Effects of Weed Control and Row Spacing in Conventional Tillage, Reduced Tillage, and Nontillage on Soybean Seed Quality

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ABSTRACT

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In a 3-yr study on an Illinois silt loam soil, soybean (*Glycine max*) seed quality was not affected by tillage practices. Under conventional, reduced, and nontillage practices, seed weight, seed germination, seedling vigor, and recovery of seedborne pathogens remained the same. In individual years, seeds from plants under nontillage had significantly ($P = 0.05$) lower weight and recovery of *Alternaria* spp. and seedborne bacteria than seeds from plants under conventional tillage, except there was a higher recovery of *Alternaria* spp. from seeds on 25-cm than on 75-cm centers. The highest yields and most effective weed control were found consistently in the conventional tillage plots. Weed control method affected seed quality more than either tillage or row spacing. Bentazon + sethoxydim herbicide application resulted in significantly heavier seeds but less weed control than alachlor + metribuzin. Seeds from nonweeded control plots had a significantly higher incidence of *Phomopsis* spp. than seeds from all herbicide-treated plots under conventional and reduced tillage but not from plots under nontillage.

Tillage primarily affects yield and weed control, but other parameters in crop production, such as plant pathogens, may also be affected. Tillage operations affect the amount of overseasoned host debris in the proximity of an emerging crop and can indirectly affect plant pathogens that depend on debris as a primary source of inoculum. High incidence of plant disease in reduced-tillage systems has been reported (5,21,24); bacterial blight, bacterial pustule, wildfire, anthracnose, and white mold of soybeans was greater under nontillage than conventional tillage, and Fusarium, Phytophthora and Rhizoctonia root rots were lower under nontillage (24). *Rhizoctonia* spp. was recovered at a higher incidence in nontillage plots than in tillage plots, but such a difference was not observed in soybeans (16). No significant differences in recovery of *Fusarium oxysporum* from soybean stems or roots in tillage vs. nontillage plots were found, although there were increased soil populations of *Fusarium* spp. in nontillage plots (7). Increased tillage activity was associated with reduced levels of Septoria brown spot of soybean (14) and bacterial blight and pustule (8). Deep plowing is recommended for control of many soybean diseases (5,20). Because many seedborne fungi overseason in crop debris, it is important to know whether reduced tillage results in higher populations of seedborne microflora, which in turn can affect seed weight, germination, and seedling vigor.

There is little information on the long-term effects of conventional, reduced, and nontillage on soybean seed quality. In this 3-yr study, we report on the effects of these tillage systems on soybean seed quality and the incidence of seedborne microflora in Illinois. The tillage systems were compared in both narrow- and wide-row spacings with four methods of weed control.

MATERIALS AND METHODS

Experimental design. This study was conducted during the 1981, 1982, and 1983 cropping seasons on the Cruse Tract, University of Illinois at Urbana-Champaign, with the following soil types: Catlin silt loam, Drummer silty clay loam, and Flanagan silt loam. The soybean cultivar Corsoy 79 was used and always planted in land annually rotated with corn (*Zea mays* L. cv. B73 × Pa91). Treatments included a factorial combination of three tillage systems: conventional (disking and moldboard plowing in the fall, then disking, incorporating herbicides, disking, and cultivating the field in the spring), reduced (same as conventional minus moldboard plowing), and two row spacings (25 and 76 cm). There were six treatments (three tillage methods, two row spacings) with three replicates for each treatment in a randomized complete block. Each experimental unit was 12 × 90 m. Data were collected from four subplots (9 × 8 m), each representing one of four weed control methods. The center 8 m of row of each experimental unit was harvested with a commercial combine with a 4.6 m header, and yield was recorded.

Weed control methods. Four methods were used. The first consisted of a preplant-incorporated (PPI) application of alachlor (Lasso EC) and metribuzin (Lexone 4L) at 3.4 and 0.6 kg a.i./ha, respectively. The second consisted of a postemergence (POST) application of sethoxydim (Poast) and bentazon (Basagran) at 0.3 and 0.9 kg a.i./ha, respectively. An unweeded plot (third method) and a hand-weeded plot with a PPI treatment (fourth method) served as controls. In 1981, sethoxydim was not available and alachlor was substituted. For this reason, the herbicide means were combined only for 1982 and 1983. Application of herbicides in nontillage plots differed from the application in the other two tillage treatments with the inclusion of paraquat (Paraquat 29.1L) (0.6 kg a.i./ha) at planting and the PPI method deployed as a preemergence treatment. Herbicide effects in nontillage plots were analyzed separately from plots with conventional or reduced tillage.

Data analysis. Data were analyzed within years and over 3 yr by combined analysis. Fisher's protected least significant difference method (FLSD) was used to separate means ($P = 0.05$) unless stated otherwise.

Seed yield and quality. Cleaned seed lots were weighed to determine total yield and 1,000-seed weight at 13% moisture. Variables of seed quality examined were germination (agar and blotter analysis), incidence (percent recovery) of seedborne

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Table 1. Effect of year on agronomic and seed quality variables on Corsoy-79 soybeans grown at Urbana, IL (1981–1983)[a]

Year	Yield (kg/ha)	Weed control (%)	1,000-Seed weight (g)	Mean percentage: Germination	Germination (blotter)[b]	Vigorous sedlings[c]	Germinated clean[d]	*Alternaria* spp.	Bacteria[e]	*Cercospora kikuchii*	*Phomopsis* spp.
1981	2,521 b[f]	74 a	148 b	92 a	94 b	48 b	69 a	7 c	19 a	1 b	2 b
1982	3,539 a	67 b	153 a	94 a	97 a	85 a	65 a	7 b	5 b	1 b	4 a
1983	2,590 b	59 b	149 b	87 b	80 c	38 c	50 b	11 a	7 b	4 a	1 c

[a] Means based on 72 observations from triplicated plots with three tillage levels, two row-spacing levels, and four herbicide levels in a factorial design. Observations in the mean percentage categories were each derived from a subsample of 100 seeds incubated for 1 wk.
[b] Seeds incubated on moistened cellulose pads. All other mean percentage data derived from seed incubated on potato-dextrose agar.
[c] Vigorous = hypocotyl length ≥ 12 cm.
[d] Clean = no recovery of seedborne fungi or bacteria.
[e] Principally *Bacillus subtilis*.
[f] Means followed by the same letter are not significantly different (FLSD, $P = 0.05$).

Table 2. Effect of tillage on agronomic and seed quality variables on Corsoy-79 soybeans grown at Urbana, IL (1981–1983).

Tillage[u]	Yield (kg/ha)	Weed control (%)	1,000-seed weight (g)	Mean percentage: *Alternaria* spp.	Bacteria[v]
			1981[w]		
Conventional	2,689 a[x]	82 a	147 a	1 a	18 a
Reduced	2,482 a	80 a	146 a	2 a	20 a
Nontillage	2,391 a	60 b	151 a	2 a	20 a
			1982[w]		
Conventional	3,543 a	72 a	154 a	6 a	6 a
Reduced	3,612 a	74 a	152 a	6 a	4 b
Nontillage	3,457 a	56 b	150 a	7 a	4 b
			1983[w]		
Conventional	3,243 a	77 a	153 a	14 a	6 a
Reduced	2,746 b	65 b	151 a	10 ab	9 a
Nontillage	1,782 c	37 c	145 b	9 b	6 a
			1981–1983[y]		
Conventional	3,158 a	37 a	151 a	7 a	10 a
Reduced	2,948 b	73 b	150 a	6 a	11 a
Nontillage	2,543 c	51 c	149 a	6 a	10 a

[u] Conventional = disking and moldboard plowing in the fall, then disking, incorporating herbicides, disking, and cultivating the field in the spring; reduced = same as conventional but minus moldboard plowing; and nontillage = soil not tilled.
[v] Principally *Bacillus subtilis*.
[w] Means based on 24 observations from triplicated plots with two row-spacing levels and four herbicide levels in a factorial design. Observations in the mean percentage categories were each derived from a subsample of 100 surface-sterilized seeds incubated on potato-dextrose agar for 1 wk.
[x] Means followed by the same letter are not significantly different (FLSD, $P = 0.05$).
[y] Means based on 72 observations from 3 yr of triplicated plots arranged with two row-spacing levels and four herbicide levels in a factorial design.

Table 3. Effects of row spacing on weed control and seed quality variables on Corsoy-79 soybeans grown at Urbana, IL (1981–1983)

Row spacing (cm)	Weed control (%)	1,000-seed weight (g)	Mean percentage: Germinated clean[u]	*Alternaria* spp.
		1981[v]		
25	70 a[w]	147 a	70 a	1.6 a
76	78 a	150 a	68 a	1.4 a
		1982[v]		
25	62 b	153 a	62 b	8.3 a
76	73 a	152 a	70 a	4.9 b
		1983[v]		
25	51 b	147 b	49 a	11.8 a
76	67 a	151 a	51 a	9.8 a
		1981–1983[x]		
25	61 b	149 a	60 a	7.2 a
76	73 a	151 a	63 a	5.4 b

[u] Clean = no recovery of seedborne fungi or bacteria.
[v] Means based on 36 observations from triplicated plots with three tillage levels and four herbicide levels in a factorial design. Observations in the mean percentage categories were derived from a subsample of 100 surface-sterilized seeds incubated on potato-dextrose agar for 1 wk.
[w] Means followed by the same letter are not significantly different (FLSD, $P = 0.05$).
[x] Means based on 108 observations from 3 years of triplicated plots with three tillage levels and four herbicide levels in a factorial design.

microflora, and seedling vigor (blotter analysis). One hundred seeds from each experimental unit were surface-sterilized in 0.5% NaOCl (Clorox) for 4 min, then rinsed three times (2 min per rinse) in sterile distilled water. All seeds were plated on potato-dextrose agar (PDA) (Difco) with five seeds per 9-cm culture plate. After 1 wk at 25 C, the following parameters were recorded in percentages: germination (germinated = combined hypocotyl and root length ≥ twice the cotyledon length), germinated "clean" (germinated with no bacteria or fungi present), recovery of seedborne bacteria or individual fungal species (number of discrete colonies on a germinated, nongerminated, and total seed basis), and total fungi. Seed germination also was tested by the blotter method. One hundred seeds per experimental unit were placed on moistened cellulose pads (Kimpac). After 1 wk at 90% relative humidity and 28 C, the numbers of seeds germinated, germinated/vigorous (hypocotyl length ≥ 12 cm), and germinated/nonvigorous (hypocotyl length ≥ 2.5 but < 12 cm) were recorded.

RESULTS

The following seed microflora were prevalent throughout the three growing seasons: *Alternaria* spp., *Bacillus*-like colonies identified earlier in this laboratory (22) as *B. subtilis* (Ehrenberg) Cohn, *Cercospora kikuchii* (T. Matsu. & Tomoyasu) Gardner, *Fusarium* spp., and *Phomopsis* spp. complex (20). These organisms can be detrimental to soybean seed quality (20).

Analysis by year. In 1983, the percentages of germinated, vigorous, and clean-germinated seed were significantly lower and the recovery of *Alternaria* spp. and *C. kikuchii* significantly higher than in the other 2 yr (Table 1). In 1982, yield, 1,000-seed weight, seed germination, and seedling vigor were significantly higher than in any other year. Weed control was best in 1981 and poorer in the next 2 yr. The superior weed control in 1981 was accompanied by the highest recovery of clean, germinated seed and the lowest recovery of *Alternaria* spp. from seed. Recovery of bacteria, however, was higher in the more weedfree year (1981) than in the other 2 yr. Recovery of *C. kikuchii* and *Phomopsis* spp. generally was less than 5%. These two pathogens are frequently recovered from 10 to 20% in Illinois seed lots, depending on seed quality and weather conditions. The highest recovery of *Phomopsis* spp. for a given year was 4% in 1982 (Table 1).

Tillage. In 1983, seeds from nontillage plots had significantly lower 1,000-seed weight than seed from the conventional tillage or reduced tillage plots. There was a significantly lower recovery of *Alternaria* spp. from seed of nontillage than conventional tillage plots (Table 2). In 1982, there was a significantly higher recovery of seedborne bacteria in the conventional tillage plots than in the other two tillage treatments. Despite these minor differences in individual years, over the 3-yr period, tillage did not significantly affect seed quality. Although conventional tillage was consistently associated with the highest yield and weed control, none of the seed quality parameters were affected by this relationship (Table 2).

Row spacing. Seeds from narrow-spaced plots had significantly more *Alternaria* spp. over combined years and in 1982 alone. Higher recoveries of *Alternaria* spp. were consistently associated with significantly poorer weed control in the narrow-spaced plots (Table 3). Seeds from narrow-spaced plots in 1983 had significantly lower 1,000-seed weight than seeds from the wider-spaced plots, but row spacing did not significantly affect 1,000-seed weight over the 3-yr period.

Weed control methods. Because the weed control methods in the nontillage plots were considerably different from those used in the other two tillage treatments (chemicals applied preemergence, paraquat treatment included), the effect of herbicides on seed quality was analyzed separately for nontillage.

Seed germination, vigor, and recovery of *Phomopsis* spp. were not significantly affected by tillage or row spacing but were affected by method of weed control. Combined data for 1982 and 1983 in nontillage plots showed that soybeans from the POST treatment had significantly higher 1,000-seed weight (152 vs. 147 g) but significantly lower yield (2,799 vs. 3,142 kg/ha) and weed control (40 vs. 70%) than PPI applied preemergence. Untreated check plots had the poorest yield, weed control, and 1,000-seed weights of all four treatments.

When data from the conventional and reduced tillage plots were combined for 1982 and 1983, POST had higher 1,000-seed weight (155 vs. 152 g) and seed germination (90 vs. 87%) than PPI, but weed control was significantly better in PPI (82 vs. 91%). Untreated check plots had significantly higher recovery of *Phomopsis* spp. and number of vigorous seedlings than hand-weeded plots. In general, the POST treatment produced seeds with significantly greater 1,000-seed weight than PPI when results were analyzed from nontillage plots alone or when results were averaged among plots from the other two tillage treatments. However, PPI plots had significantly better weed control than POST with all tillage treatments.

DISCUSSION

In this study, conventional tillage resulted in higher recovery of seedborne *Alternaria* spp. (1983) and bacteria (1982) than nontillage. However, these results were obtained in isolated years, and tillage did not affect any variable of seed quality during the 3-yr period. Nontillage has been reported to decrease the incidence of purple seed stain and wrinkled seed in soybean compared with conventional tillage methods (21). This report came from a study made in a particularly dry year in Tennessee, where nontillage plots conserved higher amounts of moisture in the 120-cm soil profile. Also, the results of the Tennessee study were based on visual ratings of stained diseased tissue, not actual recovery of the pathogen as was done in this study. In our study, as in other reports (12), weed control was significantly reduced with decreased tillage activity.

Reports on the effect of row spacing on soybean disease development are mixed. Severity of Sclerotinia stem rot of soybeans is reported to be higher in narrow rows than in wide rows (9). Some reports indicate increased disease severity of brown spot (14) and downy mildew (19) with decreasing row width; another study indicates the opposite trend for brown spot (15). In this study, significantly higher recovery of seedborne *Alternaria* spp. was obtained with decreasing row width when 3 yr of data were combined and analyzed. Weed control was poorer in narrower rows, which may have been due to the lack of mechanical cultivation 4 wk after planting. The higher incidence of Alternaria pod and seed decay may be associated with a preference of bean leaf beetles (*Ceratoma trifurcata*) for narrow rows or for the weeds between narrow rows. Pod injury caused by this beetle was correlated with incidence of seedborne *Alternaria* spp. (18).

Reports are increasing on the side-effects of herbicides on plant diseases (1,13,17) and seed quality (2–4,10). In the nontillage plots, sethoxydim + bentazon resulted in greater seed weight but poorer weed control than alachlor + metribuzin. In the other two tillage treatments, alachlor + metribuzin resulted in better weed control but lower germination and 1,000-seed weight than sethoxydim + bentazon. Thus, seed weight was improved when sethoxydim + bentazon was used in the three tillage treatments. The herbicide treatments did not affect the recovery of seedborne pathogens, so seed weight must have been affected by the herbicides through a different mechanism.

The higher seedborne populations of *Phomopsis* spp. in weed-infested plots than in weedfree plots was consistent with other reports that cite weeds as alternate hosts of seedborne soybean pathogens (3,6,11). However, it is difficult to explain why seeds from weed-infested plots had higher vigor than seeds from weedfree plots. Possibly, some of the weeds served as a physical barrier to dispersion of seedborne pathogens or insect pests.

Seed quality was affected more by weed control method than by tillage or row spacing. These studies suggest that reduced tillage or nontillage should not affect soybean seed quality in central Illinois. In this region, germination, vigor, and infection by *Phomopsis* spp. and *C. kikuchii* are the most important factors in determining good soybean seed quality. None of these factors was significantly affected by tillage or row spacing in any of the 3 yr. However, reduced tillage, nontillage, or reduced row spacings may increase weed pressure and ultimately reduce yields unless measures are taken to control weeds. Weed control and row spacings may affect seed quality under different tillage conditions, but the main concern should continue to be the response of weed control and yield to these cultural practices under specific tillage systems.

LITERATURE CITED

1. Altman, J., and Campbell, C. L. 1977. Effect of herbicides on plant diseases. Annu. Rev. Phytopathol. 15:361-385.
2. Bowman, J. E., Sinclair, J. B., and Wax, L. M. 1981. Soybean seed quality affected by preplant incorporated herbicides. (Abstr.) Phytopathology 71:862.
3. Cerkauskas, R. F., Dhingra, O. D., Sinclair, J. B., and Asmus, G. 1983. *Amaranthus spinosus*, *Leonotis nepetaefolia*, and *Leonurus sibiricus*: New hosts of *Phomopsis* spp. in Brazil. Plant Dis. 67:821-824.
4. Cerkauskas, R. F., Dhingra, O. D., Sinclair, J. B., and Foor, S. R. 1982. Effect of three desiccant herbicides on soybean (*Glycine max*) seed quality. Weed Sci. 30:484-490.
5. Cook, R. J., Boosalis, M. G., Doupnik, B. 1978. Influence of crop residues on plant diseases. Pages 147-163 in: Crop Residue Management Systems. Am. Soc. Agron. Spec. Publ. 31, Madison, WI. 248 pp.
6. Dhingra, O. D., and de Silva, J. F. 1978. Effect of weed control on the internally seedborne fungi in soybean seeds. Plant Dis. Rep. 62:513-516.
7. Ferrant, N. P., and Carroll, R. B. 1979. *Fusarium oxysporum* wilt of soybean and effect of tillage practices on occurrence of *Fusarium* spp. in roots and soil. (Abstr.) Phytopathology 69:534-535.
8. Fett, W. F. 1979. Survival of *Pseudomonas glycinea* and *Xanthomonas phaseoli* var. *sojense* in leaf debris and soybean seed in Brazil. Plant Dis. Rep. 63:79-83.
9. Grau, C. R., and Radke, V. L. 1984. Effects of cultivars and cultural practices on Sclerotinia stem rot of soybean. Plant Dis. 68:56-58.
10. Hardcastle, W. S., Wilkinson, R. E., and Young, C. T. 1974. Metribuzin effects on seed constituents of soybean varieties. Weed Sci. 22:575-577.
11. Hepperly, P. R., Kirkpatrick, B. L., and Sinclair, J. B. 1980. *Abutilon theophrasti*: Wild host for three fungal parasites of soybean. Phytopathology 70:307-310.

12. Kapusta, G. 1979. Seedbed tillage and herbicide influence on soybean (*Glycine max*) weed control and yield. Weed Sci. 27:520-526.

13. Katan, J., and Eshel, Y. 1973. Interactions between herbicides and plant pathogens. Residue Rev. 45:145-177.

14. Murhaga, M. T., Grau, C. R., and Arny, D. C. 1979. *Septoria glycines* brown spot of soybean: effect of row width and tillage practice on disease development. (Abstr.) Phytopathology 69:541.

15. Pataky, J. K., and Lim, S. M. 1981. Effects of row width and plant growth habit on Septoria brown spot development and soybean *Glycine max* yield. Phytopathology 71:1051-1056.

16. Ploetz, R. C., Mitchell, D. J., and Gallaher, R. N. 1982. Effects of tillage practices on population densities of *Rhizoctonia* spp. in a rye-soybean multi-cropping system. (Abstr.) Phytopathology 72:948.

17. Rodriguez-Kabana, R., and Curl, E. A. 1980. Nontarget effects of pesticides on soilborne pathogens and disease. Annu. Rev. Phytopathol. 18:311-332.

18. Shortt, B. J., Sinclair, J. B., Helm, C. G., Jeffords, M. R., and Kogan, M. 1982. Soybean seed quality losses associated with bean leaf beetles and *Alternaria tenuissima*. Phytopathology 72:615-618.

19. Siemens, J. C., ed. 1979. Tillage systems for Illinois. Agric. Ext. Serv. Circ. 1172. Univ. Ill. (Urbana-Champaign). 22 pp.

20. Sinclair, J. B., ed. 1982. Compendium of Soybean Diseases. 2nd ed. American Phytopathological Society, St. Paul, MN. 104 pp.

21. Sumner, D. R., Doupnik, B., and Boosalis, M. G. 1981. Effects of reduced tillage and multiple cropping on plant diseases. Annu. Rev. Phytopathol. 19:167-187.

22. Tenne, F. D., Foor, S. R., and Sinclair, J. B. 1977. Association of *Bacillus subtilis* with soybean seeds. Seed Sci. Technol. 5:763-769.

23. Tyler, D. D., and Overton, J. R. 1982. No-tillage advantages for soybean, *Glycine max* cultivar Forrest, seed quality during drought stress. Agron. J. 74:344-347.

24. Unger, P. W., and McCalla, T. M. 1980. Conservation tillage systems. Adv. Agron. 33:1-58.