Yield Reduction in Soybeans Caused by Downy Mildew

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ABSTRACT

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Seed yield reductions in soybeans (*Glycine max*) caused by downy mildew (*Peronospora manshurica*) were determined. In a 2-yr field test, there was good disease spread early in the season from the Lincoln A117 border to leaves of the unsprayed susceptible cultivars in the plots. Infected leaves on these cultivars produced abundant conidia, and the mean percentage of diseased plants was 98.5. No conidia were found on metalaxyl-sprayed or unsprayed leaves of resistant cultivars. The mean seed yield of sprayed susceptible cultivars was 11.8% more than that of the same unsprayed cultivars. Metalaxyl effectively controlled downy mildew on three susceptible cultivars. A mean of 10.6% oospore-encrusted seed occurred in unsprayed, susceptible cultivars.

Downy mildew of soybeans (*Glycine max* (L.) Merr.) caused by the fungus *Peronospora manshurica* (Naum.) Syd. ex Gaum. is a common soybean disease in the United States (1). The fungus is an obligate parasite that infects leaves and grows within plant tissue by establishing mycelium with haustoria. It also invades pods and covers seeds with a crust of oospores. Bernard and Cremeens (2) studied the inheritance of resistance to the pathogen and designated the gene controlling resistance as *Rpm*. Even though resistance is simply inherited, there has been little interest in developing cultivars resistant to *P. manshurica*. Possibly, one reason may be the lack of information. The objective of this study was to determine if downy mildew can significantly reduce soybean yields.

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MATERIALS AND METHODS

Tests were conducted on a floodplain in central Iowa. Lincoln A117 (a short derivative of Lincoln) showed exceptional susceptibility to *P. manshurica* in greenhouse tests. A preliminary test was conducted to determine if this soybean line was as susceptible when grown under field conditions. The effects of race 12 (5) of *P. manshurica* and a protective spray of maneb (80% a.i., wettable powder, 3 g/L) on seed yield of susceptible soybean cultivars Lincoln, Lincoln A117, Wayne, and Woodworth were determined. The amount of maneb applied per plot varied during the season as plant size increased. The spray contained a phthalic glyceryl alkyd resin spreader-sticker at 0.3 ml/L. Plots of each cultivar were either unsprayed or sprayed to runoff at weekly intervals from 15 June (growth stage V3) until plant maturity (growth stage R7) (6). Plants were inoculated at growth stage V3 by dragging greenhouse-grown,

Table 1. Disease incidence, leaf conidia production, seed yield, and seed oospore encrustation from unsprayed and maneb-sprayed plots of soybeans susceptible to race 12 of *Peronospora manshurica*

	Unsprayed					Sprayed				
Cultivar	Diseased plants (%)	Leaf conidia (no./cm²)	Seed yield (kg/ha)	Oospore-encrusted seed/100	Seed weight (g/100)	Diseased plants (%)	Leaf conidia (no./cm²)	Seed yield (kg/ha)	Oospore-encrusted seed/100	Seed weight (g/100)
Lincoln	100.0[a]	1,082[a]	3,077[a]	5.8[a]	16.2[a]	8.7**[b]	13**	3,409*	0.2**	16.9
Lincoln A117	100.0	2,071	1,800	14.5	12.0	11.2**	165**	2,404**	1.8**	14.0**
Wayne	97.7	1,002	3,542	2.7	18.7	1.2**	0**	3,933**	0.0**	20.2*
Woodworth	99.3	1,247	3,086	2.5	17.0	2.8**	11**	3,459**	0.2**	17.9

[a] Represents mean of six replicates.
[b] * = Significantly different from the unsprayed treatment at $P<0.05$; ** = significantly different from the unsprayed treatment at $P<0.01$, according to a protected LSD.

P. manshurica-infected Bansei soybean plants with sporulating leaf lesions (5) through plant rows just before nightfall after dew formation had begun. Other details of this test are as described for the separate 2-yr study.

For 2 yr, yield losses caused by *P. manshurica* were determined for susceptible cultivars Wayne, Williams 79, and Woodworth and resistant cultivars Beeson, Calland, and Century. Susceptibility or resistance of these cultivars was determined in the greenhouse by using methods previously described (5). Plants were grown in rows 3 m long and 1 m wide. Each plot consisted of three rows; the center row was harvested for seed yield. The experimental design was a randomized complete block with six replicates. Means were tested for significance by computing the protected least significant difference (LSD).

Plots of each cultivar were either unsprayed or sprayed until runoff with metalaxyl (25% a.i., 0.3 ml/L) and a surfactant (Tween 20, 2.5 ml/L). Plants were sprayed weekly from growth stage V1 until plant maturity (growth stage R7) (6).

The tests were located in the same floodplain described for the preliminary test and were surrounded by Lincoln A117 soybeans in a band 50 m wide. Seed of Lincoln A117 was obtained from plants inoculated with race 12 of *P. manshurica*, and the seed contained 12% oospore-encrusted seed in 1983 and 15% in 1984. Many of the Lincoln A117 plants in the border were from oospore-encrusted seed that produced systemic infections and formed conidia early in the season. These conidia caused early infections of the susceptible cultivars in the plots.

The percentage of diseased plants and estimated production of leaf conidia were determined at the full-pod stage (R4) (6) of plant development. Percentage of diseased plants was determined by examining the first 50 plants in each row. Conidial production was estimated by sampling one leaflet five nodes below the plant apex from each of the first 10 plants in the row. These leaflets were placed in a dew chamber overnight to produce sporulation. Each leaflet was sampled 2 cm from the tip by removing 1 cm² of leaf tissue, washing conidia off the sample in 1 ml of water with a camel's-hair brush, and counting conidia with a hemacytometer (8).

RESULTS AND DISCUSSION

Nearly all unsprayed plants in the preliminary test were infected, but some sprayed plants were also infected, and percentages of diseased plants of all cultivars in the unsprayed plots were significantly higher ($P<0.01$) than in the sprayed plots. The mean percentage of diseased plants for all cultivars in sprayed plots was 6.0, and ranged from 1.2% for Wayne to 11.2% for Lincoln A117 (Table 1). Maneb was effective in protecting sprayed leaves, but some leaves that developed from buds between spray applications were infected.

Conidial production on leaves for all cultivars in the unsprayed plots was significantly greater ($P<0.01$) than in the sprayed plots, and unsprayed Lincoln A117 produced more than twice the conidia produced by Lincoln, and more than four times the number produced by Wayne and Woodworth. With such heavy conidial production, Lincoln A117 was an obvious choice for use as a border for inoculum production in the 2-yr tests.

Seed yield of all sprayed cultivars was significantly greater than that of the same unsprayed cultivars. Lincoln A117 had the greatest yield reduction compared with the maneb-sprayed control (25.1%), followed by Woodworth (10.8%), Wayne (9.9%), and Lincoln (9.7%). Unsprayed cultivars produced significantly greater numbers of oospore-encrusted seed ($P<0.01$) than sprayed cultivars. Seed weight per 100 seeds was significantly reduced in unsprayed plots of Lincoln A117 and Wayne. Lincoln A117 produced shorter plants with smaller leaves than Lincoln (Fig. 1), and in sprayed plots, Lincoln A117 produced 29.5% less seed and 29.0% smaller seed than Lincoln. On the basis of these data, metalaxyl was selected to replace maneb as a fungicide because of its superior systemic action.

In the 2-yr tests, there was good disease spread early in the season from Lincoln A117 to leaves of the unsprayed susceptible cultivars in the plots. Leaves from nodes five through eight were usually infected first. Succeeding leaves tended to have more lesions per leaf. Fewer than 1% of the sprayed susceptible plants were infected (Table 2), and none of the unsprayed resistant plants were infected in either test. Unsprayed susceptible cultivars produced abundant conidia, but no conidia were found on sprayed susceptible or unsprayed resistant leaves.

Fig. 1. Field-grown soybean plants of (left) Lincoln A117 and (right) Lincoln. Vertical white bar = 15 cm. Note the reduced plant height and leaf size of the Lincoln A117 plant.

The latter part of the 1984 growing season was dry, and mean yields in unsprayed and sprayed plots were 38.9 and 37.3% less, respectively, than yields in 1983, but the incidence of downy mildew in unsprayed plots of susceptible cultivars was nearly the same both years. Respective seed yields of susceptible cultivars Wayne, Williams 79, and Wood-

Table 2. Disease incidence, leaf conidia production, seed yield, and seed oospore encrustation from unsprayed and metalaxyl-sprayed plots of soybeans resistant and susceptible to race 12 of *Peronospora manshurica*

Year, cultivar, and disease reaction[a]	Unsprayed					Sprayed				
	Diseased plants (%)	Leaf conidia (no./cm²)	Seed yield (kg/ha)	Oospore-encrusted seed/100	Seed weight (g/100)	Diseased plants (%)	Leaf conidia (no./cm²)	Seed yield (kg/ha)	Oospore-encrusted seed/100	Seed weight (g/100)
1983										
Wayne (S)	98.7[b]	1,162[b]	2,937	13.2[b]	17.5[b]	0.7**[c]	0**	3,416**	0.3**	18.8**
Williams 79 (S)	98.7	519	2,883	7.2	17.6	0.7**	0**	3,150*	0.0**	17.8
Woodworth (S)	98.0	730	2,919	8.2	15.5	0.3**	0**	3,224**	0.0**	15.8
Beeson (R)	0.0	0	3,448	0.0	19.5	0.0	0	3,413	0.0	19.5
Calland (R)	0.0	0	3,220	0.0	17.8	0.0	0	3,215	0.0	17.7
Century (R)	0.0	0	3,420	0.0	18.4	0.0	0	3,339	0.0	18.4
1984										
Wayne (S)	97.6	1,451	1,931	16.0	16.8	0.7**	0**	2,344**	0.3**	18.1**
Williams 79 (S)	99.3	1,015	1,653	11.0	16.9	0.3**	0**	1,874**	0.2**	17.8**
Woodworth (S)	98.7	809	1,801	8.0	14.6	0.7**	0**	1,989**	0.0**	15.2**
Beeson (R)	0.0	0	1,997	0.0	18.5	0.0	0	1,989	0.0	18.7
Calland (R)	0.0	0	1,952	0.0	16.9	0.0	0	1,967	0.0	17.1
Century (R)	0.0	0	2,167	0.0	17.3	0.0	0	2,221	0.0	17.2

[a] S = susceptible and R = resistant.
[b] Represents mean of six replicates.
[c] * = Significantly different from the unsprayed treatment at $P<0.05$; ** = significantly different from the unsprayed treatment at $P<0.01$, according to a protected LSD.

worth were 14.0, 8.5, and 9.5% lower ($P<0.01$, except Williams 79, $P<0.05$) in unsprayed than in sprayed plots in 1983 and were 17.6, 11.8, and 9.5% lower ($P<0.01$) in 1984.

In 1983, Wayne was the only susceptible cultivar that had significantly greater ($P<0.01$) seed weight from sprayed than from unsprayed plants, but in 1984, all sprayed susceptible cultivars had significantly greater seed weight. There was no significant difference in weight of seed from sprayed and unsprayed resistant cultivars in either 1983 or 1984. In 1983, 6.9% of the reduction of Wayne seed yield caused by downy mildew was attributed to reduced seed weight and 93.1% was attributed to reduced seed number. In 1984, 7.2, 5.1, and 3.9% of the seed yield reduction of susceptible cultivars Wayne, Williams, and Woodworth, respectively, was due to reduced seed weight.

The mean number of oospore-encrusted seeds from unsprayed susceptible cultivars ranged from 7.2 to 13.2 in 1983 and from 8.0 to 16.0 in 1984 (Table 2). There were significantly fewer ($P<0.01$) oospore-encrusted seeds from sprayed susceptible cultivars than from unsprayed susceptible cultivars in both 1983 and 1984. No oospore-encrusted seed was found in sprayed or unsprayed resistant cultivars in either year.

Plants of resistant cultivars were not infected by *P. manshurica*, and their seed yields were unaffected by treatment with metalaxyl. No disease except downy mildew reduced the yield in unsprayed plots of susceptible plants, and metalaxyl was neither phytotoxic nor stimulatory to resistant plants. Metalaxyl has been effective in controlling a variety of downy mildews (3,7,9–12), and it also gave good control of *P. manshurica* in this study.

Estimates of soybean damage caused by *P. manshurica* have varied from none to severe (1,5). Similar observations have been made for other downy mildews. Dixon (4) quotes observers of downy mildew of pea that suggested "*P. viciae* to be one of the most widespread and least important diseases of pea," whereas others have reported total destruction of pea crops by *P. viciae*. One possibility is that weather conditions, host susceptibility, and physiologic race of the pathogen are factors that interact to favor downy mildew, and determine the degree of seed yield reduction. The type of weather is the most uncertain of these factors and may be a partial reason for the lack of information on losses caused by *P. manshurica*. The incidence of diseased plants measured in this study can largely be attributed to microenvironment (lowland near a stream) and presence of ample inoculum (surrounding the tests with a highly susceptible cultivar). The yield reduction of Lincoln A117 (25.1%) probably represents the upper limit of yield reduction attributable to downy mildew, whereas the mean yield reduction for the three susceptible cultivars for the 2 yr of tests (11.8%) more nearly represents the reduction that might ordinarily be expected in a susceptible cultivar on lowland.

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