Broad Spectrum Apple Disease Control with Bitertanol

K. S. YODER, Department of Plant Pathology and Physiology, Virginia Polytechnic Institute and State University, Fruit Research Laboratory, Winchester 22601

ABSTRACT

Yoder, K. S. 1982. Broad spectrum apple disease control with bitertanol. Plant Disease 66:580-583.

The sterol-inhibiting fungicide bitertanol was field tested in a 3-yr period (1978–1980) against apple scab, powdery mildew, cedar apple rust, and several other diseases of apple (*Malus pumila*) in Virginia. Bitertanol 50W, applied at a dilute rate of 30 g/100 L, was equal to or better than the standard rate of Dikar (mancozeb + dinocap) for control of scab, powdery mildew, sooty blotch, and fly speck. Bitertanol 50W (15 g/100 L) provided better control of cedar apple rust than the Dikar standard. Equivalent rates of both materials applied with a conventional air-blast sprayer were also equal in control of Brooks fruit spot. Bitertanol did not adversely affect the finish of Miller Spur Delicious, Golden Delicious, Rome Beauty, or Jonathan apple fruit.

Common fungal diseases of apple (*Malus pumila* Miller) in the Middle Atlantic region of the eastern United States include scab (*Venturia inaequalis* (Cke.) Wint.); powdery mildew (*Podosphaera leucotricha* (Ell. & Everh.) Salm.); cedar apple rust (*Gymnosporangium juniperi-virginianae* Schw.); quince rust (*G. clavipes*); and "summer diseases" including Brooks or Phoma fruit spot (*Mycosphaerella pomi* (Pass.) Lindau), sooty blotch (*Gloeodes pomigena* (Schw.) Colby), fly speck (*Zygophiala jamaicensis* Mason), black rot (*Physalospora obtusa*), bot or white rot (*Botryosphaeria dothidea*), and bitter rot (*Glomerella cingulata*) (2). The relative prominence of these diseases may vary with annual precipitation and temperature patterns.

Control of these diseases in Virginia can require 13 or more applications of the currently available fungicides during a growing season (1). No single registered compound adequately controls all of these diseases, and several different fungicides may be required during the season. The need to minimize apple production costs and the threats of reduced fungicide effectiveness because of resistance and regulatory restriction of present fungicides demand a continuing search for compounds to control these diseases. The sterol-inhibiting fungicides show potential for filling some of these needs by providing a new mode of action against several major apple fungal diseases.

This report summarizes the results of field tests of the sterol-inhibiting compound bitertanol (β-[(1,1-biphenyl)-4-yloxy]-α-(1-1-dimethyl-ethyl)-1*H*-1,2,4-triazole-1-ethanol) for apple disease control and fruit finish effects in 1978, 1979, and 1980. A portion of this work has been cited previously (7).

Accepted for publication 29 September 1981.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

0191-2917/82/07058004/$03.00/0

MATERIALS AND METHODS

Chemical application. Bitertanol, tested as three formulations (Baycor 50W, Baycor 2.5E, KWG 0599 25W; Mobay Chemical Corp., Kansas City, MO 64120), was applied to well-pruned, mature, semidwarf apple trees of several cultivars at the Virginia Polytechnic Institute and State University Fruit Research Farm at Winchester or in a commercial orchard nearby. Treatments were applied to randomized blocks of four to six single-tree replicates. Materials were applied either as dilute treatments to the point of runoff with a single-nozzle handgun and a high-pressure sprayer at 3,446 kPa (500 psi) or as concentrate treatments (×4,935 L/ha) with a conventional air-blast sprayer (Hardie model 525, no longer commercially available).

Applications were made at 7- to 10-day intervals from the 1-cm green-tip stage to petal fall and at 14-day intervals during the cover spray period. Total applications for the dilute tests in 1978, 1979, and 1980 were 11, 11, and 9, respectively. Treatments were applied 10 times in the concentrate test in 1980. Dikar (a commercial mixture of 72% mancozeb and 4.7% dinocap; Rohm and Haas Co., Philadelphia, PA 19105) was included as the only registered material with an effect on all the diseases that were likely to appear in the test plots in the course of the season. Registered insecticides, bactericides, and growth regulators were applied separately as needed to entire test orchards. Additional information regarding dates of application, growth stages, and other materials applied is provided in annual reports for these experiments (4–6,8).

Inocula. Cedar apple rust inoculum was introduced into the research farm orchard in the form of three to five cedar galls placed in wire baskets on poles 0.5 m above each test tree. All other diseases developed from inoculum occurring naturally within the orchards.

Symptom intensity and fruit finish indexes. Foliar diseases were rated on Rome Beauty or Jonathan in midseason. Fruits were evaluated for disease incidence and finish after harvest. Fruit finish was rated on a scale of 0–5 (0 = perfect finish, 5 = very poor finish). On Miller Spur Delicious, Rome Beauty, and Jonathan, finish ratings of 1 or 2 were reserved for opalescence (milky, iridescent discoloration). Ratings of 3–5 included increasingly severe composite effects of opalescence and russet. Golden Delicious fruit finish ratings of 1 and 2 related to degrees of lenticel enlargement, and ratings of 3–5 related to composite effects of lenticel enlargement and increasingly severe russet between lenticels.

Weather conditions. Weather conditions at the Winchester Fruit Research Laboratory during the 3-yr test period are summarized in Table 1. Mills infection periods for scab are included as an index of overall wet weather disease activity. Scab activity may have been reduced by hot weather in spite of indicated infection periods during the summer months. The number of wetting periods during these months serves as an indicator of summer disease activity.

RESULTS

Apple scab. In 1978, scab incidence was low on untreated fruit and foliage and was readily controlled by both bitertanol and Dikar (Tables 2 and 3). The greatest scab incidence on fruit and foliage occurred in 1979. Bitertanol 50W (30 g/100 L) gave comparatively good control of scab on foliage and fruit. The lower concentration of bitertanol (15 g/100 L) and the Dikar standard gave poorer control on foliage.

Differences were not significant on fruit scab control in 1979, but control provided by Dikar was generally between the high and low rates of bitertanol. In 1980, treatment differences in scab control were greater on fruit than on foliage. Warm weather in June and July 1980 reduced the amount of scab on untreated foliage, but heavy early season infection was evident on untreated fruit. On Miller Spur Delicious and Rome Beauty fruit, both concentrations of the

wettable powder and of the emulsifiable concentrate formulations of bitertanol gave significantly ($P = 0.05$) better control than Dikar (Table 3). All treatments gave excellent control of fruit scab on Golden Delicious in 1980.

Cedar apple rust. Control of foliar rust with bitertanol was significantly ($P = 0.05$) better than with Dikar (Table 2), with all rates and formulations giving excellent control. Frequency of cedar apple rust infection on fruit was generally low, with the highest incidence (6%) occurring on untreated Rome Beauty fruit in 1979. All treatments, including Dikar, gave excellent control of cedar apple rust on fruit.

Powdery mildew. Treatment effect on control of powdery mildew varied with test severity, but control with bitertanol was as good or better than with Dikar. Under relatively light disease conditions with dilute treatments in the research farm orchard (Table 2), all treatments gave significant ($P = 0.05$) control compared with the untreated check, and control with one or more bitertanol treatments was significantly ($P = 0.05$) better than with Dikar. In a severe test of reduced volume (air-blast) applications on the highly susceptible Jonathan cultivar (Table 4), however, control by the low rate of bitertanol 50W (0.56 kg/ha) or Dikar was not always significantly ($P = 0.05$) better than the untreated check.

The higher rate of bitertanol (1.12 kg/ha) generally provided better mildew control than Dikar and the low rate of bitertanol, and the higher rate always provided better control than the untreated check whether assessed by percentage of leaves or fruit infected or by percentage of infected leaf area. Although the test was severe as indicated by the high incidence of mildew on foliage, all treatments significantly ($P = 0.05$) reduced downgrading of fruit due to mildew russeting.

Sooty blotch and fly speck. Sooty blotch and fly speck occurred relatively frequently on untreated fruit in 1978 and 1979 (Table 5) but did not develop during the dry late season of 1980. In both seasons that these diseases were present in sufficient frequency to provide a fungicide test, control with higher rates of bitertanol was not significantly ($P = 0.05$) different than with Dikar. Bitertanol, at the lowest rate (15 g/100 L), appeared less effective than the higher rates, but differences among treatments were not significant ($P = 0.05$).

Brooks spot. Control of Brooks fruit spot on Jonathan with bitertanol was

Table 1. Weather and infection period data for Winchester, VA, in 1978–1980 growing seasons

	Rainfall (cm)	Mean temperature (C)		Scab infection periods[z]		
		Maximum	Minimum	Light	Moderate	Heavy
1978						
April	3	18.7	5.7	1	0	0
May	13	22.8	11.1	2	4	3
June	13	27.8	15.8	0	1	6
July	16	29.1	17.7	0	0	7
August	18	30.1	19.1	0	1	5
September	6	27.3	14.7	0	1	3
1979						
April	6	17.3	6.3	2	0	2
May	17	23.9	11.8	0	3	2
June	10	27.6	14.6	0	0	4
July	13	28.6	17.7	2	4	2
August	11	29.2	17.7	0	5	4
September	14	25.3	14.2	1	1	3
1980						
April	12	18.7	6.6	1	2	2
May	13	25.9	12.7	1	2	3
June	9	27.9	14.6	1	2	2
July	11	32.3	19.2	1	1	2
August	6	31.4	17.1	0	2	1
September	4	28.8	15.1	2	2	2

[z] Based on Mills table for recorded temperature and wetting period length.

Table 2. Disease control with bitertanol and Dikar on Rome Beauty apple foliage

Treatment[x]	Formulated material (per 100 L)	Disease incidence, leaves infected (%)[y]								
		Scab			Cedar apple rust			Powdery mildew		
		1978	1979	1980	1978	1979	1980	1978	1979	1980
No fungicide	None	3 b	65 d	26 c	5 c	23 c	21 c	24 c	37 c	12 c
Bitertanol 25W	120 g	0.4 a	...	...	0.2 a	...	...	14 a	...	...
Bitertanol 50W	30 g	...[z]	9 a	0 a	...	0 a	0 a	...	0 a	1 ab
Bitertanol 50W	15 g	...	22 b	1 ab	...	0.1 a	0.4 a	...	2 ab	3 ab
Bitertanol 2.5E	50 ml	...	...	0 a	...	...	0 a	...	...	1 a
Bitertanol 2.5E	25 ml	...	...	1 ab	...	...	0 a	...	...	2 ab
Dikar 76.7W	240 g	1 a	45 c	5 b	3 b	8 b	7 b	19 b	6 b	6 b

[x] Dilute treatments applied to runoff.
[y] Based on counts of all leaves on 10 shoots from each of four to six replicate trees. Column mean separation by Duncan's multiple range test ($P = 0.05$).
[z] No test.

Table 3. Effect of bitertanol and Dikar on incidence of apple scab on apple fruit

Treatment[x]	Formulated material (per 100 L)	Fruit infected (%)[y]								
		Miller Spur Delicious			Golden Delicious			Rome Beauty		
		1978	1979	1980	1978	1979	1980	1978	1979	1980
No fungicide	None	18 b	99 b	90 c	0.3 a	100 c	71 b	0	100 b	73 c
Bitertanol 25W	120 g	0 a	...	...	0 a	...	...	0	...	...
Bitertanol 50W	30 g	...[z]	7 a	1 a	...	7 a	2 a	...	11 a	2 a
Bitertanol 50W	15 g	...	25 a	1 a	...	20 b	0 a	...	33 a	0 a
Bitertanol 2.5E	50 ml	...	...	0 a	...	...	0 a	...	...	3 a
Bitertanol 2.5E	25 ml	...	...	1 a	...	...	0 a	...	...	4 a
Dikar 76.7W	240 g	0 a	12 a	18 b	0 a	8 a	0 a	0	22 a	23 b

[x] Dilute treatments applied to runoff.
[y] Based on counts of 25 fruits from each of four to six replicate trees. Column mean separation by Duncan's multiple range test ($P = 0.05$).
[z] No test.

Table 4. Disease control by reduced volume applications of bitertanol on Jonathan apples

Treatment[w]	Formulated material (per hectare)	Powdery mildew incidence[x]							Brooks fruit spot (%)	Fruit finish[z]
		Leaves infected (%)		Leaf area infected (%)			Fruit			
		14 May	17 June	14 May	17 June	31 July	Infected (%)	Grade (%)[y]		
No fungicide	None	89 b	100 b	21 b	54 b	92 b	32 b	80 b	32 b	1.5 a
Bitertanol 50W	1.12 kg	63 a	95 a	4 a	14 a	73 a	6 a	99 a	3 a	1.1 a
Bitertanol 50W	0.56 kg	71 ab	99 ab	6 a	24 a	69 a	15 ab	96 a	1 a	1.5 a
Dikar 76.7W	7.23 kg	83 ab	96 ab	13 ab	30 a	78 ab	16 ab	96 a	3 a	1.5 a

[w] Treatments applied with a conventional air-blast sprayer in 935 L of water per hectare.
[x] Averages of four single-tree replicates. Foliar data represent readings of the same six terminal shoots from each replicate tree on successive days. Fruit data are averages of 50 fruits per replicate at harvest. Mean separation by Duncan's multiple range test ($P = 0.05$).
[y] Combined USDA Extra Fancy and Fancy grades for fruit russet attributed to powdery mildew.
[z] Rating scale of 0–5 (0 = perfect finish, 5 = very poor finish) of any finish effect other than that attributed to powdery mildew russet.

Table 5. Effect of bitertanol and Dikar on sooty blotch and fly speck incidence on apple fruit

Treatment[x]	Formulated material (per 100 L)	Fruit infected with sooty blotch (%)[y]						Fruit infected with fly speck (%)[y]					
		Miller Spur Delicious		Golden Delicious		Rome Beauty		Miller Spur Delicious		Golden Delicious		Rome Beauty	
		1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
No fungicide	None	50 b	47 b	99 b	63 b	83 b	67 b	15 b	26 b	22 b	19 b	5 b	15 b
Bitertanol 25W	120 g	0 a	...	1 a	...	0 a	...	1 a	...	1 a	...	0 a	...
Bitertanol 50W	30 g	...[z]	0 a	...	1 a	...	0 a	...	0 a	...	0 a	...	1 a
Bitertanol 50W	15 g	...	0 a	...	10 a	...	0 a	...	2 a	...	5 a	...	4 a
Dikar 76.7W	240 g	1 a	0 a	3 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a	1 a	0 a

[x] Dilute treatments applied to runoff.
[y] Based on counts of 25 fruits from each of four to six replicate trees. Column mean separation by Duncan's multiple range test ($P = 0.05$).
[z] No test.

Table 6. Effect of bitertanol and Dikar applications on fruit finish of apples

Treatment[x]	Formulated material (per 100 L)	Fruit finish rating[y]								
		Miller Spur Delicious			Golden Delicious			Rome Beauty		
		1978	1979	1980	1978	1979	1980	1978	1979	1980
No fungicide	None	2.2 a	1.5 a	1.8 a	2.3 a	2.8 c	1.7 a	1.6 a	1.7 a	2.0 b
Bitertanol 25W	120 g	2.4 a	...	...	2.4 a	...	...	1.8 ab	...	...
Bitertanol 50W	30 g	...[z]	1.4 a	1.7 ab	...	2.1 b	1.6 a	...	1.7 a	1.3 a
Bitertanol 50W	15 g	...	1.6 a	1.7 ab	...	2.2 bc	1.2 a	...	1.7 a	1.8 ab
Bitertanol 2.5E	50 ml	...	...	2.0 b	...	...	1.5 a	...	...	1.3 a
Bitertanol 2.5E	25 ml	...	...	1.1 a	...	...	1.3 a	...	...	1.7 ab
Dikar 76.7W	240 g	2.6 a	1.2 a	1.8 b	2.3 a	1.1 a	1.7 a	2.2 b	1.3 a	1.8 ab

[x] Dilute treatments applied to runoff.
[y] Averages of individual ratings of 25 fruits from each of four to six replicate trees. Rating scale of 0–5 (0 = perfect fruit finish, 5 = very poor finish). Column mean separation by Duncan's multiple range test ($P = 0.05$).
[z] No test.

comparable to that with Dikar (Table 4). On Golden Delicious in 1979 (*data not shown*), Brooks spot infected 8% of the untreated fruit, and all treatments gave good control.

Fruit finish. Fruit finish was either unaffected or improved by bitertanol treatment compared with the finish of untreated fruit (Tables 4 and 6). In no case was the finish of bitertanol-treated fruit significantly poorer ($P \leq 0.05$) than that of untreated fruit. Finish effects of bitertanol and Dikar were comparable except on Miller Spur Delicious in 1980, when Dikar resulted in significantly poorer finish than bitertanol 2.5E (25 ml/100 L), and on Golden Delicious in 1979, when Dikar fruit finish was significantly better than that with bitertanol 50W.

DISCUSSION

Bitertanol showed good potential as a broad spectrum apple fungicide in the Middle Atlantic region. Commercially acceptable control was achieved for the early season diseases scab, powdery mildew, and cedar apple rust. Bitertanol and other sterol-inhibiting fungicides should be valuable in combating strains of *V. inaequalis* resistant to dodine or benzimidazole fungicides. Postinfection activity of bitertanol and other sterol inhibitors (3) on cedar apple rust would be a valuable asset to present apple disease management programs. Bitertanol has not been adequately tested against quince rust in the region, but outstanding effectiveness against cedar apple rust suggests that the compound would also control quince rust.

The residual bitertanol activity controlling sooty blotch and fly speck demonstrated under severe test conditions in 1978 is not typical of most sterol-inhibiting fungicides (7), and this characteristic may distinguish bitertanol from related compounds.

The period of maximum benefit of bitertanol in the region's apple spray programs would be from the pink stage through the midseason cover sprays, because fungicides must be included for scab, rusts, and mildew during this period and bitertanol shows potential for control of all three diseases. Applications earlier than pink for control of scab, rusts, and mildew or later than midseason for control of mildew, sooty blotch, and fly speck could be beneficial depending on inoculum potential, weather conditions, and varietal disease susceptibility. Indicated safety to the finish of fruit during the critical period is an important asset to bitertanol's applicability to present programs.

ACKNOWLEDGMENTS

The technical assistance of A. E. Cochran II, J. R. Warren, and S. Avenius is gratefully acknowledged.

LITERATURE CITED

1. Barden, J. A., Byers, R. E., Chappell, W. E., Drake, C. R., Foy, C. L., Horsburgh, R. L., Lyons, C. G., Mattus, G. E., Phillips, E. L., Rogers, N. K., and Yoder, K. S. 1981. Virginia spray bulletin for commercial tree fruit growers. Va. Coop. Ext. Serv. Publ. 219. 33 pp.
2. Hickey, K. D., Drake, C. R., and Shear, G. M. 1970. Apple diseases and their control in Virginia. Va. Coop. Ext. Serv. Publ. 374. 20 pp.
3. Rosenberger, D. A., Meyer, F. W., and Cecilia, C. V. 1980. Apple disease control with protectant and postinfection sprays, 1979. Fungic. Nematic. Tests 35:16-17.
4. Yoder, K. S., Cochran, A. E., II, and Warren, J. R. 1979. Evaluation of experimental fungicides on three apple cultivars, 1978. Fungic. Nematic. Tests 34:21-22.
5. Yoder, K. S., Cochran, A. E., II, Warren, J. R., and Nicholls, S. A. 1980. Evaluation of experimental fungicides on three apple cultivars, 1979. Fungic. Nematic. Tests 35:25-26.
6. Yoder, K. S., Cochran, A. E., II, Warren, J. R., and Nicholls, S. A. 1981. Evaluation of experimental fungicides on three apple cultivars, 1980. Fungic. Nematic. Tests 36:21-22.
7. Yoder, K. S., and Hickey, K. D. 1981. Sterol-inhibiting fungicides for control of certain diseases of apples in the Cumberland-Shenandoah region. Plant Disease 65:998-1001.
8. Yoder, K. S., Nicholls, S. A., Cochran, A. E., II, and Warren, J. R. 1981. Control of powdery mildew by reduced volume applications of experimental fungicides, 1980. Fungic. Nematic. Tests 36:22-23.