, spores were taken from previously unsampled mildew lesions on marked leaves.

Counts of spores per square centimeter were made directly from the tapes on glass slides. No measurement was made of actual lesion area on leaves. The total number of spores, and those apparently viable, were determined in the same areas of the tapes. Six counts per square centimeter, representing about 15 mildew lesions, were made for each treatment for each sampling date. The mean of these six counts in each of the three tests served as a replicate in the determination of statistical significance at the 5% level by the Waller-Duncan method.

RESULTS

Results for three experiments are presented as the mean number of all spores per square centimeter of lesion area and the number of apparently viable, nonwrinkled spores without cytoplasmic collapse (Table 1). The force of spraying with either water or fungicide suspensions greatly reduced the number of spores, viable or not, compared with spore populations on unsprayed apple seedlings.

Total spore numbers 1 day after spraying were not significantly different between water and fungicide treatments except for a reduced number with triforine. This may have been a surfactant effect of the triforine formulation, which was much more surfactant than other fungicide formulations used. At 10 and 20 days, there were no significant differences in numbers between water and fungicide sprays.

Counts of apparently viable, nonwrinkled spores 1 day after spraying showed no significant differences among fungicides, but significantly fewer spores were present on triforine-sprayed than on

water-sprayed seedlings (Table 1). This difference was not apparent at 10 days, when only the triadimefon treatment significantly reduced new spore production compared with the water treatment. The greatest differences were at 20 days, when the spore count was significantly less with the triadimefon, etaconazole, and sulfur treatments. Although other fungicide treatments showed some reduction in spore production compared with water treatments, fungicide treatment effects were not significant.

Table 1. Number of spores of *Podosphaera leucotricha* per square centimeter of apple leaf powdery mildew area 1, 10, and 20 days after treatment

Treatment	Rate (mg a.i./L)	Total powdery mildew spores per square centimeter (days after spray) 1	10	20
Water	···	46,831 b[z]	33,672 b	44,895 ab
Triadimefon	300	43,142 b	39,663 b	36,151 b
CGA-64251	30	43,210 b	44,654 b	28,776 b
Sulfur	900	37,823 b	35,353 b	31,410[b]
Benomyl	225	34,292 b	29,290 b	25,862 b
Dinocap	75	36,974 b	44,442 b	37,873 b
Bitertanol	150	41,659 b	32,843 b	34,365 b
Triforine	167	16,730 c	33,297 b	35,677 b
Check (unsprayed)	···	94,701 a	99,466 a	107,292 a
		Apparently normal viable powdery mildew spores per square centimeter		
Water	···	1,644 ab	545 bc	4,080 ab
Triadimefon	300	1,379 bc	58 d	35 c
CGA-64251	30	1,342 bc	273 cd	53 c
Sulfur	900	1,020 bc	228 cd	98 c
Benomyl	225	816 bc	326 cd	473 b
Dinocap	75	336 bc	354 cd	1,495 b
Bitertanol	150	862 bc	545 bc	1,850 b
Triforine	167	210 c	1,760 b	2,136 ab
Check (unsprayed)	···	12,086 a	19,700 a	14,283 a

[z]Numbers followed by the same letter are not significantly different at $P = 0.05$.

DISCUSSION

Fungicide inhibition of spore production is a very important factor in control of powdery mildew. Postsymptom antisporulant action against primary infections may greatly reduce the need for pruning mildewed branches in areas of the world where this is an important strategy to protect the orchard from powdery mildew (7). Such activity against secondary infection during the growing season enhances the fungicidal effect through reduced inoculum pressure.

Our results are not in agreement those of with Sztejnberg et al (12), who reported very active antisporulant activity by benomyl. Their techniques differed in that they dipped leaves in treatments with a nonionic surfactant to enhance lesion wetting and this may have increased the activity of benomyl. The surfactant alone gave antisporulant activity for 7–10 days after application. Our results agree with those of Blake et al (3) regarding the low antisporulant activity of triforine, but triadimefon was more active in our tests. Direct comparison of results obtained by these researchers is not feasible because of differing application and spore-counting procedures and the use of surfactants.

The transparent adhesive technique enabled us to differentiate between well-developed, apparently viable spores and wrinkled or collapsed spores indicative of degradation by age, drying, or fungitoxicity. Counts of undamaged spores made possible a determination of populations of newly produced spores and an evaluation of the postsymptom action by fungicides. Studies reported earlier showed that only well-formed, noncollapsed spores are capable of germination and infection (6).

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