Soybean Seed Quality of 16 Cultivars and Four Maturity Groups in Illinois

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ABSTRACT

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Seeds of 16 soybean (*Glycine max*) cultivars of maturity groups II, III, IV, and V, harvested from 30 plots in Illinois from 1978 to 1981, were evaluated for seed quality. Seed quality was highest for group III and lowest for group II soybeans. Elf, group III, produced the highest quality while Wells, group II, produced the poorest quality seeds. The group III cultivars Will and Williams, group IV cultivars Cutler 71, Franklin, Kent, and Union, and group V cultivar Essex had very good seed quality. Wells had the highest percentage of seeds infected with *Phomopsis* spp., and Amsoy and Amsoy 71, group II, had the highest percentage of seeds infected with *Cercospora kikuchii*. Recovery of these two fungi was lowest from seeds of Elf and Essex. Beeson, group II, had the highest percentage of seeds infected with *Macrophomina phaseolina, Nematospora coryli*, and *Penicillium* spp.; Essex had the highest percentage of seeds infected with *Alternaria, Chaetomium, Cladosporium*, and *Fusarium* spp.

Many factors are involved in reducing soybean (*Glycine max* (L.) Merr.) seed quality, but a combination of susceptibility to pathogenic fungi, environmental conditions that favor disease development, and field deterioration of seeds is responsible for most seed damage. Phomopsis seed decay, caused by a *Diaporthe-Phomopsis* complex, is the most important disease associated with deterioration of soybean seeds in the field and increases as moisture increases, especially during pod filling and physiological and harvest maturity (7,10,13). In U.S. soybean-growing regions, Phomopsis seed decay is highest on early-maturing cultivars because they mature when temperature and moisture are highest (5,10). *Cercospora kikuchii* (T. Matsu. & Tomoyssu) Gardner, cause of purple seed stain, infects stems, leaves, flowers, pods, and seeds and increases as temperature and moisture increase (4,8,12).

Cooperative investigation between the Animal and Plant Health Inspection Service, USDA, and the University of Illinois at Urbana-Champaign.

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Seed infection by *C. kikuchii* has been correlated with the length of flowering of a cultivar (2), temperature at the time of inoculation (9), and rainfall during plant maturation (4,8,12). Cultivars resistant to Phomopsis seed decay and purple seed stain have been reported (9,15,17). Sclerotia of *Macrophomina phaseolina* (Tassi) Goid. are formed within infected stems when soybeans produce pods, and early maturing of cultivars caused by high temperatures and low soil moisture results in earlier and more abundant sclerotial production (18). *M. phaseolina* reduces soybean seed quality when it infects the seed coat, causing discoloration and lower germination (3).

Other factors associated with increased fungal seed infection of soybeans are delayed harvest (1,16), insect injury (6,11), and frost (14). Delays in harvesting soybeans result in increased numbers of seeds infected with species of *Alternaria* and *Phomopsis* (1,16). Early-maturing cultivars are more adversely affected by delayed harvest than late-maturing ones (16). The number of seeds infected with *Alternaria* was related to bean leaf beetle injury of pods, and differential cultivar susceptibility to pod injury but not to fungus infection was reported (11). Green stinkbugs (*Acrosternum hilare* Say) damage pods and seeds of soybeans by mechanical feeding and transmit *Nematospora coryli* Pegli, the yeast spot disease (12). In comparison to noninjured seeds, southern green stinkbug (*Nezara viridula* (L.)) injury resulted in higher numbers of seeds infected with species of *Chaetomium, Fusarium*, and *Penicillium* (6). Frost results in damage to soybean pods and seeds followed by increased numbers of seeds infected with *Alternaria, Aspergillus*, and *Fusarium* spp. (14).

Thirty soybean disease-monitoring plots were planted at 12 locations in Illinois from 1978 to 1981. Soybean seeds harvested from each plot were assayed for seedborne microorganisms and seed quality. This paper reports the association of 10 seedborne pathogens and five seed quality characteristics with 16 soybean cultivars and four maturity groups.

MATERIALS AND METHODS

The locations of the soybean plots (and years of survey) were Belleville (1978–1980), Brownstown (1978–1980), Carbondale (1978–1980), Dekalb (1978–1980), Dixon Springs (1979–1980), Eldorado (1978), Hartsburg (1978–1980), Macomb (1978–1980), Manlius (1978), Saunemin (1978), Standard (1979–1980), and Urbana (1978–1981). In 1978, seeds were harvested from two plots at the University of Illinois at Urbana-Champaign, one on the Plant Pathology Research Center and the other on the Agronomy South Farm.

Each plot consisted of three replicates of 16 cultivars grown in three-row units arranged in a randomized complete block design. Unit rows were 6.7 m long and 76.2 cm wide. The cultivars were Amsoy, Amsoy 71, Beeson, Corsoy, and Wells from group II; Elf, Will (formerly L-22), Williams, and Woodworth from group III; Clark, Clark 63, Cutler 71, Franklin, Kent, and Union from group IV; and Essex from group V. Plants from the middle row of each unit were harvested at maturity. Seeds were separated from pods with a Swanson plot thresher (Swanson Machine Co., Champaign, IL), passed through a seed cleaner, and stored in cloth bags at 5 C and 12–15% relative humidity. For each replicate, a 300-seed sample was weighed and surface-sterilized in a 10% NaOCl solution for 4 min and rinsed twice in distilled water for 1 min. One hundred seeds were randomly chosen from each sample and placed in 9-cm plastic culture plates containing potato-dextrose agar (Difco) with five seeds per plate. Seeds were incubated for 10 days at 25 C in continuous darkness and analyzed for radicle emergence, dead seed (no radicle emergence and not infected by bacteria or fungi), and bacterial and fungal infection.

The following mean values were determined: percentage of radicles

emerged, dead seeds, fungi-infected seeds, bacteria-infected seeds, seeds infected by each of 10 genera of fungi, and seed weight (g/300 seeds). Data were analyzed statistically, and means were compared by Duncan's multiple range test. Statistical differences were significant at $P = 0.05$ unless otherwise indicated.

RESULTS

Seed quality. Seed quality was highest for maturity group III and lowest for maturity group II soybeans (Table 1). Radicle emergence for maturity group III was very high, and the percentage of dead seeds was low while fungal seed infection was lower than any other maturity group. In contrast, radicle emergence for group II was significantly lower while the percentage of dead seeds and fungal infected seeds were significantly higher than for groups III, IV, and V. Maturity groups IV and V were slightly lower in seed quality than group III (Table 1).

The group II cultivar Wells had the poorest seed quality. Radicle emergence of Wells seeds was significantly lower while the percentage of fungi-infected seeds was higher than any cultivar tested. The other group II cultivars also had poor seed quality with lower radicle emergence and higher percentages of dead seeds and fungal infected seeds than the group III, IV, and V cultivars. In contrast, the group II cultivar Elf had the highest seed quality. Seeds of Elf had higher radicle emergence and lower fungal infection than any cultivar tested. Will and Williams had very good seed quality while the quality of Woodworth was slightly lower. Clark, the oldest cultivar in the study, had the poorest seed quality of the group IV cultivars. The quality of Clark 63 was better, whereas Cutler 71, Franklin, Kent, and Union had very good seed quality (Table 2).

Essex, the only maturity group V cultivar tested in this study, also had very good seed quality. Essex seeds with a high percentage of radicle emergence were the smallest and lightest of any cultivar tested (Table 2).

Seed infection. Maturity group II soybeans were most susceptible to Phomopsis seed decay and purple seed stain, the two most important soybean seed diseases in Illinois (Table 3). Seed infections by *Phomposis* spp. and *C. kikuchii* for group II were significantly higher than for groups III, IV, and V. Another seed pathogen commonly isolated from group II was *Alternaria* spp. Maturity group II also had the highest percentage of seeds infected with *N. coryli* and *M. phaseolina*. Recovery of *C. kikuchii* and *Alternaria* spp. was lowest from seeds of maturity group III. The percentage of maturity group IV seeds infected with *Cladosporium* spp. was significantly lower than for groups II, III, and V. Seed infections by *Alternaria, Chaetomium, Cladosporium,* and *Fusarium* spp. for group V were significantly higher than for groups II, III, and IV. In addition, the percentage of seeds infected with *Aspergillus* spp. was highest for group V (Table 3).

Wells had the highest percentage of seeds infected with *Phomopsis* spp., and Amsoy and Amsoy 71 had the highest percentage of seeds infected with *C. kikuchii.* Within group II, Beeson had

Table 1. Seed quality characteristics according to maturity group of soybean grown in Illinois

Maturity group	Percentage of seeds[x]				Seed weight (g)
	Radicle emerged[y]	Dead	Infected with		
			Fungi	Bacteria	
II	76.9 c[z]	4.1 a	37.2 a	12.0 b	48.3 a
III	89.2 a	2.5 b	20.0 c	13.2 ab	47.6 a
IV	86.7 b	2.8 b	22.8 bc	14.5 a	48.2 a
V	90.8 a	2.4 b	26.7 b	13.3 ab	36.0 b

[x] Based on ratings of 300 seeds (three replicates of 100 seeds per cultivar) per plot.
[y] Means represent average values for all cultivars within a maturity group and represent average values for seeds harvested from 30 plots over 4 yr.
[z] Numbers in columns followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 2. Seed quality characteristics of 16 soybean cultivars grown in Illinois

Cultivar	Maturity group	Percentage of seeds[x]				Seed weight (g)
		Radicle emerged[y]	Dead	Infected with		
				Fungi	Bacteria	
Amsoy	II	75.6 h[z]	3.8 abc	39.7 a	12.9 abc	48.7 c
Amsoy 71	II	78.8 fgh	3.7 abcd	37.1 a	12.1 bc	47.8 cd
Beeson	II	77.6 gh	4.5 a	34.1 ab	13.2 abc	54.3 a
Corsoy	II	81.4 efg	4.8 a	34.4 ab	11.0 c	43.9 ef
Wells	II	71.0 i	4.0 ab	40.7 a	11.1 c	46.7 cd
Elf	III	90.9 a	2.7 cde	14.1 e	18.2 a	47.0 cd
Will	III	90.3 ab	2.1 e	21.5 d	11.5 c	47.8 cd
Williams	III	90.0 abc	2.2 e	20.4 de	11.0 c	47.4 cd
Woodworth	III	85.4 cde	3.1 bcde	23.9 cd	12.3 bc	48.2 cd
Clark	IV	82.5 def	2.2 e	29.0 bc	10.8 c	45.9 de
Clark 63	IV	85.8 cde	2.7 cde	25.5 cd	12.6 abc	44.1 ef
Cutler 71	IV	87.7 abc	2.6 cde	20.0 de	14.5 abc	51.2 b
Franklin	IV	87.2 abc	3.2 bcde	20.8 de	17.3 ab	42.8 f
Kent	IV	87.9 abc	3.2 bcde	20.8 de	17.5 ab	51.2 b
Union	IV	89.3 abc	3.0 bcde	20.5 de	14.3 abc	54.0 a
Essex	V	90.8 a	2.4 de	26.7 cd	13.3 abc	36.0 g

[x] Based on ratings of 300 seeds (three replicates of 100 seeds per cultivar) per plot.
[y] Means represent average values for seeds harvested from 30 plots over 4 yr.
[z] Numbers in columns followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 3. Incidence of fungi recovered from surface-sterilized seeds of four maturity groups of soybeans harvested in Illinois

Maturity group	Percentage of seeds infected with[x]				
	Phomopsis spp.[y]	*Cercospora kikuchii*	*Alternaria* spp.	*Cladosporium* spp.	*Macrophomina phaseolina*
II	17.7 a[z]	7.2 a	5.1 b	2.6 b	1.0 a
III	8.3 bc	2.4 c	3.1 c	3.2 b	0.8 a
IV	9.6 b	3.9 b	3.8 c	1.9 c	0.9 a
V	5.0 c	1.0 c	9.8 a	4.3 a	0.2 a
	Fusarium spp.	*Chaetomium* spp.	*Penicillium* spp.	*Aspergillus* spp.	*Nematospora coryli*
II	1.1 b	0.5 b	0.5 a	0.5 b	0.56 a
III	0.5 c	0.6 b	0.4 a	0.4 b	0.17 ab
IV	0.4 c	0.7 b	0.5 a	0.8 ab	0.12 b
V	2.2 a	2.0 a	0.7 a	1.4 a	0.14 ab

[x] Based on ratings of 300 seeds (three replicates of 100 seeds per cultivar) per plot.
[y] Means represent average values for all cultivars within a maturity group and represent average values for seeds harvested from 30 plots over 4 yr.
[z] Numbers in columns followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

the lowest percentage of seeds infected with *Phomopsis* spp.; however, Beeson was the cultivar most susceptible to *N. coryli* seed infection, significantly higher than all other cultivars. Beeson also had the highest percentage of seeds infected with *M. phaseolina* and *Penicillium* spp. Elf and Essex had the lowest percentage of seeds infected with *C. kikuchii* and *Phomopsis* spp. Seed infection by *Alternaria* spp. was lowest for Elf, Will, and Williams, all group III cultivars. Within group IV, seed infection by *Phomopsis* spp. of Clark and Clark 63 was significantly higher than for Cutler 71, Franklin, Kent, and Union. Kent and Union had the highest percentage of seeds infected with *Aspergillus* spp. The most frequently isolated fungi from Essex were *Alternaria* spp., and the percentage of Essex seeds infected with *Alternaria* spp. was significantly higher than for all other cultivars. Essex also had the highest number of seeds infected with *Cladosporium, Fusarium*, and *Chaetomium* (Table 4).

Weather conditions. The average monthly temperature (C) and rainfall (cm) for the 30 plots from 1978 to 1981 increased during May (16.9 and 8.1) and June (22.5 and 8.6), were highest during July (24.8 and 10.4) and August (23.9 and 11.6), and decreased in September (20.5 and 8.3) and October (12.2 and 4.9). Group II soybeans developed under the hottest and wettest conditions and matured in late August to early September. Cultivars within groups III and IV matured in September and early October as temperature and rainfall were declining, and the group V cultivar Essex matured in October and early November when temperature and rainfall were the lowest.

DISCUSSION

In this survey, cultivars were grown under differing field conditions throughout Illinois to ensure better expression of seed quality differences (4). Soybean seed quality varied among cultivars and maturity groups and was closely associated with fungal infection. The data indicate that the incidence of seedborne fungi was dependent on weather conditions, relative maturity, and plant genetics.

Weather conditions during crop maturation stages affected disease development and resulted in differences among maturity groups. A comparison of data from this study and previous investigations (5,8,10) shows that, within a growing region, seeds of cultivars developing earliest are exposed to the highest temperatures and rainfall and are more susceptible than later maturing cultivars to *C. kikuchii* and *Phomopsis* spp. Several authors (4,7,8,10,12,13) have shown that seed infection by *Phomopsis* spp. is dependent on rainfall while infection by *C. kikuchii* is dependent on temperature and rainfall during the growing season.

The latest maturing cultivar, Essex, developed when rainfall and temperature were least favorable for infection by *C. kikuchii* and *Phomopsis* spp. As a result, Essex escaped severe seed infection by these pathogens. These results agree with previous reports (5,8,10,16) that *Phomopsis* spp. and *C. kikuchii* are less pathogenic on seeds of later than earlier maturing cultivars.

The results also show that frost damage and insect injury predisposed seeds of the latest maturing cultivar to fungal infection. Seeds of Essex were most susceptible to infection by *Alternaria*, *Chaetomium*, *Cladosporium*, and *Fusarium*. Because Essex stayed green longer than the other cultivars and as a result suffered more insect damage and frost injury, these pathogens probably entered through wounds in the pods and seeds. Other investigators have associated insect damage (5,6,11) and frost injury (14) with increased isolation of *Alternaria, Chaetomium*, and *Fusarium* spp. from soybean seeds. In the present study, *Alternaria* spp. also were commonly isolated from early-maturing cultivars. Pods and seeds of cultivars developing earliest were vulnerable to insect injury because they were first attacked by insects as field populations increased during the growing season.

To develop soybeans with improved seed quality, it is important to gather as much information as possible concerning the resistance and susceptibility of cultivars to seed diseases. In this study, significant differences in *Phomopsis* spp. seed infection among cultivars within maturity groups indicated various degrees of resistance for Beeson, Elf, Cutler 71, Franklin, Kent, and Union. *N. coryli* infection of Beeson seeds is an example of genetic susceptibility of a soybean cultivar to a seed pathogen.

Another method of showing resistance to seed diseases was statistical analysis of maturity groups over all cultivars. The results showed that group III was more resistant to *C. kikuchii* seed infection than groups II and IV, and the lower incidence was not due to weather conditions. Seed infection by *Alternaria* and *Fusarium* spp. was lowest for groups

Table 4. Incidence of fungi recovered from surface-sterilized seeds of 16 soybean cultivars harvested in Illinois

Cultivar	Maturity group	Percentage of seeds infected with[x] *Phomopsis* spp.[y]	*Cercospora kikuchii*	*Alternaria* spp.	*Cladosporium* spp.	*Macrophomina phaseolina*
Amsoy	II	19.4 ab[z]	8.1 ab	5.6 bc	2.9 bcde	0.7 ab
Amsoy 71	II	15.9 bcde	8.3 a	6.0 b	3.1 abcd	0.9 ab
Beeson	II	12.8 defg	6.2 abcd	4.2 bcd	3.1 abcd	1.4 a
Corsoy	II	18.2 abc	6.8 abc	4.4 bcd	2.1 cde	0.5 ab
Wells	II	22.2 a	6.8 abc	5.2 bcd	2.1 cde	1.3 ab
Elf	III	3.3 i	1.1 g	2.9 d	3.3 abc	0.9 ab
Will	III	9.0 fgh	2.7 fg	3.0 d	3.8 ab	0.9 ab
Williams	III	8.5 ghi	2.8 fg	2.9 d	2.8 bcde	0.7 ab
Woodworth	III	12.3 efg	2.8 fg	3.4 cd	2.8 bcde	0.9 ab
Clark	IV	17.9 abcd	3.1 efg	3.3 d	1.7 e	1.2 ab
Clark 63	IV	14.0 cdef	2.4 fg	4.0 bcd	1.6 e	1.2 ab
Cutler 71	IV	6.3 hi	4.1 def	4.2 bcd	2.6 bcde	1.0 ab
Franklin	IV	7.1 hi	5.5 bcde	3.8 bcd	1.7 e	0.6 ab
Kent	IV	5.8 hi	3.8 defg	4.4 bcd	2.0 cde	0.9 ab
Union	IV	6.5 hi	4.3 cdef	3.4 cd	1.9 de	0.8 ab
Essex	V	5.0 hi	1.0 g	9.8 a	4.3 a	0.2 b

Cultivar	Maturity group	*Fusarium* spp.	*Chaetomium* spp.	*Penicillium* spp.	*Aspergillus* spp.	*Nematospora coryli*
Amsoy	II	1.08 bcde	0.6 b	0.53 ab	0.17 d	0.17 b
Amsoy 71	II	1.19 bcd	0.6 b	0.29 ab	0.38 bcd	0.22 b
Beeson	II	1.23 bc	0.6 b	0.98 a	0.86 abcd	2.23 a
Corsoy	II	0.71 bcde	0.5 b	0.26 b	0.69 abcd	0.03 b
Wells	II	1.51 ab	0.3 b	0.57 ab	0.22 d	0.17 b
Elf	III	0.53 cde	0.7 b	0.60 ab	0.42 bcd	0.14 b
Will	III	0.33 de	0.5 b	0.48 ab	0.49 bcd	0.11 b
Williams	III	0.45 cde	0.9 b	0.38 ab	0.63 abcd	0.28 b
Woodworth	III	0.53 cde	0.5 b	0.30 ab	0.14 d	0.13 b
Clark	IV	0.48 cde	0.6 b	0.39 ab	0.24 cd	0.10 b
Clark 63	IV	0.34 de	0.7 b	0.47 ab	0.57 bcd	0.11 b
Cutler 71	IV	0.47 cde	0.4 b	0.41 ab	0.21 d	0.11 b
Franklin	IV	0.30 de	0.4 b	0.53 ab	0.64 abcd	0.13 b
Kent	IV	0.53 cde	1.1 ab	0.33 ab	1.49 ab	0.19 b
Union	IV	0.27 e	0.6 b	0.70 ab	1.78 a	0.10 b
Essex	V	2.18 a	2.0 a	0.69 ab	1.45 abc	0.14 b

[x] Based on ratings of 300 seeds (three replicates of 100 seeds per cultivar) per plot.
[y] Means represent average values for seeds harvested from 30 plots over 4 yr.
[z] Numbers in columns followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

III and IV and may be related to resistance to insect injury as reported for *Alternaria tenuissima* (Kunze ex Pers.) Wilt. seed infection of Elf (11). In this study, the low incidence of *A. tenuissima* on Elf seeds was associated with the dense upright pubescence of the plant, which deterred insect feeding and injury (11).

The relationship between weather conditions, crop maturation stages, incidence of seedborne fungal pathogens, and seed quality is demonstrated. Further research will be required, however, to understand the genetics of resistance and susceptibility to seed diseases and to determine which morphological and physiological characteristics of the plant affect the incidence of seed pathogens.

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