Effectiveness of a Point System for Scheduling Foliar Fungicides in Soybean Seed Fields

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ABSTRACT

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The effectiveness of a point system developed in Kentucky for predicting seed infection by *Phomopsis* sp. was evaluated in 1982 in 19 soybean fields covering a wide range of cultural, geographical, and environmental conditions. The point system included cropping history, cultivar maturity, planting date, and rainfall during seed development and maturation. The system accurately identified six fields that should not have been sprayed (8 points or less). Seed infection by *Phomopsis* sp. for these fields ranged from 0 to 11% (average 5%). The seed infection levels of the five fields for which foliar fungicides were recommended (11 or more points) ranged from 13 to 47% (average 25%). Seed infection levels for fields receiving a marginal rating (9 or 10 points) ranged from 5 to 40%. Measurement of pod infection by *Phomopsis* sp. at growth stage R6 was useful in identifying fields in this marginal category that had high levels of seed infection. A close relationship ($r = 0.86$) was shown between pod infection at R6 and seed infection at harvest maturity. This investigation showed that a point system could provide valuable information to soybean seed producers regarding potential seed infection by *Phomopsis* sp.

Additional key words: *Diaporthe phaseolorum* var. *sojae, Glycine max*

Pod and stem blight disease can be caused by either *Diaporthe phaseolorum* (Cke. & Ell.) var. *sojae* (Wehm.) or *Phomopsis* sp. Seed infection by those fungi is generally recognized as a major cause of low soybean (*Glycine max* (L.) Merr.) seed germination (8,9,11,19). Levels of seed infection are increased when soybean residues are present from a previous crop because of an additional source of inoculum (3,7). Environmental conditions during seed development and maturation strongly influence seed infection, with moisture having the greatest effect (14,16,20). Delaying the date of harvest maturity, either by delaying the date of planting for early-maturing cultivars or by planting later-maturing cultivars, has been shown to reduce seed infection and improve seed quality (4,13,19). Even though the pod and stem blight fungi infect plants throughout seed development (8), the greatest incidence of seed infection does not occur until seed maturation (5,7,8,22).

Reductions in seed infection by *Phomopsis* sp. have been reported following the recommended split application of foliar fungicides (1,13). A single foliar fungicide treatment at a higher rate reduced seed infection when applied at the R4–R5 (6) or the R6 (21) growth stages, but was ineffective at the R7 growth stage. Unfortunately, the pod and stem blight disease is symptomless on young plants, and soybean seed producers have no easy method of predicting when infection will occur and whether a foliar fungicide should be used. For this reason, several "point systems" have been proposed to provide a guide to growers on the use of foliar fungicides (10,15,18). The purpose of this investigation was to evaluate the effectiveness of the point system developed in Kentucky (17) for predicting seed infection by *Phomopsis* sp. over a wide range of environmental conditions and soybean cultivars.

MATERIALS AND METHODS

The point system under evaluation (Fig. 1) was developed for use on soybeans grown for seed production and included the following factors that have been reported to be related to seed infection by *Phomopsis* sp.: cropping

Points

I. CROPPING HISTORY

In soybeans the previous 2 or more years . . . . 3 ______
In soybeans the previous year . . . . 2 ______
Not in soybeans last year . . . . 0 ______

II. CULTIVAR SELECTION

Early season cultivar . . . . 3 ______
Mid season cultivar . . . . 2 ______
Late season cultivar - foliar fungicides should not be used on late season cultivars

III. PLANTING DATE

Prior to May 20 . . . . 3 ______
Between May 20 and June 20 . . . . 2 ______
After June 20 . . . . 0 ______

IV. RAINFALL - Based on existing rainfall and rainfall predictions during seed development and maturation between R2 and R7 stages of growth

Rainfall below normal . . . . 0 ______
Rainfall near normal (± 1.25 cm) . . . . 2 ______
Rainfall above normal . . . . 4 ______

TOTAL ______

Fig. 1. Kentucky point system for use of fungicides for soybean seed production: 11 points or more = fungicide should be applied, 9 or 10 points = fungicide may be beneficial, and 8 points or fewer = fungicide should not be applied. Foliar fungicides are not recommended for use in soybean seed production when any of the following conditions exist: 1) yield potential is less than 20 bu/acre (1,344 kg/ha), 2) heavy weed pressure exists, and 3) a late-season cultivar is planted.

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history, cultivar maturity, planting date, and rainfall during seed development and maturation. Each category in the point system is assessed with a number that fits the conditions of the seed field being evaluated. The numbers from each of the four categories are summed, and the use of a foliar fungicide is recommended on the basis of total points accumulated. A total of 11 points or more indicates that foliar fungicides should be applied. A total of 8 points or less indicates that foliar fungicides should not be applied. A total of 9 or 10 points indicates that foliar fungicides may be beneficial and should be given serious consideration. The ultimate decision on the use of foliar fungicides on these marginal seed fields (9 or 10 points) depends on the seed producer and may be influenced by the value of the seed crop, the location and previous disease history of the field, and unusual field conditions (i.e., extremely early planting date or excessive moisture during seed development).

In 1982, seven production locations were selected in Kentucky that represented a range in latitude from the most southern location, Fulton County (36°30′ north latitude), to the most northern location, Boone County (39°4′ north latitude) (Table 1). Two to four seed fields were identified at each location that had been planted to cultivars of similar maturities but with differing planting dates and/or cropping histories. Six cultivars ranging from maturity group (MG) III (Pella) to MG IV (Mitchell) were compared. In Kentucky, cultivars in MG II and III are classified as early-season, those in MG IV as midseason, and those in MG V and VI as late-season. Since foliar fungicides are not recommended for late-season cultivars (MG V and VI), none were included in the experiment. Planting dates and previous cropping history of each field are shown in Table 1. Planting dates ranged from 10 April to 17 June.

Reproductive growth stages (2) were determined at weekly intervals in each field to identify when 50% of the plants had reached growth stages R2 (full bloom), R6 (full seed), R7 (one mature pod on the main stem), and R8 (95% mature pods). Rain gauges were placed in each field at reproductive growth stage R2, and rainfall was recorded from R2 to R7. The total rainfall occurring at that location was compared with the 25-yr average at the closest weather station, and the rainfall was determined to be above, below, or near normal (±1.25 cm of the mean) for each field. A composite soil sample was removed from each field at growth stage R2 and analyzed for available potassium at the Soil Testing Laboratory, University of Kentucky. Seed moisture was monitored in each field, and within 7 days of harvest maturity (when the seed first dried to <14% moisture), the field was harvested and a 1,000-g seed sample was collected. A 50-plant sample was removed from the field at harvest and each plant was rated visually (scale of 0–4) for intensity of pycnidia of *Phomopsis* sp. on infected stems as outlined by Prasartee et al (12). The level of seed infection with *Phomopsis* sp. was determined by plating 100 seeds on acidified (pH 4.5) potato-dextrose agar (PDA) as described earlier (19). Fungi classified as *Phomopsis* sp. included colonies of both the imperfect stage, *Phomopsis* sp., and *D. phaseolorum* var. *sojae*.

At growth stage R6, pod samples were taken to determine the level of pod infection by *Phomopsis* sp. One pod was collected from the middle nodes on the main stem of each of 50 soybean plants; these were placed in paper bags and held at room temperature. Within 24 hr of each collection, the 50 pods were washed in running water for 30 min, surface-sterilized by soaking in 95% ETOH for 60 sec and 0.5% NaOCl for 4 min, rinsed with sterile distilled water, and blotted dry. Each pod was aseptically dissected, and one carpel half per pod was plated on acidified PDA. Three carpel halves were placed on each petri dish. Plates were held under fluorescent light at room temperature for 10–14 days before identification of *Phomopsis* sp. was made on the basis of colony morphology.

RESULTS AND DISCUSSION

Seed infection by *Phomopsis* sp. ranged from 0 to 47% for the 19 fields, with an average of 18% (Table 1). Total points accumulated for the same fields ranged from a low of 5 to a high of 12, which was one point below the highest possible point total.

The number of fields falling into each classification for the four parameters used in the point system and the mean and range of seed infection by *Phomopsis* sp. for each classification are shown in Table 2. Average seed infection values in fields where cropping history indicated that soybeans were grown for the last two or more consecutive years ranged from 5 to 47%, with an average of 26%. Those fields not planted to soybeans the previous year or those planted in soybeans only the previous year had similar average levels of seed infection; however, only three fields were in the category of soybeans only the previous year. Two fields that were not in soybeans the previous year had extremely high (37 and 40%) seed infection. Thus, to state that fields that are rotated (i.e., where soybeans have not been grown the previous years) do not need fungicide applications would be incorrect. Fields in continuous soybean culture are more likely to need fungicide application, yet one field had only 5% seed infection by

Table 1. Location and descriptions of the 19 fields and six cultivars evaluated in 1982 for seed infection by *Phomopsis* sp.

Cultivar	Location (county)	Latitude (N)	Maturity group[a]	Days later than Pella	Planting date	Crop (previous year)	Rainfall (cm)[b]	Total points	*Phomopsis* sp. seed infection (%)
Pella	Boone	39°4′	III	0	17 May	Wheat	9 (−)	6	4
					7 June	Soybean[c]	17 (+)	12	16
Williams	Fayette	38°2′	III	3	14 May	Soybean[c]	11 (−)	9[d]	35
					14 May	Red clover	11 (−)	6	11
					14 June	Red clover	20 (+)	9	19
Cumberland	McLean	37°26′	III	6	10 April	Corn	20 (+)	10[d]	40
					15 April	Corn	20 (+)	10[d]	37
	Logan	36°51′	III	6	10 May	Soybean	11 (N)	10[d]	10
					10 June	Barley	10 (N)	7	1
	Fleming	38°25′	III	6	16 June	Summer fallow	19 (+)	9	8
	Logan	36°51′	III	6	17 June	Soybean[c]	10 (N)	10	5
Union	Fulton	36°36′	IV	9	5 May	Soybean[c]	14 (+)	12	32
	McLean	37°26′	IV	9	5 May	Soybean[c]	20 (+)	12	47
	Fleming	38°25′	IV	9	14 May	Corn	11 (−)	5	0
					16 May	Corn	14 (−)	5	1
	Hardin	37°42′	IV	9	17 May	Soybean[c]	21 (+)	12	19
	Fulton	36°36′	IV	9	15 June	Grass	27 (+)	8	11
Jacques 125	Hardin	37°42′	IV	10	13 May	Soybean	18 (+)	11	13
Mitchell	Hardin	37°42′	IV	13	17 June	Soybean	19 (+)	10	15

[a] Maturity groups III and IV represent early and midseason maturity, respectively.
[b] Rainfall between growth stages R2 and R7 was above (+), below (−), or near normal (N) (±1.25 cm) for each location compared with 25-yr average for same period.
[c] Fields where soybeans had been grown the previous 2 yr or longer.
[d] Foliar fungicide was recommended in these marginal (9 or 10 points) fields after *a priori* evaluation of eight marginal fields.

Phomopsis sp. Cropping history is an important parameter in a point system but cannot be used as the only determining factor.

Cultivar evaluations from a variety of production areas have shown generally low levels of seed infection by *Phomopsis* sp. in late-maturing cultivars (4,13,19). Levels of seed infection by *Phomopsis* sp. for midseason cultivars in this study ranged from 0 to 47 (average 17%), whereas early cultivars ranged from 1 to 40 (average 17%) (Table 2). A limitation of the cultivar evaluation in this experiment was that the midseason cultivars, Union and Jacques 125, were only 3 or 4 days later than Cumberland, which was classified as an early cultivar. Previous reports (13,19) have shown that differences in seed infection and quality can occur between early and midseason cultivars; this justifies leaving this criterion in the point system. Cultivar maturity cannot be used as the only criterion, however, since several fields planted to early-maturing cultivars had ⩽10% seed infection by *Phomopsis* sp. (Table 1).

Average seed infection by *Phomopsis* sp. for early planting dates ranged from 0 to 47% (average 21%), and for midseason planting dates, from 1 to 19% (average 11%) (Table 2). Even though the lower average levels of seed infection by *Phomopsis* sp. for the midseason planting dates support the point system, low infection levels from several fields planted early discourage the use of planting date as the only criterion for fungicide application.

The 11 fields receiving above-average rainfall had higher average levels of seed infection by *Phomopsis* sp. (23%) than those receiving normal or below-normal rainfall (5 and 10%, respectively) (Table 2). However, one field with below-normal rainfall produced seed with 35% seed infection, whereas one field with above-normal rainfall had only 8% seed infection by *Phomopsis* sp. Thus rainfall as the only criterion for scheduling fungicide sprays could be misleading.

No single variable of the four included in the point system related closely to the level of seed infection by *Phomopsis* sp. When the scores of all variables were added together, however, the total score accurately identified six fields that should not have been sprayed (8 points or less). Seed infection for these fields ranged from 0 to 11% and averaged 5% (Table 2). Seed infection levels of the five fields for which a foliar fungicide was recommended (11 or more points) ranged from 13 to 47% and averaged 25%. Eight fields had a total point accumulation of 9 or 10, which placed them into the marginal classification regarding foliar fungicide application. The average seed infection for these eight fields was 21% and ranged from 5 to 40%.

The point system accurately identified those fields that should or should not have been sprayed but did not clearly distinguish between those fields in the marginal classification (9 or 10 points). Thus, an *a priori* evaluation of the eight marginal fields was made at growth stage R6 to determine if a foliar fungicide application should be recommended. This resulted in the recommendation for foliar fungicide application in four of the eight fields (Table 1) because of the location and previous disease history of the field, planting date, or excessive rainfall during seed development. The average seed infection by *Phomopsis* sp. for the four marginal fields for which foliar fungicides were recommended was 30% and ranged from 10 to 40%. The average seed infection for the four other fields for which fungicides were not recommended was 12% and ranged from 5 to 20%. After the *a priori* test for the eight fields in the marginal classification was made, foliar fungicides would have been recommended for nine of the 19 fields in the study. Seed infection by *Phomopsis* sp. in the nine fields ranged from 10 to 47% and averaged 28% (Table 2). The 10 fields for which spraying was not recommended ranged from 0 to 19% seed infection by *Phomopsis* sp. and averaged 8%. Although somewhat subjective and not easily quantified, the *a priori* procedure may be used by seed growers when making a decision regarding foliar fungicides in marginal seed fields.

A pod test at growth stage R6 to predict the amount of seed infection by *Phomopsis* sp. was evaluated to determine if the point system could be improved. Pods were collected from soybean plants in 13 of the 19 fields and bioassayed for pod infection by *Phomopsis* sp. All fields that had point values of 11 or more had high pod infection levels (87–97%), whereas all fields that had values of 8 or less had low pod infection levels (10–43%). Of the eight fields that were in the marginal (9 or 10 points) classification, seven were evaluated for pod infection. Three marginal fields had R6 pod infection levels of 77, 85, and 93% and seed infection levels at harvest maturity of 37, 40, and 35%, respectively. Three other marginal fields had low levels of pod (10, 20, and 23%) and seed (8, 10, and 5%) infection, whereas one field had an intermediate pod infection level of 57% and an intermediate seed infection level of 19%. There was a close relationship ($r = 0.86$) ($\alpha = 0.01$) between pod infection at growth stage R6 and seed infection at harvest maturity for the 13 fields

Table 2. Number of fields and average and range of *Phomopsis* sp. seed infection for each point classification of four factors

			Phomopsis sp. seed infection	
Criteria[a]	**Points**	**No. of fields**	**Mean**	**Range**
Cropping history	3	6	26	5–47
	2	3	13	10–15
	0	10	13	0–40
Cultivar selection	3	11	17	1–40
	2	8	17	0–47
	0	0	-	-
Planting date	3	12	21	0–47
	2	7	11	1–19
	0	0	-	-
Rainfall	4	11	23	8–47
	2	3	5	0–10
	0	5	10	0–35
Accumulated points	11 or more	5	25	13–47
	9 or 10	8	21	5–40
	8 or fewer	6	5	0–11
Foliar fungicide recommendation[b]	Apply	9	28	10–47
	Do not apply	10	8	0–19

[a]Specific criterion for each of four factors was outlined in Figure 1.
[b]After classification of marginal fields (9 or 10 points) using *a priori* evaluation.

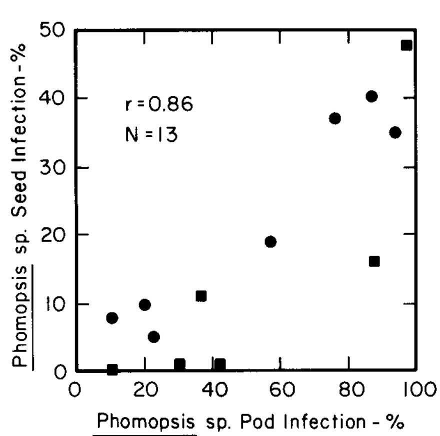

Fig. 2. Relation of seed infection by *Phomopsis* sp. at harvest maturity to pod infection by *Phomopsis* sp. at growth stage R6. Circles indicate fields classified as marginal according to the point system; squares indicate fields where foliar fungicides were (⩾11 points) or were not (⩽8 points) recommended.

evaluated (Fig. 2). Additional comparisons of 38 pod and seed samples over a 4-yr period (1979–1982) showed a similar association between R6 pod infection with *Phomopsis* sp. and seed infection at harvest maturity ($r = 0.73$). The data suggest that pod infection would have to exceed 50% in Kentucky before seed infection would be 20% or more, and foliar fungicides would be recommended.

The pod test requires additional time, effort, and expertise that does not appear to be warranted for Kentucky seed producers for all seed fields. When the current point system indicates that a fungicide application is advised (11 points or more) or when the system recommends that fungicides are not needed (8 or less points), the pod test appears unnecessary. The value of the pod test was most evident, however, when used on marginal fields (9 or 10 total points), and it accurately predicted which of those fields would benefit from fungicide use.

There was little relationship between the stem rating for pycnidial development at maturity and seed infection by *Phomopsis* sp. ($r = 0.43$). Likewise, there was also little association between soil potassium levels and seed infection by *Phomopsis* sp., similar to results from Ohio (6).

This investigation indicates that a point system based on four variables can provide valuable information to soybean seed producers regarding the potential for seed infection by *Phomopsis* sp. The Kentucky point system tends to be more conservative than some other point systems that would have recommended fungicide application in most of the fields evaluated in this study. Thus it may prevent the use of costly foliar fungicides if not necessary but may improve seed quality when fungicides are needed and used. Adjustment of cultivar selection and planting date classifications could also make the point system useful in other soybean seed production areas.

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