Disease Pressure on Soybean in Illinois

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ABSTRACT

Eathington, S. R., Lim, S. M., Nickell, C. D., Pataky, J. K., and Esgar, R. W. 1993. Disease pressure on soybean in Illinois. Plant Dis. 77:1136-1139.

Development of disease resistant cultivars is a primary emphasis of many soybean (*Glycine max*) breeding programs. By understanding the magnitude and frequency of economic loss caused by soybean pathogens, breeding programs can establish breeding priorities. Therefore, 13 yr of disease monitoring data comprising 89 trials and 52 cultivars were analyzed to determine disease pressure on soybeans in Illinois. Of the 12 diseases observed, brown spot (*Septoria glycines*) was the predominant foliar disease, while brown stem rot (*Phialophora gregata*) was the most frequent soilborne disease. Prior probabilities of disease occurrence were developed for brown spot, bacterial blight (*Pseudomonas syringae* pv. *glycinea*), and downy mildew (*Peronospora manshurica*) by partitioning (based on a z-score of ±0.43 from the sample mean) the distribution of disease severity ratings taken at the R6 growth stage. Based on this analysis, the probability of severe symptoms of brown spot is 23% in northern, 31% in central, and 15% in southern Illinois. Brown stem rot occurred at 64 and 52% of the locations in the northern and central regions, respectively, but was not observed in the southern region. Brown spot caused yield reduction throughout Illinois, while other diseases reduced yields at specific locations.

Soybean (*Glycine max* (L.) Merr.) is affected by more than 100 infectious pathogens and their diseases, of which about 35 are economically important (22). In 1991, soybean diseases caused losses of $125 million in Illinois, as estimated by the USDA-CSRS committee on soybean diseases (NCR-137). Breeding programs developing germ plasm and cultivars with disease resistance must set priorities on which pathogens are potential problems and warrant the investment of increasingly limited resources.

Data from disease monitoring plots can provide a quantitative measure of disease pressure, while also detecting changes in pathogen populations and occurrences of new pathogens (23). In 1979, Pataky et al (19) evaluated soybean diseases in monitoring plots and reported that the most prevalent foliar diseases of soybean in Illinois were brown spot (*Septoria glycines* Hemmi), bacterial blight (*Pseudomonas syringae* pv. *glycinea* (Coerper) Young, Dye, & Wilkie), and downy mildew (*Peronospora manshurica* (Naumov) Syd. in Gaum.). From the Illinois monitoring plots, race 33 of *P. manshurica* (14) was discovered on the soybean cultivar Union (2), which contains the *Rpm* gene (5) that was previously known to be resistant to all known races of *P. manshurica*. Likewise, changes in the frequency of race 0 and race 1 of *Exserohilum turcicum* (Pass.) K.J. Leonard & E.G. Suggs were documented by the Dekalb Genetics disease monitoring program (24). Eyespot (*Pseudocercosporella herpotrichoides* (Fron) Deighton) was first discovered on winter wheat (*Triticum aestivum* L.) from the long-term monitoring plots in the United Kingdom (7).

In addition to early detection, disease severity data collected from monitoring plots over an extended period of time can be used to estimate the probability of disease severity for a given area. These prior probabilities are important aspects in understanding disease pressure. Any prolonged aberration in prior probabilities would suggest a change in the ecosystem related to that pathogen. In addition, prior probabilities are a fundamental element of risk analysis, which is a procedure used to make decisions under conditions of uncertainty (1).

Therefore, the objectives of this research were to 1) evaluate 13 yr of data from disease monitoring plots to develop prior probabilities of soybean disease severity in Illinois, and 2) summarize the current disease pressure on soybeans in Illinois.

This research was supported in part by the Illinois Soybean Program Operating Board, the Illinois Crop Improvement Association, the University of Illinois Variety Testing Program, the USDA-ARS, and a Brockson Graduate Fellowship.

Accepted for publication 31 July 1993.

MATERIALS AND METHODS

Monitor plots were evaluated throughout Illinois from 1977 to 1987 and in 1990 and 1991 with a minimum of four locations in 1977 and a maximum of 11 locations in 1978. Overall, 17 different locations (Fig. 1) were tested, with a total of 89 trials during the 13 yr. The experimental procedure differed slightly among years, with treatments ranging from 11 to 16 cultivars per trial for a total of 52 cultivars being evaluated. Of the 52 cultivars, 7, 11, 20, 13, and 1 were from maturity groups (MG) I, II, III, IV, and V, respectively. Experimental plots consisted of four rows, with a between-row spacing of 76 cm and a row length of 3.3 or 5.5 m. Planting density was 26 seeds per meter of row. Cultivars were arranged in a randomized complete block design with three replicates. All trials had corn (*Zea mays* L.) production the previous year and had standard fertility management practices. Cultural practices ranged from conventional tillage to reduced tillage, conventional tillage being defined as no remaining corn residue, while reduced tillage maintained less than 50% of the corn residue. All diseases were the result of natural inoculum.

Disease severity was rated using a modified Horsfall-Barratt scale (17). For foliar diseases, values from the scale were converted to percentages that represented the total leaf area showing symptoms (severity). Soilborne and systemic diseases were rated for the percentage of total plants infected (incidence).

At a few trials, some diseases were rated only at the reproductive growth stage 5 (R5) (21), and in a few cases only at the R4 growth stage. Where possible, these ratings were adjusted using a multiplier to estimate the severity or incidence at the R6 growth stage. The multiplier [R6 disease rating/(R5 or R4 disease rating)] was an average value for each trial calculated from all cultivars that were rated at the R4 or R5 and R6 growth stage.

To develop prior probabilities, Illinois was divided into three regions. The regions north of latitude 41°25′, south of latitude 39°, and the area between were designated northern, southern, and central Illinois, respectively (Fig. 1). To minimize error created by genetic diversity, disease data from the cultivar Williams (3), which was common to all trials, was used to derive prior probabilities. It was assumed that the host (Williams) was constant throughout the years and that the quantity of inoculum and environmental conditions came from normally and independently distributed populations. Therefore, a z-score of ±0.43 from the sample mean which is approximately equivalent to one-third of a normal distribution was used to distinguish the relative low, medium, and high ranges for each disease (25). Thus, this classification of disease severity is not based on an economical injury level, but upon a normal distribution of disease severity. Disease severity on Williams was used to determine the percentage of trials in each region in the low, medium, and high ranges. These percentages represent the probability of a given disease severity for any one trial in each region. Since more than one location was evaluated each year in the central and southern regions, and in the northern region in 1978, the probability for a level of disease for a given year in each region also was calculated. Analysis of variance was performed on each location for each disease. Using the error term, a protected Fisher's least significant difference test (LSD) was performed at the alpha = 0.05 level to determine if the disease reaction on Williams represented the population of MG III cultivars (25).

Where disease occurrence was not frequent enough to develop prior probabilities, descriptive statistics were calculated from all cultivars to describe disease pressure.

RESULTS AND DISCUSSION

Of the 12 diseases observed (Table 1), only brown spot, downy mildew, and bacterial blight occurred frequently enough to develop prior probabilities. Based on the analyses of variance and LSDs, disease reactions on the cultivar Williams were not representative of the population of MG III cultivars. Severity of brown spot and downy mildew were typically higher on Williams compared to the MG III cultivars tested, while severity of bacterial blight on Williams was typically lower. However, this was expected since the monitor plots were designed to detect changes in pathogen populations by using cultivars with varying levels and sources of disease resistance. Even though disease severity on Williams is not representative of MG III soybean cultivars, it still provides the best basis by which to derive prior probabilities from this data.

Brown spot, which has the potential to reduce yield as much as 34% (12,26), is the most widely distributed soybean disease in Illinois. Severity of brown spot on Williams at −0.43 and +0.43 standard deviations from the sample mean were 28.8 and 46.5%, respectively. These values were used to group years and trials into low, medium, and high levels of disease severity (Table 2). Brown spot severity was in the medium range in approximately 1 out of 2 yr in all three regions. Severity of brown spot was high in approximately 23, 31, and 15% of the years in northern, central, and southern Illinois, respectively. For 2 yr in the southern region, brown spot severity was within 1% of the high range, and probably warrants being included in this range. Thus, the southern region would have a 31% probability of high severity and a 39% probability of medium

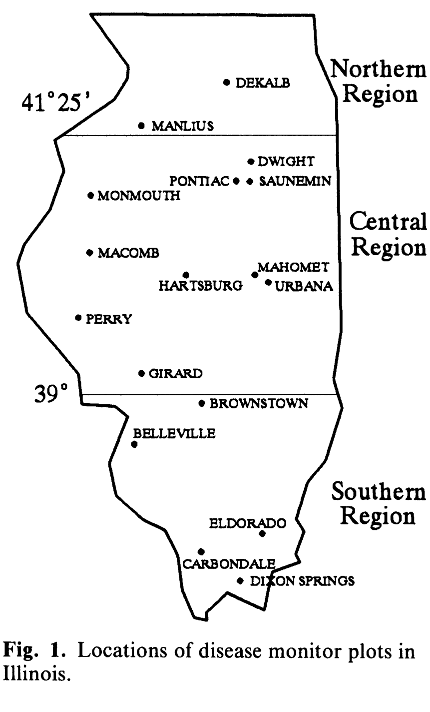

Fig. 1. Locations of disease monitor plots in Illinois.

Table 1. Diseases observed in the Illinois soybean monitor plots from 1977 to 1987, 1990, and 1991

Causal agent	Common name
Alternaria sp.[a]	Alternaria leaf spot
Pseudomonas syringae pv. *glycinea*[b]	Bacterial blight
Xanthomonas campestris pv. *glycines*[c]	Bacterial pustule
Septoria glycines[d]	Brown spot
Phialophora gregata[e]	Brown stem rot
Macrophomina phaseolina[f]	Charcoal rot
Peronospora manshurica[g]	Downy mildew
Phyllosticta sojicola[h]	Phyllosticta leaf spot
Phytophthora megasperma Drechs. f. sp. *glycinea*[i]	Phytophthora rot
Microsphaera diffusa[j]	Powdery mildew
Soybean mosaic virus	Soybean mosaic virus
Fusarium solani[k]	Sudden death syndrome

[a] *Alternaria tenuissima* (Kunze:Fr.) Wiltshire, *A. atrans* W. Gibson, *A. alternata* (Fr.) Keissl.
[b] (Coerper) Young, Dye, & Wilkie.
[c] (Nakano) Dye (syns. *X. campestris* pv. *phaseoli* (Smith) Dye and *X. phaseoli* (Smith) Downson var. *sojensis* (Hedges) Starr & Burkholder).
[d] Hemmi.
[e] (Allington & D.W. Chamberlain) W. Gams (syn. *Cephalosporium gregatum* Allington & D.W. Chamberlain).
[f] (Tassi) Goidanich (syns. *M. phaseoli* (Maubl.) S. Ashby, *Rhizoctonia bataticola* (Taubenhaus) E.J. Butler, *Sclerotium bataticola* Taubenhaus, and *Botryodiplodia phaseoli* (Maubl.) Thirumalachar).
[g] (Naumov) Syd. in Guam. *Peronospora sojae* F. Lehm. & F.A. Wolf.
[h] C. Massal. (syn. *P. glycinea* Tehon & E.Y. Daniels); *Pleosphaerulina sojicola* Miura (teleomorph).
[i] T. Kuan & D.C. Erwin (syns. *P. megasperma* Drechs. var. *sojae* A.A. Hildebrand and *P. sojae* M.J. Kaufmann & J.W. Gerdemann).
[j] Cooke & Peck (syns. *Erysiphe polygoni* DC., *E. glycines* Tai, and *Microsphaera* sp.).
[k] (Mart.) Sacc.

Table 2. Prior probability of disease severity for years and trials for brown spot, downy mildew, and bacterial blight at the R6 growth stage

Disease	Northern Illinois		Central Illinois		Southern Illinois	
Severity	Year[a] (%)	Trial[b] (%)	Year (%)	Trial (%)	Year (%)	Trial (%)
Brown spot[c]						
Low	15	14	15	22	31	46
Medium	62	57	54	48	54	31
High	23	29	31	30	15	23
Downy mildew[d]						
Low	15	14	0	17	8	9
Medium	54	57	54	35	54	48
High	31	29	46	48	38	43
Bacterial blight[e]						
Low	39	36	46	58	92	91
Medium	46	50	54	42	8	9
High	15	14	0	0	0	0

[a] Probability of having disease severity in the low, medium, or high range in a given year.
[b] Probability of having disease severity in the low, medium, or high range at a given trial within a given year.
[c] Low is less than 28.8%, medium is 28.8–46.5%, and high is greater than 46.5%.
[d] Low is less than 1.3%, medium is 1.3–5.0%, and high is greater than 5.0%.
[e] Low is less than 0.3%, medium is 0.3–8.9%, and high is greater than 8.9%.

severity of brown spot. Probabilities of brown spot based on trials (Table 2) followed the same trend as those based on average regional values for the northern and central regions; however, in the southern region, prior probabilities for individual trials were shifted toward the low range of severity. This probably is due to greater environmental variation in southern Illinois, which could result in more trials that are less favorable to the growth of *S. glycines*.

Of the 52 cultivars evaluated, 18 had a maximum severity of brown spot below the average maximum of 76%. These cultivars may possess low levels of partial resistance to brown spot. Two of these cultivars, Beeson (20) and Hodgson (10), were used as susceptible checks by Lim when he screened more than 8,000 plant introductions (PI) from the USDA-ARS Northern Soybean Germplasm and 400 wild annual soybeans (*G. soja* Sieb. & Zucc.) for resistance to brown spot (11; S. M. Lim, *unpublished*). In addition, Lim and Hymowitz (15) evaluated 186 accessions from six perennial wild species of *Glycine*, but resistance to *S. glycines* has not been improved in *G. max*. Thus, the below-average severity of brown spot expressed by these 18 cultivars may be due to environmental variation or other sources of random error. A study in which these and other cultivars are inoculated and precisely rated would help ascertain if any contain partial resistance to brown spot that could be utilized in a breeding project.

Table 3. Descriptive statistics of diseases from all cultivars at R6 growth stage in the Illinois soybean monitor plots

Disease Location	Range of severity or incidence[a] (%)	Frequency of occurrence[b] (%)	Mean of occurrence[c]	Mean of all trials[d]
Alternaria leaf spot				
Northern	0–38	14	11.0	0.7
Central	0–19	25	5.6	0.1
Southern	0–16	37	1.8	0.5
Bacterial blight				
Northern	0–63	100	9.9	7.7
Central	0–38	90	5.5	2.6
Southern	0–16	60	3.5	0.4
Bacterial pustule				
Northern	0–22	36	9.4	1.2
Central	0–69	73	15.3	2.7
Southern	0–63	63	11.3	1.3
Brown spot				
Northern	0–88	100	39.6	39.6
Central	0–98	100	41.5	41.5
Southern	0–91	100	33.1	33.1
Brown stem rot				
Northern	0–63	64	6.7	1.4
Central	0–38	53	6.2	0.6
Southern	0–0	0	0.0	0.0
Charcoal rot				
Northern	0–0	0	0.0	0.0
Central	0–63	15	12.6	0.4
Southern	0–63	9	10.9	0.5
Downy mildew				
Northern	0–38	93	4.4	2.3
Central	0–38	98	5.1	3.0
Southern	0–38	97	5.0	3.6
Phyllosticta leaf spot				
Northern	0–0	0	0.0	0.0
Central	0–9	5	2.8	0.0
Southern	0–1	6	1.2	0.0
Phytophthora rot				
Northern	0–1	21	0.5	0.0
Central	0–5	25	1.0	0.0
Southern	0–1	3	0.4	0.0
Powdery mildew				
Northern	0–38	21	6.8	0.2
Central	0–63	13	9.6	0.1
Southern	0–0	0	0.0	0.0
Soybean mosaic virus				
Northern	0–22	36	3.1	0.3
Central	0–24	33	2.9	0.3
Southern	0–44	51	3.6	0.5

[a]Range = minimum and maximum disease values. Severity = percentage of total leaf area infected (foliar diseases). Incidence = percentage of total plants infected (soilborne or systemic diseases).

[b]Percentage of trials with disease. Northern Illinois had 14 trials, central Illinois had 40, and southern Illinois had 35.

[c]Mean of disease symptoms for all cultivars showing symptoms at trials where the disease occurred.

[d]Mean of disease symptoms for all cultivars at all trials within that region.

Lim (12) developed a yield loss model for brown spot that indicated a 3.2% reduction in grain yield for each 10.0% increment in brown spot severity at the R6 growth stage. In the monitor plots, the average severity of brown spot of about 38% translates into an estimated average yield reduction of about 20% based on this yield loss model. This estimate suggests a substantial yield reduction, but may be high for several reasons. First, the regression equation for yield reduction and brown spot severity explained only 36% of the variation in yield (12). Unexplained variation may have resulted from differences in plant age during infection, environmental factors during soybean plant development, or the rapid spread of brown spot as natural plant senescence proceeded (8). Also, benomyl (Benlate 50WP) was applied to control natural infection of brown spot in the check plots of the yield loss study (12). Benomyl may have affected additional factors (e.g., other diseases) that may have increased yield in check plots which resulted in a greater percent yield reduction by brown spot. Horn et al (9) showed that benomyl increased seed yield of soybean. Also, the yield potential of soybeans may be dominated to some degree by the upper leaves, as is the case in wheat, where a major proportion of grain dry weight comes from flag leaf assimilates (16). If so, estimates of yield reduction may be overstated when inoculated trials are compared to natural infection. In spite of these potential problems in estimating the exact yield loss due to brown spot, data from the monitor plots indicated that brown spot is consistently widespread in Illinois at levels of severity which are reducing yield.

Prior probabilities for high and low levels of downy mildew were based on the disease severities of 1.3 and 5.0% (Table 2). The probability of downy mildew greater than 5% severity in a given year was 31, 46, and 38% for the northern, central, and southern regions, respectively. Severity of downy mildew less than 1.3% for the entire central region was not expected, although for a specific trial in the central region there was a 17% chance that downy mildew was less than 1.3%. Dunleavy (6) reported an average yield reduction of 11.8% for cultivars infected with *P. manshurica*. The severity of the infection caused plant stunting, and susceptible plants had an average production of 948 conidia per square centimeter of leaf area. In Illinois, the severity of downy mildew was greater than 10% at the R6 growth stage in only 13 of 89 trials. Stunted plants were never observed. Therefore, little to no yield reduction would be expected based on the severity of downy mildew observed in the Illinois monitor plots.

The expression of bacterial blight was frequent enough to develop prior probabilities, but the distribution of severity was skewed to the low range. Since bacterial blight occurred in only five trials in the southern region and less than 50% of the trials in the central region, both regions were excluded before ranges for low, medium, and high levels of severity were calculated. Values of 0.3 and 8.9% severity were used to develop prior probabilities for bacterial blight in all regions (Table 2). Severity of bacterial blight greater than 8.9% was expected only in northern Illinois. Usually, bacterial blight is at low levels of severity because it is typically expressed at earlier reproductive growth stages, and the total percentage of leaf area infected decreases as soybeans develop more leaves. Also, the growth of *Pseudomonas syringae* pv. *glycinea* is slowed or stopped by the warmer temperatures that typically occur in July and August in Illinois (22). Yield reductions due to bacterial blight have been estimated as high as 18% (18,26), but little to no yield reduction would be expected on a widespread basis in Illinois based on the severities observed in the monitor plots.

For diseases that did not occur frequently enough to develop prior probabilities, frequency of occurrence and severity or incidence of disease symptoms were evaluated (Table 3) based on disease ratings from all possible cultivars evaluated in the monitor plots. Bacterial pustule (*Xanthomonas campestris* pv. *glycines* (Nakano) Dye) was more common to the central and southern regions of Illinois. All other foliar diseases had relatively low severity or frequency of occurrence. Soybean mosaic virus was the only virus observed in the monitor plots and was slightly more common to the southern region. Soybean mosaic virus symptoms were observed on the breeding line L25 (4), which contains the *Rsv1* gene (5). This indicates that strains other than G1–G6 are present in Illinois (13).

Brown stem rot (*Phialophora gregata* Allington & D.W. Chamberlain) W. Gams was the most frequently occurring soilborne disease (Table 3). Charcoal rot (*Macrophomina phaseolina* (Tassi) Goidanich) obtained high levels of disease severity, but in all trials where charcoal rot symptoms were expressed, soil moisture was limited and temperatures were above normal. Phytophthora root rot (*Phytophthora megasperma* Drechs. f. sp. *glycinea* T. Kuan & D.C. Erwin) was observed in the monitor plots, but occurrence and incidence were low.

Based on the information from this analysis of the monitor plots, brown spot showed levels of severity that would have consistently resulted in yield reduction throughout Illinois. Other diseases did not regularly reach levels of severity or incidence that were high enough to reduce yields throughout Illinois, although local occurrences of many diseases may have resulted in yield reductions in a given trial. Resistance to bacterial blight, bacterial pustule, downy mildew, powdery mildew (*Microsphaera diffusa* Cooke & Peck), soybean mosaic virus, brown stem rot, and phytophthora root rot (5) has been identified and incorporated into soybean cultivars; however, resistance to brown spot has not been identified. With the continual incorporation of genes for resistance to soybean diseases and the discovery of new sources of resistance, disease pressure on soybeans in Illinois should continue to be limited to local situations.

Monitoring pathogens in Illinois should be continued to detect changes in existing pathogen populations or the occurrence of new pathogens. Prior probabilities of disease severity also can be revised as data is accumulated. A prolonged increase in the severity of a disease would suggest the development of more aggressive pathogens or other changes in the environmental niche of that pathogen. Evaluation of genes for resistance in various environments will provide a better understanding of the distribution of avirulent and virulent pathogens. Evaluation of new cultivars will aid in determining if the occurrence of certain diseases is being increased or decreased by those cultivars. In general, the monitor project can continue to define priorities of applied research on the control of diseases of soybean.

ACKNOWLEDGMENTS

We thank R. L. Warsaw (USDA-ARS Agricultural Research Technician) and all past graduate students who helped with the disease monitor plots.

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