Cultivar, Environment, and Fungicide Effects on Foliar Disease Losses in Soybeans

P.A. Backman, R. Rodriguez-Kabana, J.M. Hammond, and D.L. Thurlow

Departments of Botany and Microbiology (first three authors), and Agronomy and Soils (fourth author), Auburn University Agricultural Experiment Station, Auburn, AL 36830.

These studies were supported in part by a grant from the Alabama Soybean Producers.
Accepted for publication 13 November 1978.

ABSTRACT

BACKMAN, P.A., R. RODRIGUEZ-KABANA, J.M. HAMMOND, and D.L. THURLOW. 1979. Cultivar, environment, and fungicide effects on foliar disease losses in soybeans. Phytopathology 69: 562-564.

In 33 replicated soybean tests conducted throughout Alabama, yield of early- and late-maturing cultivars increased an average of 15.3 and 11.0%, respectively, if conditions favorable for infection by foliar pathogens occurred (>5 wet days between bloom and pod fill) and benomyl was applied. If weather was dry (<5 wet days) yield increases attributable to benomyl were 1% or less. Other tests, with planting dates staggered so plants of each cultivar bloomed at the same time, were used for critical comparisons of cultivar susceptibility. In order of yield reduction potential, the principal pathogens were: *Colletotrichum dematium* f. *truncata*, *Septoria glycines*, *Cercospora sojina*, and *Diaporthe phaseolorum* var. *sojae*. Evaluation of three fungicides for control of these pathogens indicated that benomyl was more effective than fentin hydroxide (FTH) against *S. glycines*, and slightly less effective than FTH against *C. dematium* f. *truncata*. Thiabendazole was less effective than the other products except for control of *C. sojina*.

Soybeans (*Glycine max* [L.] Merr.) grown in the USA include many cultivars, each with different resistances to each of several foliar pathogens. In the southeastern United States, the most frequently observed foliage, stem, or pod pathogens are *Septoria glycines* Hemmi (cause of brown spot), *Cercospora sojina* Hara (cause of frogeye leafspot), *Peronospora manshurica* (Naum.) Syd. (cause of downy mildew), *Diaporthe phaseolorum* (Cke. &Ell.) Sacc. var. *sojae* (Lehman) Wehm (cause of pod and stem blight), and *Colletotrichum dematium* (Fr.) Grove f. *truncata* (Schw.) Arx (cause of anthracnose) (8). Several other fungal and bacterial diseases affect soybeans, but these are erratic in occurrence and distribution. Loss estimates for all soybean diseases vary greatly, due to the subjective bases employed in assessment, and wide differences in disease severity (9).

Development of appropriate recommendations for the control of soybean diseases requires the following information: what fungi cause significant yield and seed quality losses; what environmental conditions predispose plants to infection; and what fungicides will control the damaging pathogens?

Results obtained by the authors and by the fungicide manufacturer (both *unpublished*) indicate that maximal yield response to benomyl is achieved by applications at early pod set and 14—18 days later. Benomyl sprays applied earlier or later are of little benefit probably because the fungal infections responsible for yield reductions occur between bloom and pod-fill. The belief commonly held by growers that the early-maturing cultivars respond more consistently with yield increases following benomyl treatment has not been substantiated.

Horn et al (6) inoculated three soybean cultivars with *D. phaseolorum*, *C. sojina*, and *Corynespora cassicola*, and found that *C. cassicola* caused the greatest overall yield losses followed in decreasing order by *C. sojina* and *D. phaseolorum*. They also concluded that yield increases were more commonly related to larger seed size than to numbers of seed harvested.

This study was conducted to determine: disease susceptibility of cultivars and maturity groups and their response to benomyl; soybean yield losses relative to the severity of the principal diseases; and the efficacy of certain fungicides for controlling these diseases.

MATERIALS AND METHODS

Thirty-three tests were conducted statewide in Alabama to determine the response of various soybean cultivars to fungicides. As the soybeans approached early pod set (R_3), fungicides were applied, followed by a second application 14—18 days later ([R_5] early pod-fill). R-ratings refer to the reproductive stages of the soybean plant as outlined by Fehr et al (4). All fungicides were applied with a high-clearance ground sprayer operating at 6.0 kg/cm^2 and delivering 40 L/ha through hollow-cone type nozzles. Three nozzles were positioned one above the top and one on each side of the row. All tests were arranged in randomized complete block or split-plot designs with five to eight replications. For the purpose of this report, only the results from the untreated control plots and plots treated with benomyl 50 WP (0.56 kg/ha/application) will be presented here. These results are related to prevailing weather conditions during the bloom to pod-fill periods as recorded by nearby stations operated by the U.S. National Weather Service.

Two tests were conducted to determine the principal pathogens of soybeans and their relative pathogenic potentials. Cultivars evaluated in these tests were Forrest, Davis, Bragg, and Hutton, representing maturity groupings V, VI, VII, and VIII, respectively. For Alabama conditions, maturity groups V and VI are considered early-maturing, and groups VII and VIII late-maturing cultivars. Differences in severity of the various diseases were achieved through differential susceptibilities of the cultivars, and by treatment of the cultivars with fungicides. Cultivars were planted at different times that were staggered to coordinate bloom occurrence (R_1) on the same date ($\pm$ 2 days) for each cultivar. This allowed cultivars from different maturity groupings to be evaluated following treatment with fungicides under the same environmental conditions, and at the same developmental stage. Fungicides used in this study were benomyl 50 WP (0.56 kg/ha at each application), fentin hydroxide (FTH) 47 WP (0.56 kg/ha at each application), and thiabendazole (TBZ) 42.3% flowable (0.3 L/ha at each application). Fungicides were applied as described for the statewide tests. Fungicides were applied to four-row split plots with cultivars the whole plot. Treatment $\times$ cultivar combinations were replicated eight times at each of the two locations.

Samples for foliar disease estimation were obtained with the following systems: (i) approximately 15 trifoliolate leaves including petioles were picked about one-third of the way down the plant at intervals throughout the length of the two middle rows of each plot; and (ii) at harvest, combine trash was randomly bagged from each plot to include representative samples of stems and pods.

Bases for the severity ratings of the various diseases and damage were:

(i) Brown spot, frogeye leafspot and downy mildew; lesion frequency on trifoliolate samples.

00031-949X/79/000099$03.00/0

(ii) Anthracnose and pod and stem blight; severity on dried stem samples after harvest.

(iii) Senescence; relative senility when control plots were 50% defoliated (on 1—5 scale, where 1 = 1 full green and 5 = dead).

Disease severity for each of the diseases present was monitored for each cultivar × treatment and related to environmental conditions occurring during the spray period. Disease ratings were made on a 1—5 rating scheme where; 1 = no symptoms; 2 = scattered infection; 3 = moderate infection (most leaves, stems, or pods multiply infected); and 4 and 5 = increasingly severe levels of infection. Ratings were estimated to the one-tenth unit. In trials involving several cultivars sprayed during the bloom to pod-fill periods (coordinated bloom studies), foliar disease ratings were made as each cultivar approached senescence, and reflected the performance of the fungicide at a similar physiological state (pre-senescence) for each cultivar. However, it should be noted that early-maturing cultivars reached senescence sooner after treatment than did the late-maturing cultivars.

Yields for both state-wide and coordinated bloom tests were obtained by harvesting the center 2-rows of the four-row plots. The ends of the plots were trimmed-off before harvest to eliminate any edge effect. The yields reported reflect actual seed yields after harvesting with a 2-row combine.

TABLE 1. Changes in soybean yields following benomyl treatment: Summary of 33 tests 1974—1977

Weather conditions	Yield[a] increase (kg/ha) Cultivar maturity group V & VI	VII & VIII	Weighted mean
Wet	375 (9)[b]	300 (12)	332 (21)
Dry	20 (6)	−146 (6)	−63 (12)
Weighted mean	233 (15)	151 (18)	188 (33)

[a]Number in parentheses indicates number of tests represented by the mean.
[b]Average untreated yield 2,347 kg/ha (34.9 bu/acre).

RESULTS

On a multi-year, multi-location basis, soybean yield responses to fungicides were erratic, varying from actual losses to 40% increases. When the 33 tests of this study were evaluated for response to benomyl, it was clear that the largest increase occurred in tests conducted in wet locations with 5 or more days of rainfall in the 3 wk immediately after bloom initiation. Any day with >2.0 mm of rain was considered "wet". Yields of both early and late maturing cultivars were increased (300—375 kg/ha) by benomyl in "wet" environments, but were not increased in "dry" environments (Table 1).

Soybean cultivars from the coordinated bloom test conducted at the Marion Junction location predominantly were infected with *S. glycines* and *C. dematium* (Table 2). Levels of anthracnose were similar for all cultivars. Yield differences between fungicide treatments were related to control of these two pathogens. The yield of cultivar Forrest plants, however, was severely reduced by drought. Benomyl was effective against *S. glycines* and *C. dematium*, fentin hydroxide primarily against *C. dematium*, while thiabendazole was not effective against either organism.

In coordinated bloom studies conducted at Tallassee, AL, anthracnose and frogeye leafspot most frequently were observed at severe levels (Table 2). Even though relative disease severities (*Colletotrichum-Cercospora*) were similar to the severities of the *Septoria-Colletotrichum* complex observed at Marion Junction, yield responses to fungicide treatments were only 50—60% of those observed in the earlier study. Plants of cultivar Davis was resistant

TABLE 2. Response of soybean cultivars and diseases to two applications of benomyl, fentin hydroxide (FTH), or thiabendazole (TBZ) in a coordinated bloom test at each of two Alabama locations[w, x, y]

Treatment	Tallassee, AL Forrest	Davis	Bragg	Hutton	Mean	Marion Junction, AL[z] Forrest	Davis	Bragg	Hutton	Mean
Cercospora sojina (Frogeye):										
Control	5.00 a	2.38 a	4.12 a	4.00 a	3.88 a	1.88 a	1.88 a	2.12 a	2.88 a	2.19 a
Benomyl	2.75 c	2.50 a	2.06 c	2.06 b	2.34 c	1.88 a	1.88 a	2.00 a	1.94 a	1.92 a
FTH	4.12 b	2.62 a	2.69 b	2.25 b	2.92 b	1.62 a	2.00 a	2.06 a	2.31 a	2.00 a
TBZ	3.62 b	2.12 a	2.75 b	2.44 b	2.73 b	1.62 a	1.38 a	2.38 a	2.50 a	1.97 a
Septoria glycines (Brown spot):										
Control	1.75 a	2.00 a	1.75 a	2.06 a	1.89 a	4.75 a	5.00 a	3.38 a	2.81 a	3.98 a
Benomyl	1.25 a	1.50 a	1.38 a	1.31 a	1.36 b	3.12 b	3.62 b	2.50 b	2.12 a	2.84 c
FTH	1.38 a	1.62 a	1.31 a	1.19 b	1.38 b	3.88 b	4.50 a	2.56 b	2.44 a	3.34 b
TBZ	1.12 a	1.12 b	1.38 a	1.38 a	1.25 b	4.62 a	5.00 a	2.75 ab	2.38 a	3.69 ab
Colletotrichum dematium f. *truncata* (Anthracnose):										
Control	4.30 a	2.94 a	4.30 a	4.17 a	3.96 a	3.70 a	3.94 a	3.84 a	4.02 a	3.88 a
Benomyl	2.64 b	2.29 b	2.26 b	3.10 b	2.56 b	3.04 c	2.74 b	2.76 c	2.69 c	2.81 c
FTH	2.92 b	2.24 b	2.22 b	2.34 c	2.44 b	3.29 c	3.05 b	2.34 c	2.47 c	2.80 c
TBZ	3.95 a	3.08 a	3.90 a	3.90 a	3.69 a	3.52 b	3.67 ab	3.31 b	3.51 b	3.50 b
Senescence rating:										
Control	4.38 a	4.06 a	4.01 a	3.75 a	4.05 a	3.46 b	3.78 a	3.98 a	3.82 a	3.76 a
Benomyl	3.61 b	3.64 b	3.45 b	3.38 b	3.52 c	3.05 c	3.05 b	2.92 c	2.89 c	2.98 c
FTH	3.21 c	3.34 c	3.34 b	3.10 b	3.25 d	3.79 a	3.76 a	3.15 bc	3.05 bc	3.44 b
TBZ	3.38 bc	3.42 bc	4.22 b	3.88 a	3.72 b	3.86 a	3.85 a	3.42 b	3.21 b	3.59 ab
Yield (kg/ha):										
Control	2,277 a	2,700 a	2,487 a	2,970 a	2,606 a	1,109 a	2,179 a	1,654 a	1,644 a	1,647 a
Benomyl	2,549 ab	2,914 a	2,895 b	3,165 bc	2,902 bc	1,237 a	2,853 b	2,236 b	1,780 a	2,027 b
FTH	2,654 b	2,974 a	2,968 b	3,383 b	2,982 c	1,170 a	2,608 b	1,960 ab	1,905 a	1,911 a
TBZ	2,525 a	2,798 a	2,923 a	3,111 c	2,831 b	1,062 a	2,410 ab	1,852 ab	1,701 a	1,721 a

[w]Cultivar × treatment means in columns followed by the same letter are not significantly different, $P=0.05$, according to Duncan's multiple range test.
[x]All means except yields represent subjective disease ratings based on: 1 = no disease or no sign of senescence, and 5 = severe disease or plants completely senescent; readings were made to the tenth (0.1) unit.
[y]Cultivar × treatment means are averages of eight replications.
[z]Forrest cultivar at Marion Junction was severely stunted by drought and associated iron chlorosis.

to *C. sojina*, but still responded at 70−80% of the increased yield of varieties with both frogeye and anthracnose. Thiabendazole was again ineffective against *Colletotrichum;* at this location yield improvements following thiabendazole treatment must therefore be related to control of *C. sojina*.

In both coordinated bloom studies, neither downy mildew nor pod and stem blight responded to fungicide treatment. Downy mildew infections preceded treatment, and did not seem to increase after bloom. Pod and stem blight appeared to develop well-after pod fill and thus could not effect yield. Observations on these two diseases, therefore, are not reported here.

Delayed senescence was found to be a good indicator for reduction in total disease load (Table 2). In both coordinated bloom tests delay in the onset of senescence was typically related to increased yield and disease control.

DISCUSSION

These data indicate that for significant yield increases to occur in response to benomyl, soybeans must be under periods of recurrent rainfall from bloom to pod fill. These "wet" periods would correspond to infection periods for the principal foliar pathogens. Untreated controls in the 21 "wet" tests had much higher levels of disease than did the untreated controls in the "dry" tests. The 5 wet-days scheme as described, appeared to be a good predictor for the efficacy of benomyl. As modified for the two-spray program recommended in Alabama (4), farmers are advised to make the first application of 0.56 kg/ha benomyl 50 WP at R_3 if 2−3 wet days have occurred since bloom. If these wet conditions have not been met by 1 wk after R_3 the application is omitted. A second application of benomyl at the same rate is made only if two additional wet days occur during the 10-day period following the first application. Use of this prediction system would have eliminated at least one-third of the benomyl applications made in the 33-test study. Statistical analysis of data from the 33 tests of this study was not attempted due to differing experimental designs. However, of the results represented in Table 1, only two of the 12 dry tests treated with benomyl had yields > 6% over the nontreated control. Of the six lowest-yielding wet tests treated with benomyl, all had yield improvements of 6−10% over the control; the other 15 wet tests were considerably higher in yield.

Reports that late-maturing cultivars sprayed with fungicides do not respond with yield increases as great as early-maturing cultivars are partially confirmed (Table 1). However, it should be noted that early-maturing cultivars usually proceed from bloom to pod-fill during the wetter late-July through August period (3). The lower yield response of later cultivars to fungicides may merely be a reflection of fewer infection periods occurring during September, rather than disease tolerance.

Coordinated bloom studies allowed evaluation of the damage potential of each of several soybean diseases. Levels of disease achieved through fungicide application and cultivar resistance served as the basis for damage determinations (Table 2). Yields from each cultivar served as the integrating factor for total disease damage, and reflected the cumulative disease load. Data from Marion Junction revealed brown spot to be as damaging to yield as anthracnose. This can be deduced by comparing the yield responses of Hutton (low brown spot) and Davis (high brown spot) to benomyl treatment, when each had about equal levels of anthracnose (frogeye levels were negligible). The Davis soybeans responded with a 31% yield increase; Hutton's yield increased 8.2%. Soybeans treated with fentin hydroxide achieved greater yields than benomyl, only on Hutton, primarily because this fungicide was very active against *C. dematium* but poor against *S. glycines*. Since Hutton had high levels only of anthracnose, treatment with fentin hydroxide was effective.

The Tallassee tests yields (Table 2) indicate that anthracnose affected yield more than did frogeye leafspot. This is apparent when comparing yield response of Davis (very little frogeye) to benomyl, with that of Forrest, Bragg, and Hutton cultivars (high levels of frogeye). Only low levels of brown spot were found in this test. Yields increased primarily in response to anthracnose control rather than to the control of frogeye leafspot.

Comparison of yields from the Marion Junction test with the Tallassee test, indicate the greater percentage yield increases following fungicide treatment at Marion Junction were due to the presence of high levels of *S. glycines* on the cultivars that exhibited highest yield responses.

These tests indicate that in order of damage potential, anthracnose is slightly more damaging than brown spot, and frogeye is least damaging. In these tests, *C. sojina*, *S. glycines*, and *C. dematium*, all apparently invaded between R_1 and R_5. Pod and stem blight infects much later with little yield loss. Yield reductions from these organisms were probably due to reduced photosynthetic capability because of premature sensecence, resulting in smaller seed as observed by Horn et al(6). Kinetin-like activity has been ascribed to benomyl in previous studies (8). However, neither Horn et al (7) nor our data indicated any kinetin-like activity to benomyl applied to soybeans.

In the 33 state-wide tests reported in this paper, *Colletotrichum dematium* was dominant in every test with recorded yield increases. *Septoria glycines* occurred more sporadically, but yields were also improved where it was controlled. Superior control was exhibited by benomyl against both pathogens, and against *C. dematium* by fentin hydroxide. Thiabendazole at the rates employed was inferior in activity against these pathogens, although good activity against *Cercospora sojina* was detected.

Further studies are warranted on environmental conditions between R_1 and R_5 that predispose soybeans to one foliar pathogen (eg, *S. glycines*) to exclusion of a second *(C. sojina)*. The understanding of the epidemiology of the damaging pathogens might allow prediction of which of the pathogens would infect, and could lead to scheduling of an appropriate fungicide. Soybean recommendations for Alabama growers (5) indicate that foliar fungicides should be used only when wet conditions, as defined above, favor disease development (1). This predictive scheme alone should prevent many unnecessary applications and improve the overall efficacy of fungicides in soybeans. Future research should also stress economic thresholds for multiple disease systems. Multiple regression equations relating total pathogen load vs. yield would be the starting point for these determinations.

LITERATURE CITED

1. BACKMAN, P.A. 1977. Foliar fungicides for soybeans. Auburn Univ. Agric. Exp. Stn., Highlights of Agric. Res. 24(2):14.
2. BACKMAN, P.A., and D.L. THURLOW. 1977. A coordinated bloom approach to disease susceptibility evaluations in soybean cultivars. Proc. Am. Phytopathol. Soc. 4:151.
3. DAVIS, J.M., and C.M. SAKAMOTO. 1976. An atlas and tables of thunderstorm and hail day probabilities in the southeastern United States. Auburn Univ. Agric. Exp. Stn. Bull. 477. 75 pp.
4. FEHR, W.R., C.E. CAVINESS, D.T. BURNMOND, and J.S. PENNINGTON. 1971. Stages of development descriptions for soybeans, Glycine max (L.) Merrill. Crop. Sci. 11:929-931.
5. GRAY, F.A., W.S. GAZAWAY, R. RODRIGUEZ-KABANA, and P.A. BACKMAN. 1978. Soybean disease and nematode control recommendations. Auburn Univ. Ext. Serv. Circ. ANR-34. 5 pp.
6. HORN, N.L., F.N. LEE, and R.B. CARVER. 1975. Effects of fungicides and pathogens on yields of soybeans. Plant Dis. Rep. 59:724-728.
7. HORN, N.L., G. WHITNEY and T. FORT. 1978. Yields and maturity of fungicide sprayed and unsprayed disease-free soybean plants. Plant Dis. Rep. 62:247-249.
8. SKENE, K.G.M. 1972. Cytokinin-like properties of the systemic fungicide benomyl. J. Hortic. Sci. 47:179-183.
9. WHITNEY, G. 1978. Southern soybean disease losses. Proc. S. Soybean Dis. Workers 5:3-5.