Quality of Harvested Seed Associated with Soybean Cultivars and Herbicides Under Weed-Free Conditions

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ABSTRACT

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Different herbicides were applied to soybean plants in field plots planted to different soybean cultivars located at four locations in Illinois between 1997 and 2000. Treatments varied from hand weeded to preemergence herbicides to postemergence herbicides. Soybean seeds were harvested and evaluated for different seed quality parameters. The percentage of seeds infected with *Phomopsis* spp. ranged from 1 to 40%, and the percentage of seeds infected with *Cercospora kikuchii* was low, ranging from 0 to 4%. Herbicides had little or no effect on seed quality parameters such as percent germination and incidence of seed pathogens or on protein and oil concentrations. Soybean seed quality was affected by *Phomopsis* spp. in that there were significant ($P \leq 0.05$) inverse correlations between *Phomopsis* spp. incidence and percentage seed germination. It appears that *Phomopsis* spp. may be a more prevalent seed pathogen than *C. kikuchii* for soybean fields in central to northern Illinois.

Additional keywords: *Glycine max*, pod and stem blight, purple seed stain

Phomopsis seed decay of soybean (*Glycine max* (L.) Merr.), caused primarily by *Phomopsis longicolla* Hobbs, but also caused by other *Phomopsis* and *Diaporthe* spp., is endemic to Illinois (33). Infected seeds may have reduced germination, split more readily, and suffer other quality losses compared to noninfected seeds (16,24,35). Purple seed stain of soybean, caused by *Cercospora kikuchii* (Matsu. & Tomoyasu) Gardner, is a seed disease of soybean that may cause purple speckling of seed, reduced germination, and other quality losses (27,44,46). These diseases also cause an economic loss to growers, in that grain buyers may discount the price paid for soybeans if seed is discolored due to infection (34,36).

Herbicides have been shown to affect different seed quality factors and the presence of seed pathogens. Bowman et al. (5) found that seeds from soybean plants treated with a mixture of bentazon and sethoxydim were heavier than seeds from plants growing in soil treated with a mixture of alachlor and metribuzin. Other researchers found that herbicides could cause small alterations of soybean seed components, but considered the alterations unimportant (14,28,38). Weed control can affect development of seedborne diseases by indirectly influencing the microenvironment and population of alternate hosts. Less seed infection by *Fusarium semitectum*, *C. kikuchii*, *Phomopsis* spp., and *Rhizoctonia solani* have occurred in plots where weeds were controlled compared to weedy control plots (5,8,10,12). Direct effects of herbicides on root and foliar soybean diseases have been examined (3,4,6,7,9,11,31,32), but direct effects of herbicides on seed diseases have not been examined in weed-free conditions.

The objectives of this research were to determine the effects of herbicides and seedborne pathogens on different soybean seed quality parameters, and to determine the effect of herbicides on the presence of seedborne pathogens in soybean seeds grown in weed-free plots located throughout Illinois.

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MATERIALS AND METHODS

Plot maintenance, design, and treatments. Plots were established at Champaign (1998 to 1999), DeKalb (1997 to 1998), Monmouth (1999 to 2000), and Urbana (1998 to 1999), Illinois. Soybean cultivars planted at Champaign and Urbana were Asgrow 3704 (maturity group, MG, III), Asgrow 3904 (MG III), Jack (MG II), Pioneer 9363 (MG III), and Savoy (MG II). Cultivars planted at DeKalb were BSR 101 (MG I), Jack, Pioneer 9254 (MG II), and Savoy. Cultivars planted at Monmouth were Asgrow 3002 (MG III), Pioneer 93B01 (MG III), Pioneer 9363, and Siebens 2701 (MG II). Cultivars were chosen based on MG and regional popularity for each location. Plots were four to eight rows wide on 0.76-m centers and 4.6 to 6.1 m long, and planted 19 May 1998 and 20 May 1999 at Champaign, 24 May 1999 and 15 May 2000 at Monmouth, 17 May 1997 and 27 May 1998 at DeKalb, and 17 May 1998 and 20 May 1999 at Urbana. The plots were arranged in a randomized complete block design with four replicates.

Herbicide treatments at Champaign and Urbana were a hand-weeded control, pendimethalin (Prowl, BASF Corp., Research Triangle Park, NC), a mixture of dimethenamid (Frontier, BASF Corp.) and metribuzin (Sencor, Bayer Corp., Kansas City, MO), acifluorfen (Blazer, BASF Corp.), and imazethapyr (Pursuit, BASF Corp.). Herbicide treatments at DeKalb were a hand-weeded control, pendimethalin, acifluorfen, imazethapyr, and a prepackaged mixture of acifluorfen and bentazon formulated as Galaxy (BASF Corp.). At Monmouth, all cultivars were glyphosate tolerant (Roundup Ready, Monsanto Company, St. Louis, MO), and the entire study received a treatment of glyphosate (Roundup Ultra, Monsanto Company) for weed control. The herbicide treatments at Monmouth were a glyphosate-only control, pendimethalin, acifluorfen, and imazethapyr. Pendimethalin and the mixture of dimethenamid and metribuzin were applied preemergence (PRE) immediately after planting. Glyphosate was applied postemergence (POST) when soybean plants were at the V3 growth stage (13). Acifluorfen, the acifluorfen plus bentazon mixture, and imazethapyr were applied POST when plants were at the V4 growth stage. Herbicides were applied at the normal field use rates and were: 1.39 kg a.i./ha pendimethalin; 1.47 and 0.42 kg a.i./ha dimethenamid and metribuzin, respectively; 0.42 kg a.i./ha acifluorfen; 0.07 kg a.i./ha imazethapyr; 0.19 and 0.84 kg a.i./ha, acifluorfen and bentazon, respectively; and 1.12 kg a.i./ha glyphosate. Crop oil concentrate (COC) was applied as an adjuvant with acifluorfen, imazethapyr, and acifluorfen + bentazon at 1% vol/vol. Herbicides were applied using a CO_2-pressurized backpack sprayer with a 3-m hand-held boom that had five 8003 flat-fan nozzles (Spraying Systems Co., Wheaton, IL) calibrated to deliver a total of 187 liters per ha at Champaign, DeKalb, and Urbana. At Monmouth, herbicides were applied with a tractor mounted sprayer with a 3-m boom that had five 8003 flat-fan nozzles calibrated to deliver a total of 140 liters per ha. Weeds that emerged after herbicides were applied were removed by hand in all plots.

Seed quality. Samples of soybean seeds from each plot were collected at harvest (13 to 14% moisture), dried under forced air at 32°C for 7 days so that seeds were of uniform moisture and taken to the laboratory to determine percent germination and incidence of seed pathogens. Split seeds were removed by hand, and 100 seeds from each sample were weighed to determine 100-seed weight and placed on moistened wadded cellulose paper (Kimpak) in a seed germinator (Stults Scientific Engr. Corp., Springfield, IL) for 7 days at 90% relative humidity at 25°C. The number of seeds germinated was then recorded. A seed was counted as germinated if the radicle was 2.5 times the length of the cotyledons. Forty seeds from each sample were surface-sterilized in a 0.5% solution of NaOCl for 4 min and then rinsed twice (4 min per rinse) in sterile distilled water. All 40 seeds were plated on potato dextrose agar (PDA, Difco Laboratories, Detroit, MI) with 10 seeds per 9-cm petri dish. Plated seeds were then placed in an incubator for 5 days at 25°C, and the incidence of seeds with *Phomopsis* spp. and *C. kikuchii* growing from them was recorded based on morphological characters (2,17). *Phomopsis* spp. were typically recognized by characteristic floccose, dense, white colonies. *Cercospora kikuchii* was typically recognized by colonies that produced an intense maroon-to-purple pigment usually growing from a purple stain on the seed coat. Seed samples (500 g) collected at Champaign and Urbana were sent to Iowa State University Grain Quality Laboratory (Ames, IA) for analysis of seed protein and oil concentrations using an Infratec 1220 series near-infrared analyzer (Foss North America, Eden Prairie, MN).

Data analysis. Data from 1998 and 1999 collected at Champaign and Urbana were analyzed together because treatments were the same at both locations. At the other locations, years were analyzed together within each location. Years and locations were analyzed separately if there were significant ($P \leq 0.05$) year or location by treatment interactions. Analysis of variance was conducted using the general linear models procedure (PROC GLM) of SAS (SAS Institute, Inc., Cary, NC). Location, years, and blocks were considered random effects. Fisher's least significant difference (LSD) was used at the 5% probability level to compare means. Pearson correlation coefficients were determined using SAS (PROC CORR) for 100-seed weight, percent germination, *Phomopsis* spp. infected seed incidence, *C. kikuchii* infected seed incidence, protein concentration, and oil concentration.

RESULTS

Years and locations are presented separately due to significant ($P \leq 0.05$) year and location by treatment interactions. Only main effects are presented, due to no significant cultivar by herbicide interactions.

Champaign. In 1998, there was significant ($P \leq 0.05$) variation among cultivars for seed germination, 100-seed weight, incidence of *Phomopsis* spp., and protein and oil concentration (Table 1). Asgrow 3704 had significantly greater seed germination (92%) than the other cultivars. Savoy had significantly greater 100-seed weight (16 g) than the other cultivars, but also had a significantly greater incidence of *Phomopsis* spp. (16%). Asgrow 3704 and 3904 and Pioneer 9363 had significantly greater protein concentration than the other cultivars (38%). Jack had the greatest oil concentration (20%). There were no significant differences among cultivars for *C. kikuchii* incidence. Herbicides did not have a significant effect on the seed quality parameters measured.

Table 1. Quality parameters of soybean seed harvested at Champaign, IL

Year	Cultivar	Herbicide	Germination (%)[a]	Seed weight (g)[b]	*Phomopsis* spp. (%)[c]	*Cercospora kikuchii*(%)[d]	Protein (%)[e]	Oil (%)
1998	Asgrow 3704	…	92	13	3	0	38	19
	Asgrow 3904	…	87	15	5	1	38	19
	Jack	…	81	13	8	2	35	20
	Pioneer 9363	…	88	13	4	0	37	19
	Savoy	…	84	16	16	1	37	19
	$LSD_{0.05}$[f]	…	3	1	4	NS[g]	1	1
	…	Hand weed	86	14	8	1	37	19
	…	Dimethenamid + metribuzin	86	14	8	1	37	19
	…	Pendimethalin	87	14	8	1	37	19
	…	Acifluorfen	86	14	4	1	37	19
	…	Imazethapyr	86	14	8	1	37	19
	…	$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
1999	Asgrow 3704	…	94	15	4	0	37	18
	Asgrow 3904	…	90	15	6	2	38	17
	Jack	…	82	14	23	2	37	18
	Pioneer 9363	…	92	15	11	3	38	18
	Savoy	…	88	16	24	0	38	18
	$LSD_{0.05}$[f]	…	3	NS	5	1	1	1
	…	Hand weed	88	14	14	2	38	18
	…	Dimethenamid + metribuzin	88	15	12	1	38	18
	…	Pendimethalin	90	15	13	0	38	18
	…	Acifluorfen	90	16	14	2	38	18
	…	Imazethapyr	89	15	15	2	38	18
	…	$LSD_{0.05}$	NS	1	NS	NS	NS	NS

[a] Percent seed germination.
[b] 100-seed weight.
[c] Incidence of seed infected with *Phomopsis* spp.
[d] Incidence of seed infected with *Cercospora kikuchii*.
[e] Protein concentration.
[f] Fisher's protected least significant difference at $\alpha = 0.05$.
[g] Not significant at $P \leq 0.05$.

In 1999, there was significant ($P \leq 0.05$) variation among cultivars for seed germination, incidence of *Phomopsis* spp., incidence of *C. kikuchii*, and protein and oil concentration (Table 1). Asgrow 3704 had significantly greater seed germination (94%) than all of the other cultivars except for Pioneer 9363 (92%). Incidence of *Phomopsis* spp. was significantly greater in Savoy (24%) and Jack (23%) than the other cultivars. There were significant, but minute differences among cultivars for *C.*

Table 2. Quality parameters of soybean seed harvested at Urbana, IL

Year	Cultivar	Herbicide	Germination (%)[a]	Seed weight (g)[b]	*Phomopsis* spp. (%)[c]	*Cercospora kikuchii* (%)[d]	Protein (%)[e]	Oil (%)
1998	Asgrow 3704	…	94	14	7	0	35	20
	Asgrow 3904	…	87	15	10	0	36	19
	Jack	…	80	13	12	0	34	20
	Pioneer 9363	…	94	13	4	0	36	19
	Savoy	…	88	18	15	0	36	19
	$LSD_{0.05}$[f]	…	3	1	5	NS[g]	1	1
	…	Hand weed	89	14	10	0	36	19
	…	Dimethenamid + metribuzin	88	14	9	0	36	19
	…	Pendimethalin	89	14	12	0	36	19
	…	Acifluorfen	88	15	10	0	36	20
	…	Imazethapyr	88	15	8	0	36	20
	…	$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
1999	Asgrow 3704	…	93	15	4	0	35	19
	Asgrow 3904	…	87	15	8	1	36	17
	Jack	…	82	14	17	4	35	18
	Pioneer 9363	…	88	14	7	2	36	19
	Savoy	…	83	17	16	0	37	19
	$LSD_{0.05}$[f]	…	3	1	6	2	1	1
	…	Hand weed	85	15	8	2	36	18
	…	Dimethenamid + metribuzin	87	15	11	1	36	18
	…	Pendimethalin	86	15	11	1	36	18
	…	Acifluorfen	88	15	11	2	36	18
	…	Imazethapyr	87	15	11	2	36	18
	…	$LSD_{0.05}$	NS	NS	NS	NS	NS	NS

[a] Percent seed germination.
[b] 100-seed weight.
[c] Incidence of seed infected with *Phomopsis* spp.
[d] Incidence of seed infected with *Cercospora kikuchii*.
[e] Protein concentration.
[f] Fisher's protected least significant difference at $\alpha = 0.05$.
[g] Not significant at $P \leq 0.05$.

Table 3. Quality parameters of soybean seed harvested at DeKalb, IL

Year	Cultivar	Herbicide	Germination (%)[a]	Seed weight (g)[b]	*Phomopsis* spp. (%)[c]	*Cercospora kikuchii* (%)[d]
1997	BSR 101	…	80	24	5	2
	Jack	…	94	22	3	3
	Pioneer 9254	…	98	21	1	0
	Savoy	…	96	20	1	1
	$LSD_{0.05}$[e]	…	4	NS[f]	2	NS
	…	Hand weed	91	22	1	2
	…	Pendimethalin	90	23	3	1
	…	Acifluorfen	94	21	3	2
	…	Acifluorfen + bentazon	93	20	3	2
	…	Imazethapyr	91	22	3	1
	…	$LSD_{0.05}$	NS	NS	NS	NS
1998	BSR 101	…	86	17	40	0
	Jack	…	94	14	22	1
	Pioneer 9254	…	96	14	20	0
	Savoy	…	94	18	11	0
	$LSD_{0.05}$	…	2	1	6	NS
	…	Hand weed	91	16	25	0
	…	Pendimethalin	92	16	21	0
	…	Acifluorfen	94	16	24	0
	…	Acifluorfen + bentazon	93	16	23	1
	…	Imazethapyr	92	16	22	0
	…	$LSD_{0.05}$	NS	NS	NS	NS

[a] Percent seed germination.
[b] 100-seed weight.
[c] Incidence of seed infected with *Phomopsis* spp.
[d] Incidence of seed infected with *Cercospora kikuchii*.
[e] Fisher's protected least significant difference at $\alpha = 0.05$.
[f] Not significant at $P \leq 0.05$.

kikuchii incidence and protein and oil concentration. There were no significant differences among cultivars for 100-seed weight. There was significant variation among herbicides for 100-seed weight. Plots sprayed with acifluorfen had the greatest 100-seed weight (16 g). Herbicides did not have a significant effect on seed germination, incidence of *Phomopsis* spp. or *C. kikuchii*, or protein and oil concentration.

Urbana. In 1998, there was significant ($P \leq 0.05$) variation among cultivars for seed germination, 100-seed weight, incidence of *Phomopsis* spp., and protein and oil concentration (Table 2). Asgrow 3704 and Pioneer 9363 had the significantly greatest seed germination (94%). Savoy had the significantly greatest 100-seed weight (18 g). Incidence of *Phomopsis* spp. was greatest in Savoy (15%), but did not significantly differ from Jack (12%). Protein concentration was greatest in Asgrow 3904, Pioneer 9363, and Savoy (36%), and oil concentration was greatest in Asgrow 3704 and Jack (20%). Incidence of *C. kikuchii* did not significantly differ among cultivars. Herbicides did not have a significant effect on the seed quality parameters measured.

In 1999, there was significant ($P \leq 0.05$) variation among cultivars for seed germination, 100-seed weight, incidence of *Phomopsis* spp. and *C. kikuchii*, and protein and oil concentration (Table 2). Asgrow 3704 had the significantly greatest seed germination (93%). Savoy had the significantly greatest 100-seed weight (17 g). Jack and Savoy had the greatest incidence of *Phomopsis* spp. (17 and 16%,

Table 5. Pearson correlation coefficients between seed quality parameters of soybean seed harvested at Champaign, IL[a]

Year	Variables		Pearson correlation coefficient	Probability
1998	Germination[b]	*Phomopsis* spp.[c]	–0.28	0.0056
	Germination	*Cercospora kikuchii*[d]	–0.04	0.6885
	Germination	Seed weight[e]	–0.02	0.8551
	Germination	Protein	0.40	0.0001
	Germination	Oil	–0.28	0.0067
	Phomopsis spp.	*C. kikuchii*	–0.02	0.8583
	Phomopsis spp.	Seed weight	0.34	0.0007
	Phomopsis spp.	Protein	–0.17	0.0954
	Phomopsis spp.	Oil	0.18	0.0807
	C. kikuchii	Seed weight	–0.01	0.9253
	C. kikuchii	Protein	–0.25	0.0164
	C. kikuchii	Oil	0.21	0.0463
	Seed weight	Protein	0.10	0.3296
	Seed weight	Oil	–0.02	0.8799
	Protein	Oil	–0.79	0.0001
1999	Germination	*Phomopsis* spp.	–0.42	0.0001
	Germination	*C. kikuchii*	–0.06	0.5643
	Germination	Seed weight	0.03	0.7941
	Germination	Protein	–0.02	0.8465
	Germination	Oil	0.04	0.6888
	Phomopsis spp.	*C. kikuchii*	0.00	0.9727
	Phomopsis spp.	Seed weight	0.07	0.4916
	Phomopsis spp.	Protein	0.20	0.0447
	Phomopsis spp.	Oil	0.25	0.0111
	C. kikuchii	Seed weight	–0.03	0.7861
	C. kikuchii	Protein	0.15	0.1265
	C. kikuchii	Oil	–0.27	0.0073
	Seed weight	Protein	0.20	0.0443
	Seed weight	Oil	0.03	0.7615
	Protein	Oil	–0.07	0.4747

[a] Correlation coefficients were based on 100 observations each year.
[b] Percent seed germination.
[c] Incidence of seed infected with *Phomopsis* spp.
[d] Incidence of seed infected with *Cercospora kikuchii*.
[e] 100-seed weight.

Table 4. Quality parameters of soybean seed harvested at Monmouth, IL

Year	Cultivar	Herbicide	Germination (%)[a]	Seed weight (g)[b]	Phomopsis spp. (%)[c]	*Cercospora kikuchii*(%)[d]
1999	Asgrow 3002	…	91	15	4	1
	Pioneer 93B01	…	96	13	0	0
	Pioneer 9363	…	93	14	11	1
	Siebens 2701	…	89	13	1	3
	$LSD_{0.05}$[e]	…	3	1	5	2
	…	Glyphosate only[f]	92	14	2	0
	…	Pendimethalin	93	14	6	1
	…	Acifluorfen	93	14	4	1
	…	Imazethapyr	92	14	3	2
	…	$LSD_{0.05}$	NS[g]	NS	NS	NS
2000	Asgrow 3002	…	85	14	0	2
	Pioneer 93B01	…	92	12	3	2
	Pioneer 9363	…	90	12	1	3
	Siebens 2701	…	88	13	1	3
	$LSD_{0.05}$	…	3	1	2	NS
	…	Glyphosate only	89	12	0	3
	…	Pendimethalin	89	12	2	3
	…	Acifluorfen	89	12	2	3
	…	Imazethapyr	88	13	1	3
	…	$LSD_{0.05}$	NS	NS	NS	NS

[a] Percent seed germination.
[b] 100-seed weight.
[c] Incidence of seed infected with *Phomopsis* spp.
[d] Incidence of seed infected with *Cercospora kikuchii*.
[e] Fisher's protected least significant difference at $\alpha = 0.05$.
[f] Glyphosate was applied on the entire study to control weeds.
[g] Not significant at $P \leq 0.05$.

respectively). Jack had the greatest incidence of *C. kikuchii* (4%). Savoy had the greatest protein concentration (37%). Asgrow 3704, Pioneer 9363, and Savoy had the greatest oil concentration (19%). Herbicides did not have a significant effect on the seed quality parameters measured.

DeKalb. In 1997, there was significant ($P \leq 0.05$) variation among cultivars for seed germination and incidence of *Phomopsis* spp. (Table 3). Pioneer 9254 had significantly greater seed germination (98%) than all of the other cultivars except for Savoy (96%). Incidence of *Phomopsis* spp. was greatest in BSR 101 (5%). There were no significant differences among cultivars for 100-seed weight and incidence of *C. kikuchii*. Herbicides did not have a significant effect on the seed quality parameters measured.

In 1998, there was significant ($P \leq 0.05$) variation among cultivars for seed germination, 100-seed weight, and incidence of *Phomopsis* spp. (Table 3). Pioneer 9254 had the significantly greatest seed germination (96%). Savoy had the significantly greatest 100-seed weight (18 g). BSR 101 had the significantly greatest incidence of *Phomopsis* spp. (40%). There were no significant differences among cultivars for incidence of *C. kikuchii*. Herbicides did not have a significant effect on the seed quality parameters measured.

Monmouth. In 1999, there was significant ($P \leq 0.05$) variation among cultivars for seed germination, 100-seed weight, and incidence of *Phomopsis* spp. and *C. kikuchii* (Table 4). Pioneer 93B01 had significantly greater germination (96%) than the other cultivars. Asgrow 3002 had significantly greater 100-seed weight (15 g) than the other cultivars. Pioneer 9363 had the significantly highest incidence of *Phomopsis* spp. (11%). Siebens 2701 had the greatest incidence of *C. kikuchii* (3%). Herbicides did not have a significant effect on the seed quality parameters measured.

In 2000, there was significant ($P \leq 0.05$) variation among cultivars for seed germination, 100-seed weight, and incidence of *Phomopsis* spp. (Table 4). Pioneer 93B01 had significantly greater germination (92%) than the other cultivars except for Pioneer 9363 (90%). Asgrow 3002 had the greatest 100-seed weight (14 g). Pioneer 93B01 had the greatest incidence of *Phomopsis* spp. (3%). There were no significant differences among cultivars for incidence of *C. kikuchii*. Herbicides did not have a significant effect on the seed quality parameters measured.

Table 6. Pearson correlation coefficients between seed quality parameters of soybean seed harvested at Urbana, IL[a]

Year	Variables		Pearson correlation coefficient	Probability
1998	Germination[b]	*Phomopsis* spp.[c]	–0.19	0.0604
	Germination	*Cercospora kikuchii*[d]	ND[f]	ND
	Germination	Seed weight[e]	–0.01	0.9102
	Germination	Protein	0.28	0.0046
	Germination	Oil	–0.04	0.7039
	Phomopsis spp.	*C. kikuchii*	ND	ND
	Phomopsis spp.	Seed weight	0.36	0.0002
	Phomopsis spp.	Protein	0.02	0.8115
	Phomopsis spp.	Oil	–0.08	0.4575
	C. kikuchii	Seed weight	ND	ND
	C. kikuchii	Protein	ND	ND
	C. kikuchii	Oil	ND	ND
	Seed weight	Protein	0.41	0.0001
	Seed weight	Oil	–0.36	0.0003
	Protein	Oil	–0.76	0.0001
1999	Germination	*Phomopsis* spp.	–0.38	0.0001
	Germination	*C. kikuchii*	–0.21	0.0380
	Germination	Seed weight	–0.03	0.7733
	Germination	Protein	–0.18	0.0813
	Germination	Oil	–0.05	0.6001
	Phomopsis spp.	*C. kikuchii*	–0.02	0.8506
	Phomopsis spp.	Seed weight	0.01	0.9550
	Phomopsis spp.	Protein	0.12	0.2307
	Phomopsis spp.	Oil	0.05	0.6449
	C. kikuchii	Seed weight	–0.23	0.0188
	C. kikuchii	Protein	–0.12	0.2368
	C. kikuchii	Oil	0.02	0.8397
	Seed weight	Protein	0.35	0.0003
	Seed weight	Oil	–0.07	0.4909
	Protein	Oil	–0.26	0.0091

[a] Correlation coefficients were based on 100 observations each year.
[b] Percent seed germination.
[c] Incidence of seed infected with *Phomopsis* spp.
[d] Incidence of seed infected with *Cercospora kikuchii*.
[e] 100-seed weight.
[f] Not determinable due to no detectable incidence of *C. kikuchii* from seed harvested at Urbana, IL in 1998.

Correlations. At Champaign in 1998, there were significant ($P \leq 0.05$) negative correlations between seed germination and incidence of *Phomopsis* spp., between seed germination and oil concentration, between incidence of *C. kikuchii* and protein concentration, and between protein concentration and oil concentration (Table 5). There were significant positive correlations between seed germination and protein concentration, between incidence of *Phomopsis* spp., and between incidence of *C. kikuchii* and oil concentration.

At Champaign in 1999, there were significant ($P \leq 0.05$) negative correlations between seed germination and incidence of *Phomopsis* spp. and between incidence of *C. kikuchii* and oil concentration (Table 5). There were significant positive correlations between incidence of *Phomopsis* spp. and protein concentration, between incidence of *Phomopsis* spp. and oil concentration, and between 100-seed weight and protein concentration.

At Urbana in 1998, there were significant ($P \leq 0.05$) negative correlations between 100-seed weight and protein concentration, and between protein concentration and oil concentration (Table 6). There were significant positive correlations between seed germination and protein concentration, between incidence of *Phomopsis* spp. and 100-seed weight, and between 100-seed weight and protein concentration.

At Urbana in 1999, there were significant ($P \leq 0.05$) negative correlations between seed germination and incidence of *Phomopsis* spp., between seed germination and incidence of *C. kikuchii*, between incidence of *C. kikuchii* and 100-seed weight, and between protein concentration and oil concentration (Table 6). There was a significant positive correlation between 100-seed weight and protein concentration.

At DeKalb in 1997, there was a significant ($P \leq 0.05$) negative correlation between seed germination and incidence of *Phomopsis* spp. (Table 7). At DeKalb in 1998, there were significant negative correlations between seed germination and incidence of *Phomopsis* spp., and between seed germination and 100-seed weight.

At Monmouth in 1999, there were no significant ($P \leq 0.05$) correlations (Table 8). At Monmouth in 2000, there was a significant negative correlation between seed germination and 100-seed weight.

DISCUSSION

In our studies, herbicides did not increase or decrease the concentration of protein or oil within soybean seeds. This agrees with other reports that herbicides did not affect protein and/or oil concentration in soybean seeds (18,28,38). These previous studies, reported from 1969 to 1973, tested some herbicides that are no longer used in soybean production in the

United States. In our studies, herbicides from relatively newer herbicide classes were included (i.e. diphenyl ethers, imidazolinones). From this and other research, it appears that the use of herbicides does not alter important soybean seed components, indicating that soybean growers should choose herbicides based on economic reasons and the population of weed species present in a field, and not be concerned with the effects on seed composition. The management of weeds in soybean fields is still an important factor in obtaining good seed quality, in that it reduces the population of other hosts of soybean seed pathogens (15,23,25), and reduces competition that might affect seed size and overall yield. The study presented herein was designed to test direct effects of herbicides on soybean seed quality. The indirect effect of herbicides controlling weeds, which may serve as hosts or contribute to a more conducive microenvironment for seed pathogens to infect was not tested in these studies, but has been documented (5,8,10,12).

Tested under four field environments, Asgrow 3704 ranked first for seed germination each time. Savoy, which was tested under six field environments, ranked either first or second for highest incidence of *Phomopsis* spp. at Champaign and Urbana for both years (15 to 24%), but had the least incidence of *Phomopsis* spp. at DeKalb for both years (1 to 11%). BSR 101 had the greatest incidence of *Phomopsis* spp. both years at Dekalb (5 and 40%). When Savoy, which is MG II, was planted at Champaign and Urbana, most of the other cultivars were MG III. At DeKalb, all cultivars were MG II, except for BSR 101, which is MG I. This agrees with other reports that earlier maturing cultivars may develop more *Phomopsis* infected seed if environmental conditions are conducive (21,40,42,45).

There were significant ($P \leq 0.05$) inverse relationships between incidence of seed infected with *Phomopsis* spp. and seed germination in seed from Champaign, Urbana, and DeKalb, which is a typical reaction of soybean seed infected with *Phomopsis* spp. (22). There was a significant positive relationship detected between incidence of *Phomopsis* spp. and soybean seed weight at Champaign and Urbana in 1998. Hepperly and Sinclair (16) and Mbuvi et al. (25), however, reported that soybean seeds showing symptoms of *P. longicolla* infection weighed less than asymptomatic seeds. In our studies, a significant relationship between incidence of seed infected with *Phomopsis* spp. and concentration of protein or oil within soybean seeds was detected at Champaign in 1999 only. This relationship was positive, which agrees with Hepperly and Sinclair (16) who reported that seeds with symptoms of *Phomopsis* spp. infection contained more oil and protein than asymptomatic seeds; however, Velicheti et al. (43) found that *P. longicolla* was able to degrade seed proteins. The severity of infection, which is influenced by environment (1,19,20,29,30,33,37,41), could play a role in determining how seed weight and constituents such as protein and oil are affected. Additionally, not all infected seeds show symptoms, therefore, this could account for different interpretations between studies that measure infection vs. symptoms.

The incidence of seed with *C. kikuchii* was very low at each location, which limits the conclusions that can be drawn from correlations between *C. kikuchii* infection and seed quality parameters. There was a significant ($P \leq 0.05$) positive correlation between *C. kikuchii* and oil concentration at Champaign in 1998, but there was also a significant negative relationship between the same two variables at Champaign in 1999. *C. kikuchii* has been reported to reduce seed germination (27,46) and oil concentration (27,39), but the relationship is unclear from our study due to a lack of disease. BSR 101, which has been reported as being susceptible to *C. kikuchii* (26), was planted at the DeKalb location, and although it produced seed with poor germination, it did not differ from the other cultivars in seed infection by *C. kikuchii*.

From our research, it appears that *Phomopsis* spp. may be a more prevalent seed pathogen than *C. kikuchii* for soybean fields in central to northern Illinois. We feel that both pathogens are important, however, and that with severe infection they may be able to inflict considerable damage to seeds. Damages caused by these pathogens are not only important to soybean growers, but are also important to seed companies and food processors.

Table 7. Pearson correlation coefficients between seed quality parameters of soybean seed harvested at DeKalb, IL[a]

Year	Variables		Pearson correlation coefficient	Probability
1997	Germination[b]	*Phomopsis* spp.[c]	–0.53	0.0001
	Germination	*Cercospora kikuchii* [d]	–0.00	0.9903
	Germination	Seed weight[e]	–0.20	0.0828
	Phomopsis spp.	*C. kikuchii*	0.13	0.2372
	Phomopsis spp.	Seed weight	0.05	0.6648
	C. kikuchii	Seed weight	–0.07	0.5399
1998	Germination	*Phomopsis* spp.	–0.56	0.0001
	Germination	*C. kikuchii*	0.07	0.5160
	Germination	Seed weight	–0.28	0.0109
	Phomopsis spp.	*C. kikuchii*	–0.06	0.5856
	Phomopsis spp.	Seed weight	–0.06	0.5967
	C. kikuchii	Seed weight	–0.10	0.3883

[a] Correlation coefficients were based on 80 observations each year.
[b] Percent seed germination.
[c] Incidence of seed infected with *Phomopsis* spp.
[d] Incidence of seed infected with *Cercospora kikuchii*.
[e] 100-seed weight.

Table 8. Pearson correlation coefficients between seed quality parameters of soybean seed harvested at Monmouth, IL[a]

Year	Variables		Pearson correlation coefficient	Probability
1999	Germination[b]	*Phomopsis* spp.[c]	–0.04	0.7728
	Germination	*Cercospora kikuchii* [d]	–0.20	0.1230
	Germination	Seed weight[e]	–0.10	0.4356
	Phomopsis spp.	*C. kikuchii*	0.06	0.6542
	Phomopsis spp.	Seed weight	0.19	0.1329
	C. kikuchii	Seed weight	–0.06	0.6617
2000	Germination	*Phomopsis* spp.	0.07	0.5855
	Germination	*C. kikuchii*	–0.07	0.5698
	Germination	Seed weight	–0.60	0.0001
	Phomopsis spp.	*C.a kikuchii*	0.15	0.2168
	Phomopsis spp.	Seed weight	–0.15	0.2347
	C. kikuchii	Seed weight	0.05	0.6728

[a] Correlation coefficients were based on 64 observations each year.
[b] Percent seed germination.
[c] Incidence of seed infected with *Phomopsis* spp.
[d] Incidence of seed infected with *Cercospora kikuchii*.
[e] 100-seed weight.

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