Application Rates and Spray Schedules of Ergosterol-Biosynthesis Inhibitor Fungicides for Control of Black Spot of Rose

A. K. HAGAN, Extension Plant Pathologist and Associate Professor, Department of Plant Pathology, C. H. GILLIAM, Professor, Department of Horticulture, D. C. FARE, Research Associate, Department of Horticulture, and K. BOWEN, Assistant Professor, Department of Plant Pathology, Alabama Agriculture Experiment Station, Auburn University, Auburn 36849

ABSTRACT

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The ergosterol-biosynthesis inhibitor (EBI) fungicides myclobutanil, flusilazole, and tebuconazole were compared with chlorothalonil and triforine for the control of black spot on rose. Myclobutanil at 0.024 or 0.048 g a.i./L and flusilazole at 0.07 or 0.14 g a.i./L, applied weekly, were as effective as chlorothalonil and superior to triforine in controlling black spot. Disease control with myclobutanil and flusilazole at 14-day spray intervals gave poorer control than weekly applications. Tebuconazole did not control black spot. None of the sterol-biosynthesis fungicides screened was phytotoxic to rose plants.

Ergosterol-biosynthesis inhibitor (EBI) fungicides have been evaluated for the control of black spot caused by *Diplocarpon rosae* F. A. Wolf and powdery mildew caused by *Sphaerotheca pannosa* (Wallr.:Fr.) Lév. var. *rosae* Woronichin on rose. Of the fungicides tested, most provided better disease control of powdery mildew than black spot (1,2,7,9, 10,11,13). Currently, triforine is the only EBI fungicide registered for control of both black spot and powdery mildew; all other EBI fungicides are labeled only for the control of powdery mildew. Hagan et al (4) reported similar black spot control with pyrifenox and myclobutanil as with the recommended fungicides chlorothalonil and triforine, but control with diniconazole was poorer (5). Efficacy of these EBI fungicides for the control of black spot over a range of application rates and treatment schedules was not reported (4). Peterson (14) noted that prochloraz and tebuconazole, when applied at 10- to 14-day intervals, gave excellent season-long protection from black spot. In the same study, pentaconazole and diniconazole failed to provide the level of disease control obtained with the former fungicides (13). The objective of these field trials was to evaluate the efficacy of the EBI fungicides tebuconazole, flusilazole, and myclobutanil over a range of application rates and spray schedules for the control of rose black spot under conditions conducive to disease development. A preliminary report has been published (3).

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MATERIALS AND METHODS

On 21 February 1986, *Rosa* sp. cvs. Mister Lincoln and Lowell Thomas were established in a sandy loam soil amended with pine bark (1:1, v/v). Lowell Thomas roses were replaced in February 1988 with the cv. First Prize. Annual maintenance practices were as follows: 227 g (8 oz.) of 8:3.2:6.6 NPK fertilizer were

distributed at 3-mo intervals during the growing season around the base of each plant; plants were watered as needed with overhead sprinklers; suckers and spent flowers were regularly removed; aldicarb (Temik 10G) was applied bimonthly at label rates for spider mite control; and weed control was maintained with directed applications of glyphosate (Roundup) and paraquat (Gramoxone Super), applied at label rates plus some hand weeding. A 10-cm layer of pine straw mulch was annually placed around the base of the test plants. Fungicides were applied to runoff on leaf surfaces with a hand-pump compressed air sprayer. A randomized complete block design with four single-plant replicates was used. Visual ratings of disease were made at the date indicated below on a scale of 1–5 where 1 = no disease and 5 = severe defoliation and heavy spotting of remaining leaves.

In 1986, myclobutanil 40W (Nova) at 0.012, 0.024, and 0.048 g a.i./L; chlorothalonil 4.17F (Daconil 2787) at 1.35 g a.i./L; and triforine 1.6E (Triforine) at 0.18 g a.i./L were applied on a 1-, 2- or 4-wk spray schedule from 18 April through 6 October. Also, benomyl 50W (Benlate) at 0.30 g a.i./L was applied on a 1-wk spray schedule. Activate Plus adjuvant was tank-mixed with myclobutanil at 0.06 ml/L of spray volume (0.25%, v/v). Disease ratings were made on 13 May, 6 June, 27 June, 11 August, and 6 October 1986.

Tebuconazole 1.2E (Lynx) at 0.02, 0.04, and 0.08 g a.i./L; myclobutanil 40W at 0.012, 0.024, and 0.048 g a.i./L; and flusilazole 3.3E (Nustar) at 0.04, 0.07, and 0.14 g a.i./L were compared in 1987 with chlorothalonil 4.17F at 1.35 g a.i./L and triforine 1.6E at 0.18 g a.i./L for the control of black spot. Myclobutanil was tank-mixed with Activate adjuvant (0.25%, v/v). Tebuconazole was applied at 1-, 2-, or 4-wk intervals, whereas applications of the other fungicides were made weekly. Disease severity was assessed on 2 May, 2 June, 2 July, 1 August, and 28 August 1987.

Trials were repeated in 1988 with tebuconazole 1.2E at 0.04, 0.08, and 0.16 g a.i./L and flusilazole 3.3E at 0.04, 0.07, and 0.14 g a.i./L, with chlorothalonil 4.17F at 1.35 g a.i./L and triforine 1.6E at 0.18 g a.i./L as fungicide standards. Flusilazole was applied at 1-, 2-, or 4-wk intervals, whereas applications of the remaining fungicide treatments were made weekly from 5 April through 2 September. Disease ratings were made on 6 May, 9 June, 6 July, 10 August, and 26 September 1988.

The significance of treatment effects was tested by analyses of variance. Within year and treatment means were compared with Fisher's protected least significant difference (LSD) test (14). Areas under the disease progress curves (AUDPC) were calculated for each treatment as: $\text{AUDPC} = \Sigma_{i=1}^{n} [(1/2)\ (y_{i+1} + y_i)\ (t_{i+1} - t_i)]$ where y = the disease rating at time t and i = the day of the assessment from the first date of assessment (15). AUDPCs were used as comparative measures of black spot levels in plots within years. Treatments were compared among years by calculating the proportion that the AUDPC was reduced by a treatment relative to the untreated control in that year.

RESULTS

From 1986 through 1988, severe spotting of the leaves and disease-related leaf shed, as indicated by the area under the disease progress curve, was recorded each year on the nontreated control plants of each rose cultivar (Table 1). Black spot incidence was significantly reduced ($P \leq 0.05$) through the growing season with weekly applications of all fungicide treatments as compared with the nontreated controls. However, differences in disease control were noted among the fungicide treatments. Chlorothalonil consistently provided the best control each year on all rose cultivars. Low AUDPC values underscore the very light spotting of the leaves annually observed on the roses treated with chlorothalonil. Myclobutanil in 1 of 2 yr and flusilazole in both years proved equally effective as chlorothalonil in controlling black spot. Again, few lesions were found in years in which either of these fungicides was evaluated for black spot control. Despite season-long reductions in disease ratings compared with the nontreated controls, tebuconazole, benomyl, and triforine were less effective in controlling black spot than chlorothalonil. Heavy leaf spotting and some leaf shed were observed annually on the roses treated with these fungicides.

In 1986, efficacy of myclobutanil across several application rates and spray schedules was evaluated for the control of black spot. Applied weekly, myclobutanil at 0.048 g a.i./L gave better ($P \leq 0.05$) season-long disease control than the two lower rates of the same fungicide (Fig. 1). Only a few isolated lesions were noted on the leaves of plants treated with the high rate of myclobutanil. No differences in disease control were noted with the two lower rates of myclobutanil. Similar disease reductions were obtained with the highest rate of myclobutanil and chlorothalonil, and both gave better ($P \leq 0.05$) disease control than triforine (*data not shown*).

Chlorothalonil and all rates of myclobutanil were more effective when applied weekly than on longer time intervals (Fig. 1). Of the treatments evaluated on a 2-wk spray schedule, only chlorothalonil and the high rate of myclobutanil prevented extensive lesion formation on the leaves and disease-related leaf shed. Although the two lower rates of myclobutanil reduced disease levels compared with the nontreated control, numerous lesions were noted on the leaves, along with some premature leaf shed (Fig. 1). On a 4-wk spray schedule, all treatments failed to prevent heavy spotting of the leaves and disease-related leaf shed, although plants treated with chlorothalonil had less disease ($P \leq 0.05$) than the nontreated control.

In 1987, all rates of tebuconazole applied weekly reduced ($P \leq 0.05$) disease compared with the nontreated control, but chlorothalonil applied on the same schedule gave better ($P \leq 0.05$) disease control (Fig. 1). When applied weekly, all rates of tebuconazole were equally effective in controlling black spot. In contrast, several rates of myclobutanil and flusilazole applied on a 1-wk spray schedule were as effective as chlorothalonil in controlling black spot (*data not shown*). With the 2-wk spray interval, only tebuconazole at 0.08 g a.i./L reduced ($P \leq 0.05$) AUDPC compared with the untreated control. Other tebuconazole rates and spray schedules did not reduce damage related to black spot.

Rainfall patterns in 1988 did not favor rapid disease development until mid-July. By late September, heavy leaf spotting, along with light to moderate leaf shed, was associated with most treat-

Table 1. Area under disease progress curve for weekly applications of tebuconazole, flusilazole, and myclobutanil with several registered fungicides for control of black spot on three rose cultivars, 1986–1988

	1986		1987		1988	
Fungicide (g a.i./L)	**Mister Lincoln**	**Lowell Thomas**	**Mister Lincoln**	**Lowell Thomas**	**Mister Lincoln**	**First Prize**
Nonsprayed control	510.25[a]	539.50	451.87	508.12	464.87	475.37
Triforine (0.18)	320.37	368.62	247.38	316.87	274.37	302.50
Benomyl (0.30)	280.37	338.12	ND	ND	ND	ND
Chlorothalonil (1.35)	168.75	189.12	125.12	118.00	197.50	208.00
Myclobutanil (0.024)	270.12	332.12	138.62	179.62	ND	ND
Tebuconazole (0.04)	ND[b]	ND	313.50	366.62	285.37	274.83
Flusilazole (0.07)	ND	ND	139.00	196.37	208.00	265.75
LSD ($P = 0.05$)	33.07	67.08	42.53	40.32	60.24	66.13

[a] Mean separation within columns according to Fisher's least significant difference test ($P = 0.05$).
[b] ND = Not done.

ments. Applied weekly, all rates of flusilazole reduced ($P \leq 0.05$) black spot below levels recorded on the nontreated control (Fig. 1). The highest rate of flusilazole provided better disease control than chlorothalonil and the two lower rates of flusilazole. Similar reductions in disease were observed with the two lower rates of flusilazole and chlorothalonil. Blackspot control with all rates of flusilazole rapidly declined at spray schedules exceeding 1 wk. Significant reductions in disease levels compared with the nontreated control were not obtained with triforine or any of the three rates of tebuconazole (*data not shown*).

In all 3 yr, weekly applications of chlorothalonil reduced season-long black spot between 55 and 75% relative to the control (Fig. 1). Less disease reduction was observed as spray intervals increased (Fig. 1), although even a 4-wk chlorothalonil spray schedule reduced disease intensity.

Powdery mildew was not observed at any time over the 3-yr test period on any of the three rose cultivars.

DISCUSSION

Earlier studies have demonstrated that some EBI fungicides have good protective activity against black spot of rose (4,7,13). Our results show that myclobutanil applied weekly gave superior season-long control of black spot to triforine, especially under conditions highly conducive to disease development. Similar results were obtained by Hagan et al (4). At the two highest rates tested, myclobutanil and flusilazole were equally effective in controlling this disease as chlorothalonil, which was previously reported as the most efficacious fungicide for the control of black spot (4). Although significant reductions in disease were obtained with the lowest rates of both fungicides, neither controlled black spot quite as effectively as chlorothalonil.

Tebuconazole was the least efficacious of the fungicides screened for the control of black spot of rose. Although weekly applications of tebuconazole provided some modest reductions in disease, chlorothalonil and all rates of flusilazole and myclobutanil gave significantly better control of black spot. Peterson (13) obtained better disease control than was shown in this study with a similar rate of tebuconazole (0.07 g a.i./L) applied on a 10-day spray schedule. Differences in disease pressure probably account for the variation in the control of black spot with tebuconazole observed in these two studies.

In Alabama's warm, humid climate, a weekly spray schedule has been recommended for effective control of black spot with protectant fungicides and triforine (5). Spray schedule recommendations of the Alabama Cooperative Extension Service are supported by results of this study, which show that weekly applications of chlorothalonil gave better disease control than the same fungicide applied at longer intervals. Excellent protection from black spot with the EBI fungicides tebuconazole and prochloraz applied on a 10- and 14-day schedule, respectively, was obtained in a previous study (13). In this study, we did not record the level of disease control with EBI fungicides at 2-wk spray schedules as previously noted by Peterson (13). For example, myclobutanil and flusilazole were most effective in controlling black spot when applied on a weekly spray schedule. Significant increases in disease were observed with all rates of both myclobutanil and flusilazole when spray schedules were lengthened from 1 to 2 wk. Not surprisingly, all fungicides applied on a 4-wk schedule were largely ineffective in controlling black spot on rose.

Variations in tebuconazole efficacy, which performed well in the New Jersey study (13) but poorly in Alabama, highlights the impact of differing disease pressure on fungicide efficacy. Weather patterns conducive for the development of black spot, which occur over a much longer time period in Alabama than in more temperate locations (6), probably result in more severe disease pressure. In addition, summer heat and frequent rain showers would also have a detrimental effect on the retention of both protectant and EBI fungicide residues on the foliage and ultimately on fungicide efficacy (8).

Plant growth regulator effects have often been associated with the use of many EBI fungicides (8). The risk of damage to roses is rather high because numerous fungicide applications are required to maintain season-long disease

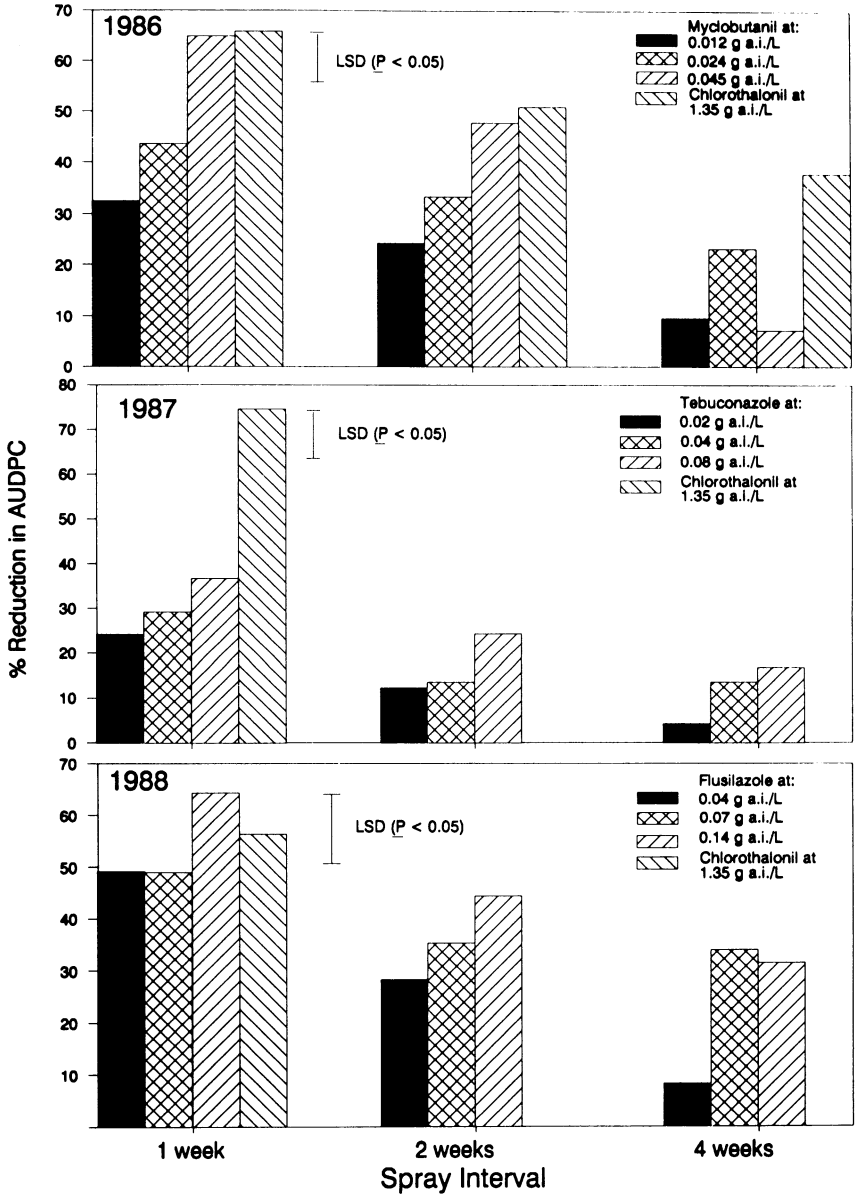

Fig. 1. Percentage of reduction in area under disease progress curve (AUDPC) on all rose cultivars by selected treatments, compared with the nonsprayed control, 1986–1988. Chlorothalonil applied at 1-wk interval in 1987 and 1988. Fisher's protected LSD was calculated for all treatments presented, as well as for the nonsprayed control.

control. Darkening of the leaves and reduced shoot elongation noted on roses in previous studies (4,12) with EBI fungicides and more typical symptoms of pesticide phytotoxicity were not observed on the plants treated with myclobutanil, flusilazole, or tebuconazole. Leaves of the roses treated with myclobutanil, flusilazole, or tebuconazole generally were superior in appearance because of the low level of visible residues as compared with the objectionable white residues on the roses treated with chlorothalonil.

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