Studies with Benomyl and Thiabendazole on Control of Cotton Diseases

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ABSTRACT

Field studies indicate that losses due to seedling disease, *Verticillium* wilt, and boll rot were slightly reduced with moderate rates of either methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (benomyl) or 2-(4-thiazolyl)benzimidazole (thiabendazole). Only a slight degree of seedling disease control was obtained with either material. Thiabendazole was more phytotoxic than benomyl, particularly when applied on, or adjacent to, the cottonseed. A combination of seed, soil, and early-season foliage applications of both systemic fungicides significantly reduced incidence of *Verticillium* wilt and increased yield. When applied as foliage sprays late in the season, both fungicides significantly reduced loss due to boll rot. A higher level of disease control and higher yields were consistently obtained with benomyl than with an equal rate of thiabendazole. However, the results do not indicate economic control of cotton diseases with these fungicides using the rates and methods of application evaluated. Phytopathology 61:783-786.

Additional key words: application methods, surfactants.

Greenhouse and laboratory studies with seed, soil, and foliage applications of methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (benomyl) and 2-(4-thiazolyl)benzimidazole (thiabendazole) have been reported to reduce *Verticillium* wilt (6, 7, 8, 9, 14) and seedling disease (1, 2) of cotton. In field studies, however, significant reduction of wilt caused by *Verticillium albo-atrum* Reinke & Berth. was seldom obtained (6, 8, 10, 14). In 1967, my field tests at Stoneville, Miss. (*unpublished data*) indicated that seed treatment, in-the-furrow sprays, soil injection below the seed, and mid-season foliage applications of benomyl each contributed a degree of control to *Verticillium* wilt. The degree of *Verticillium* wilt control increased with multiple low-rate applications to seed, soil injection, and foliage; whereas high rates, applied as a single treatment, were not as effective. Results indicated an apparent reduction in boll rot associated with the foliage applications. Field tests were established in 1968 and 1969 to evaluate control of seedling disease, *Verticillium* wilt, and boll rot of cotton with benomyl and thiabendazole.

Materials and Methods.—In 1968, two tests were planted on 8 May, using 20 lb./acre of Deltapine 16 cottonseed which was treated with 2.2% cyano (methylmercury) guanidine, 3 oz/cwt. Tests were a split-plot design with five replications. Main plots were methods of application; subplots were fungicides. Subplot size was two 40-inch rows × 63 ft. Where a systemic fungicide was applied to the mercury-treated seed, a 1:1, w/v, water slurry was used. Seed were tumbled 5 min in a drum-treater to obtain uniform coverage. Fungicides were injected into the soil with a Bell injector (Bell, Inc., Inverness, Miss.), designed for herbicide injection, which placed three bands of fungicide in the soil 1.5 inches below the seed. One band was under the cottonseed; the other bands were 3 inches on either side of the center band. Sidedress treatments were applied on 27 June by spraying the fungicides in 6-inch deep slits 14 inches on either side of the drill. Foliage applications were made with a high-clearance ground sprayer. A surfactant, polyhydric alcohol esters (Trem D14 or Du Pont Surfactant F), was used at the rate of 2.7 ml/gal in all foliage applications. Foliage applications were applied as follows: two applications, 15 August and 16 September; and four applications, 15 and 29 August and 16 and 26 September. To minimize differences due to possible machine damage, the sprayer was driven through all plots on 15 August and 16 September. Only those plots receiving four foliage applications were subjected to four trips with the ground sprayer.

Plots were rated on 1 October for incidence of *Verticillium* wilt on a scale of 0 (no evidence of disease) to 10 (all plants defoliated and dead). Boll-rot loss was evaluated by hand-picking a healthy boll at the same relative position on an adjacent plant, for each boll with two or more locks so rotted as to be nonharvestable by a mechanical picker. Stained or partially rotted locks were not counted as boll rot.

The 1969 test was planted on 5 May using 20 lb./acre of Coker 201 cottonseed treated with 2.2% cyano (methylmercury) guanidine, 3 oz/cwt, and either benomyl or thiabendazole at the rate of 10 oz active/cwt. Test design was a randomized block with five replications. Plot size was four 40-inch rows × 63 ft. Fungicides were injected into the soil with a modified bell injector that placed three bands of fungicide in the soil 1.5 inches below the seed. One band was under the seed, and the other bands were 1-0.5 inches on either side of the center band.

Results of Rawlins & Booth (18) indicate an increase in uptake of benomyl and thiabendazole by using polyoxyethylene sorbitan monolaurate (Tween 20) in suspensions applied in the soil. I added Tween 20 at the rate of 5,000 ppm to the fungicide suspensions injected into the soil. In foliage applications, Tween 20 was used

TABLE 1. Evaluation of benomyl and thiabendazole in controlling cotton seedling disease

Method of application	Rate, active/ acre	Plants per acre[a]		
		Benomyl	Thiaben- dazole	Mean
In-furrow spray	2.0 lb.	39,750	35,250	37,500 a
Injected, 6-inch band[b]	3.75 lb.	37,000	33,800	35,400 ab
In-furrow spray	0.5 lb.	31,400	34,450	32,925 b
Check	0	31,950	32,700	32,325 b
Seed treatment at 5 oz/cwt	1 oz	33,200	31,300	32,250 b
Seed treatment at 10 oz/cwt	2 oz	33,200	28,700	30,950 b
Mean		34,415 a	32,700 b	

[a] Means not followed by the same letter are significantly different at the .05 level as measured by Duncan's new multiple range test.

[b] Broadcast rate would be 25 lb./acre; on band of 6 inches and 13,064 feet of 40-inch row, this would be 3.75 lb./acre.

in a 1:1 ratio with the amount of active fungicide (1,666 ppm); spray volume was 36 gal/acre. The work of Hine et al. (11) indicated that the maximum activity and degree of translocation occurred on plants 4-8 weeks old. The foliage application schedule was changed from that used in 1968 to the following: two applications, 2 and 23 June; six applications, 2 and 23 June, 14 July, 4 and 25 August, and 15 September. In 1969, the high clearance sprayer was only driven through plots receiving foliage applications. In evaluating wilt incidence on 1 October, any plant exhibiting wilt symptoms, irrespective of degree, was considered diseased.

RESULTS.—Stand data were collected from only one of the 1968 tests, as all treatments likely to affect seedling disease were included in this test (Table 1). Plantings treated with benomyl had significantly better stands than plantings treated with thiabendazole. Where benomyl was used, the plant population increased as dosage increased. Where thiabendazole was used, however, the higher rates reduced stands. This is especially evident where the fungicide was on, or immediately adjacent to, the cottonseed. The in-the-furrow spray, 2 lb./acre, significantly increased stand.

A visual evaluation of *Verticillium* wilt incidence on 1 October 1968 indicated that all the fungicide-treated plots had significantly less wilt than the check plots. However, there were no differences between fungicides used. Yield data failed to indicate any differences due to either method of application or fungicide used.

In the visual evaluation of *Verticillium* wilt incidence in the second test on 1 October 1968, there were significant differences between methods of application (Table 2). Evaluations of boll rot control (Table 2) indicate that plots receiving four foliage applications of either fungicide had significantly less boll rot than the check plots, and in general there was less boll rot where foliage applications were made. Soil applications at planting time, or later in the season, failed to show any beneficial effect on boll rot. Differences between benomyl and thiabendazole were not significant for either wilt incidence or boll rot loss. Yield data indicate only a single significant difference between application methods. However, max yields were consistantly associated with the injection treatment of benomyl. Benomyl treatment gave significantly higher yields than thiabendazole treatment in this test.

Results of the 1969 study are summarized in Table 3. In this study, *Verticillium* wilt infection was apparent in 20% of the check plants on 1 October 1969, and wilt loss was high. Also, boll rot loss was high in this planting. Several of the benomyl treatments, particularly those including foliage treatments, were responsible for significantly less *Verticillium* wilt and boll rot and significantly higher yields than the check plantings. Significant reduction in boll rot was obtained only where late-season foliage applications of benomyl were used.

DISCUSSION.—My results on seedling disease, caused by *Rhizoctonia solani* Kuehn (16), support the report of Allam et al. (2) that benomyl and thiabendazole are not as effective as other systemic fungicides used for seedling disease control (17).

The combination of seed treatment with either in-the-furrow sprays, or injection below the seed at planting time, seems to be the most beneficial application method for *Verticillium* wilt control. In my studies, the max control of *Verticillium* wilt was obtained with a combination of seed and soil applications at planting and early-season foliage applications, indicating that the foliage applications contributed to disease control. Foliage applications late in the season were not effective in reducing loss due to *Verticillium* wilt. However, these late season applications were effective in reducing boll rot loss. In these studies, only two treatment combinations resulted in yield increases of 12% or more. Considering the amount of materials used and the method of application, this cannot be considered as economic control.

The work of Hine et al. (11) on uptake and translocation of benomyl show foliage application to be an effective way of introducing benomyl into the cotton plant. It has long been recognized that surfactants increase penetration of herbicides and other pesticides into plants (12, 13, 15). The mechanisms by which surfactants increase pesticide activity are not entirely clear, but results show that surfactants aid the entry of pesticides into plants and increase the response obtained from a given rate of pesticide. Uptake of benomyl and thiabendazole is increased by using a surfactant in solutions applied to the soil (18); it seems logical that this response due to surfactants might also occur with foliage applications. To be effective as control agents, systemic fungicides must enter the plant in sufficient concentration to arrest or inhibit disease development. In the case of seedling disease, the effective concentration level may be required for only 2 or 3 weeks. With a systemic disease such as *Verticillium* wilt, a concentration of fungicide sufficient to inhibit the disease must be present for most of the growing season. Control of *Verticillium* wilt either in greenhouse studies (6, 7, 8, 9, 14), where a more or less continuous supply of materials is present in the root zone, or in field studies (6, 8, 10, 14), occurred only where multiple applications were made over a considerable period of time. To be effective under field conditions, methods must be developed which will increase the uptake of fungicides applied. Improved timing and placement of the materials undoubtedly will help, but increasing chemical absorption and uptake will probably be the decisive factor if practical control is obtained with these fungicides.

Late-season applications of either of these materials were effective in reducing boll rot loss. Studies by

TABLE 2. Effect of benomyl and thiabendazole treatments on incidence of *Verticillium* wilt, boll rot, and yield of seed cotton

Method and time of application		Rate, lb. active/acre		Wilt rating 10/1/68[a]	Boll rot loss, lb. seed-cotton/acre[a]	% Boll rot[a]	Yield, lb. seed cotton/acre		
Planting	Postplant	Plant	Postplant				Benomyl	Thiaben-dazole	Mean[a]
Injected, 6″ band[b]	Sidedress	3.75	4.0	4.1 a	234 b	7.82 b	3140	2935	3,037 ab
Injected, 6″ band[b]	2 foliage	3.75	0.5 + 0.5	4.3 ab	189 ab	6.13 ab	3182	2995	3,088 a
None	2 foliage	—	0.5 + 0.5	4.4 ab	215 ab	7.16 ab	3074	2877	2,975 ab
Injected 6″ band[b]	None	3.75	—	4.5 ab	227 b	7.43 b	3188	2922	3,055 ab
In-furrow spray	2 foliage	4.0	0.5 + 0.5	4.5 ab	171 ab	5.86 ab	3070	2781	2,925 b
None	4 foliage	—	0.5 + 0.5 + 0.5 + 0.5	4.8 bc	157 a	5.32 a	3065	2862	2,964 ab
None	None	—	—	5.3 c	223 b	7.60 b	2931	2916	2,923 b
Mean				c	c	c	3093 a	2898 b	

[a] Means not followed by the same letter are significantly different at the .05 level as measured by Duncan's new multiple range test.
[b] Broadcast rate would be 25 lb./acre; on band of 6 inches and 13,064 feet of 40-inch row, this would be 3.75 lb./acre.
[c] Values are means of benomyl and thiabendazole treatments. Differences between fungicides (benomyl and thiabendazole) were not significant.

TABLE 3. Summary of study on cotton disease control with benomyl and thiabendazole. Effect of various methods of application on incidence of *Verticillium* wilt, boll rot, and yield of seedcotton

Treatment[a]			*Verticillium* wilt, wilted plants/acre on 10/1/69[b]	% Boll rot[b]	Yield, lb. seedcotton/acre[b]
Fungicide	Application methods	Rate, active/acre			
Benomyl	Seed treatment Soil injection Foliage sprays (6)	2 oz 2 lb. 3 lb.	3,497 ab	10.80 a	2,354 a
Benomyl	Seed treatment Foliage sprays (6)	2 oz 3 lb.	4,298 abc	11.38 ab	2,316 ab
Benomyl	Seed treatment Soil injection Foliage sprays (2)	2 oz 2 lb. 1 lb.	3,034 a	14.10 c	2,269 abc
Benomyl	Seed treatment Soil injection	2 oz 2 lb.	6,404 cd	14.36 c	2,269 abc
Thiabendazole	Seed treatment Soil injection Foliage sprays (2)	2 oz 2 lb. 1 lb.	5,583 abcd	13.52 bc	2,175 abcd
Thiabendazole	Seed treatment Soil injection	2 oz 2 lb.	8,090 d	13.92 c	2,170 abcd
None		0	7,298 d	15.52 c	2,065 cd
Thiabendazole	Seed treatment Soil injection Foliage sprays (6)	2 oz 2 lb. 3 lb.	5,899 bcd	14.68 c	2,052 d
Thiabendazole	Seed treatment Foliage sprays (6)	2 oz 3 lb.	5,878 bcd	13.66 bc	2,033 d

[a] A surfactant polyoxyethylene sorbitan monolaurate (Tween 20) was added to the fungicide solutions injected into the soil at a level of 5,000 ppm. In the foliage sprays, equal rates of Tween 20 (0.5 lb., 1,666 ppm) and active fungicide were used.
[b] Means not followed by the same letter are significantly different at the .05 level as measured by Duncan's new multiple range test.

Bagga (3, 4) have shown that benomyl either in vivo or in vitro will control many of the organisms involved in the boll rot complex. Al-Beldawi & Pinckard (1) and Davis & Pinckard (5) have shown that *Diplodia gossypina* Cke., a common boll rot organism, was effectively inhibited by low levels of translocated benomyl. In my study, no attempt at bioassay was made, and it is not known whether the boll rot control obtained was due to contact action or absorption-translocation. Irrespective of the mode of action, a significant level of boll rot control was obtained with relatively low application rates.

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