# Tillage, Rotation Sequence, and Cultivar Influences on Brown Stem Rot and Soybean Yield

E. A. Adee, E. S. Oplinger,* and C. R. Grau

**Yield of soybean [*Glycine max* (L.) Merr.] is often reduced when grown in fields using no-till (NT) and shorter crop rotations with corn (*Zea mays* L.) than with conventional tillage (CT) and longer crop rotations. The objective of this study was to determine the effect of tillage system, rotation sequence, and cultivar on severity of brown stem rot (BSR) [caused by *Phialophora gregata* (Allington and D.W. Chamberlain) W. Gams] and yield of soybean. Field studies were conducted near Arlington, WI, for 4 yr (1989–1992) on a Plano silt loam (fine-silty, mixed, mesic Typic Argiudoll) under both NT and CT. Seven crop sequences with soybean were evaluated: (1) first-year soybean after a minimum of 5 yr corn; (ii) soybean annually alternated with corn; (iii) 2, 3, 4, 5 yr of continuous soybean after 5 yr of corn; and (iv) continuous soybean. When averaged over all rotations, severity of BSR was 38% greater and yield of soybean 10% less in NT than in CT. Severity of BSR was 30% greater and yield 15% lower in annually alternated soybean grown in NT than in CT. First-year soybean following 5 yr of corn had 44% less severity of BSR, 11% greater yield, and 4.8% greater seed weight than soybean annually alternated with corn. Severity of BSR tended to increase, and yield and seed weight of soybean tended to decrease with an increase in frequency of soybean in the rotation. Severity of BSR was almost 10 times greater, yield 19% less, and seed weight 10% lower in BSR-susceptible cv. Corsoy 79 than in the BSR-resistant cv. BSR 101 across all tillages and rotations. The reduction of soybean yield observed with NT and shorter crop rotations was attributed primarily to greater severity of BSR.**

E.A. Adee and C.R. Grau, Dep. of Plant Pathology, 1630 Linden Dr.; E.S. Oplinger, Dep. of Agronomy, 1575 Linden Dr., Univ. of Wisconsin, Madison, WI 53706. Contribution from the Deps. of Plant Pathology and Agronomy, Univ. of Wisconsin-Madison. Supported by Hatch projects 142-3536 and 1890, the Wisconsin Soybean Marketing Board and CSRS NCR IPM grant 91-34103-5965. Received 26 July 1993. *Corresponding author (email esopling@facstaff.wisc.edu).

Published in J. Prod. Agric. 7:341–347 (1994).

BROWN STEM ROT of soybean is caused by the fungus *Phialophora gregata* [syn. *Cephalosporium gregatum* Allington and D.W. Chamberlain (1948)]. The disease is considered of economic importance in the Upper Midwest (Mengistu and Grau, 1987). Increasing importance of BSR as a disease of soybean has been attributed to increases in soybean acreage and fewer years of non-host crops between soybean crops (Dunleavy, 1966). Kennedy and Lambert (1981) reported that the incidence of BSR was lower, and yield was 13% higher in soybean grown in rotation culture than in continuously cropped soybean. Whiting and Crookston (1993), however, found BSR not to be a significant factor in the reduction of soybean yield in corn/soybean rotations compared with continuous soybean. Crookston et al. (1991) reported that soybean yields decreased gradually with extended monoculture. First-year soybean yielded 15% better, and soybean annually alternated with corn yielded 8% better than soybean in monoculture. Yield of soybean has been reported to be lower with a BSR-susceptible cultivar of soybean than with a BSR-resistant cultivar as less tillage was used and as years between soybean crops were reduced (Meese et al., 1991). The researchers speculated that BSR was a significant factor in this phenomenon.

Other agronomic factors also have an effect on yield loss due to BSR. Decreasing plant density in 30 in. row soybeans increased the percentage of plants exhibiting symptoms of BSR (Nicholson et al., 1973). Yield loss to BSR and severity of BSR was greatest when soil moisture was optimal for crop development (Mengistu and Grau, 1987). Cultivars resistant to BSR (Tachibana et al., 1987) significantly reduced yield loss to BSR (Mengistu et al., 1986). However, Tachibana (1982) did not encourage the widespread use of BSR-resistant cultivars, and recom-

**Abbreviations:** AUDPC, area under disease progress curve; BSR, brown stem rot; CT, conventional tillage; NT, no-till.

Table 1. Rotation sequences for corn (C) and soybean (S).

| Crop sequence | Year 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|
| A | C | C | C | C | C | S | S | S | S | S |
| B | S | C | C | C | C | C | S | S | S | S |
| C | S | S | C | C | C | C | C | S | S | S |
| D | S | S | S | C | C | C | C | C | S | S |
| E | S | S | S | S | C | C | C | C | C | S |
| F | S | S | S | S | S | C | C | C | C | C |
| G | C | S | S | S | S | S | C | C | C | C |
| H | C | C | S | S | S | S | S | C | C | C |
| I | C | C | C | S | S | S | S | S | C | C |
| J | C | C | C | C | S | S | S | S | S | C |
| K | C | C | C | C | C | C | C | C | C | C |
| L | C | S | C | S | C | S | C | S | C | S |
| M | S | C | S | C | S | C | S | C | S | C |
| N | S | S | S | S | S | S | S | S | S | S |

| Year in rotation† | Year 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|
| 1 | B | C | D | E |
| 1-C/S | M | L | M | L |
| 2 | A | B | C | D |
| 3 | J | A | B | C |
| 4 | I | J | A | B |
| 5 | H | I | J | A |
| Cont. | N | N | N | N |

† 1 = first-year soybean, after several years of corn; 1-C/S = first-year soybean, alternated annually with corn; 2, 3, 4, 5 = second-, third-, fourth-, and fifth-year soybean, respectively; Cont. = seventh-year soybean in 1989, eighth-year soybean in 1990, ninth-year soybean in 1991, and 10th-year soybean in 1992.

mended instead that they be limited to fields with high BSR potential in order to manage genetic resistance to *P. gregata*.

Our study was conducted to focus on the effect of tillage and crop rotation sequence on the severity of BSR and yield of soybean. The effects of BSR on soybean production were measured by comparing disease severity ratings and yield of a BSR-susceptible cultivar to a BSR-resistant cultivar.

## MATERIALS AND METHODS

Field research was conducted for 4 yr (1989–1992) on a Plano silt loam at the Arlington, WI, Agricultural Research Station. The experiment was established in a split-split-split plot randomized complete block arrangement of treatments with four replicates. Whole plots were either NT or CT and were established in 1986. Conventional tillage was accomplished by a moldboard plow in the fall and a field cultivar prior to planting. For NT, crops were planted into the undisturbed residue of the previous crop. The sub-plots consisted of 14 rotation sequences involving corn and soybean, which had been initiated in 1983 on land previously planted to corn (Table 1). Seven of the rotation sequences had soybean as the current crop. These seven rotation sequences allowed comparisons to be made every year during 1989, 1990, 1991, and 1992 of: (i) first-year soybean after a minimum of five consecutive years of corn; (ii) soybean annually alternated with corn; (iii) 2, 3, 4, 5 yr of continuous soybean following 5 yr of corn; and (iv) continuous soybean (continuous = seventh-, eighth-, ninth-, and 10th-year soybean in 1989, 1990, 1991, and 1992, respectively). Nitrogen in the form of 28% urea ammonium nitrate was spoke wheel injected at the V2 to V3 stage of growth (Fehr et al., 1971) to sub-sub plots at rates of 0 and 30 lb/acre. Sub-sub-sub plots were two soybean cultivars, Corsoy 79 (BSR-susceptible) and BSR 101 (BSR-resistant). These cultivars were selected because they are near group II maturity soybeans with similar yield potential in the absence of BSR. The 1990 and 1991 average yield for Corsoy 79 was 58 bu/acre and BSR 101 55 bu/acre at four southern Wisconsin soybean yield trials (Oplinger et al., 1991). The seed of the two cultivars was very similar in size when compared at three locations with NT and CT when symptoms of BSR were not present (Oplinger et al., 1992). The size of the sub-sub-sub plot experimental units was 7.5 ft by 30 ft.

Soybean seed was drilled in both tillage systems in rows spaced 8 in. apart at a depth of 1.5 in. with a Tye No-Till drill (Tye Company, Lockney, TX) equipped with rippled coulters in front of double disk openers and a double press wheel. Soybean was planted on 11 May 1989, 18 May 1990, 1 May 1991, and 6 May 1992 at 180 000 seeds/acre. In 1989, 1.5 lb a.i./acre metolachlor was applied pre-emergence and 2 lb a.i./acre bentazon and oil were applied post-emergence to control weeds. In 1990, 1.5 lb a.i./acre of metolachlor was applied pre-emergence for weed control. In 1991, 1.5 lb a.i./acre of metolachlor was applied pre-emergence and 0.0625 oz a.i./acre of trifensulfuron methyl was applied post-emergence for weed control. In 1992, 2 lb a.i./acre of glyphosate was applied preplant, 1.5 lb a.i./acre metolachlor was applied pre-emergence, and 2 lb a.i./acre bentazon and 2 pt/acre adjuvent were applied post-emergence for weed control. Hand weeding was used if necessary.

Soybean data collected all 4 yr included: severity of BSR foliar symptoms, plant height and lodging, grain

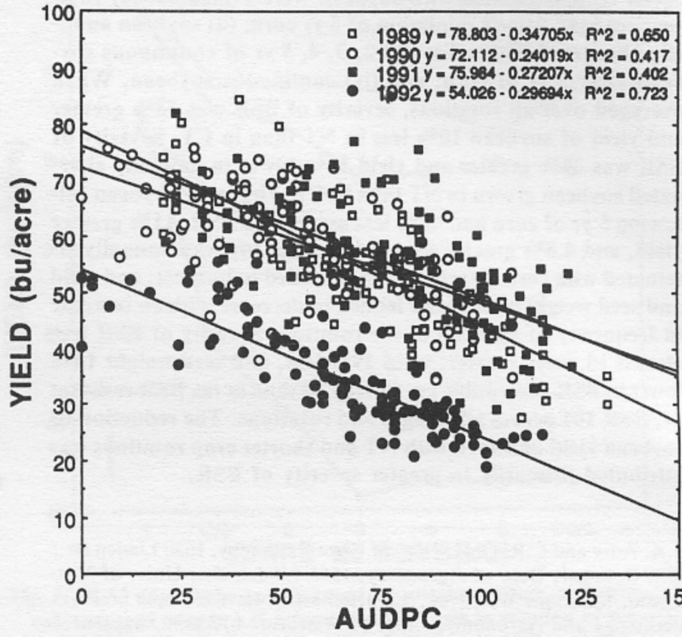


**Fig. 1. Correlation of brown stem rot (BSR) severity with yield of soybean (cv. Corsoy 79) (y = 68.666 − 0.267x, *P* < 0.001, r = −0.518). An area under disease progress curve (AUDPC) was calculated to present the severity and progress of foliar symptoms of BSR for each year.**

Table 2. Main effects of year, tillage, rotation sequence, and cultivar on soybean for four combined years (1989–1992) of corn/soybean rotation study.

| Main effect | AUDPC† | Yield | Seed weight | Plant height | Lodging‡ |
|---|---|---|---|---|---|
| | | bu/acre | mg/seed | in. | 1–5 |
| Year | | | | | |
| 1989 | 46.4 | 61.2 | 169 | 37.5 | 2.6 |
| 1990 | 30.0 | 61.2 | 180 | 37.4 | 2.8 |
| 1991 | 39.8 | 61.0 | 168 | 41.5 | 2.6 |
| 1992 | 33.1 | 42.9 | 147 | 35.7 | 2.8 |
| $P$ = | <0.001 | <0.001 | <0.001 | <0.001 | 0.01 |
| LSD (10%) | 2.9 | 2.2 | 5.2 | 0.6 | 0.1 |
| Tillage | | | | | |
| No-till | 43.3 | 53.6 | 165 | 38.2 | 2.9 |
| Conv. till | 31.3 | 59.5 | 166 | 37.8 | 2.5 |
| $P$ = | <0.001 | <0.001 | 0.006 | 0.14 | 0.006 |
| Rotation sequence | | | | | |
| First-year soybean | 19.0 | 65.1 | 174 | 40.4 | 2.9 |
| Soybean/corn | 33.8 | 58.5 | 166 | 38.5 | 2.9 |
| Second-year soybean | 37.5 | 56.4 | 166 | 38.3 | 2.8 |
| Third-year soybean | 42.8 | 54.5 | 164 | 37.7 | 2.7 |
| Fourth-year soybean | 43.2 | 54.0 | 164 | 37.4 | 2.6 |
| Fifth-year soybean | 43.0 | 53.4 | 164 | 37.3 | 2.5 |
| Cont. soybean | 41.9 | 54.2 | 164 | 36.5 | 2.3 |
| $P$ = | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| LSD (10%) | 2.8 | 1.8 | 1.8 | 0.6 | 0.1 |
| Cultivar | | | | | |
| Corsoy 79 | 67.8 | 50.5 | 157 | 40.6 | 3.5 |
| BSR 101 | 6.8 | 62.6 | 175 | 35.4 | 1.9 |
| $P$ = | <0.001 | 0.003 | <0.001 | <0.001 | 0.002 |

† AUDPC = area under disease progress curve for foliar symptoms of brown stem rot of soybean.
‡ Lodging: 1 = all plants upright to 5 = all plants flat.

moisture, grain yield, and seed weight. Foliar symptoms of BSR were rated weekly after the initiation of symptoms by use of the Horsfall-Barratt scale (Mengistu et al., 1986), from which an area under disease progress curve (AUDPC) was calculated for each treatment. Foliar symptoms of BSR were rated every 5 to 8 d after initiation of symptoms from 27 Aug. to 12 Sept. 1989, 29 Aug. to 18 Sept. 1990, 9 Aug. to 28 Aug. 1991, and 18 Aug. to 2 Sept. 1992.

A plot combine was used to harvest the six middle soybean rows from each plot on 28 Sept. 1989, 5 Oct. 1990, 26 Sept. 1991 and 5 Oct. 1992. Yields were based on 13% moisture content of grain.

Factorial and correlation analysis was performed on the data using MSTAT-C (MSTAT-C, Michigan State University, East Lansing, MI). Data were analyzed over years by use of a strip block analysis of variance with separate error terms for each main effect, and mean comparisons were made by use of the FLSD test. Replicates were considered fixed effects while all other effects were randomized at the initiation of the experiment but fixed thereafter in determining the expected mean squares and appropriate F-tests in the combined analysis of variance.

## RESULTS AND DISCUSSION

The plot area is typical of most midwestern fields. BSR appears as soybean culture is increased. Ratings for severity of BSR from these plots were first recorded in 1986. From 1989 to 1992, the severity of BSR in these plots was as high as the severity observed in growers fields with similar cropping histories.

### Main Effects

*Year*. There was a correlation between AUDPC and yield of Corsoy 79 for 4 yr of the corn/soybean rotation study ($y = 68.666 - 0.267x$, $P < 0.001$, $r = -0.518$) (Fig. 1). There were differences between regressions of AUDPC against yield for the different years. The y-intercept for 1992 was lower than the three other years ($P < 0.001$), reflecting the reduced yield potential of the crop in response to cooler temperatures and poorer growing conditions. For each increment of disease severity the change in yield was slightly different between years. The slope for 1989 was greater than the three other years at $P = 0.025$, but was not different from the slope for 1992 at $P = 0.097$. The slopes for 1990, 1991, and 1992 were not different at $P = 0.05$ in pair-wise comparisons, however, the slope for 1992 was greater than 1990 ($P = 0.08$). We believe the climatic conditions were responsible for the differences. For example, while 1989 was warmer and dryer than normal early in the growing season, timely rains in August coincided with pod fill. Mengistu and Grau (1987) reported that optimal soil moisture conditions result in greater severity of, and yield loss caused by, BSR.

The severity of BSR, averaged across all factors for the growing season varied among years (Table 2). Interactions of year with other factors were due primarily to the magnitude of the response, and therefore results will be presented as the mean response over 4 yr.

*Nitrogen*. The application of N reduced the severity of BSR in Corsoy 79 in all crop rotation sequences except the 2 and 3 yr continuous soybean (data not shown). There was no interaction between N rate and rotation sequences for severity of BSR in BSR 101. Nitrogen also increased the yield of Corsoy 79 and BSR 101 compared with no N in some of the rotation sequences (data not shown). The interaction between tillage and N rate was not significant for yield of soybean. This data is presented in more detail in Adee et al., 1994. All values are averages of N treatments.

*Tillage*. Severity of BSR on soybean was 38% greater and yield of soybean was 10% less in NT than in CT (Table 2). Seed weight of soybean in NT was less than in CT and lodging of soybean was greater in NT than in CT. The negative correlation of BSR severity, expressed as AUDPC, with yield of Corsoy 79 ($P < 0.001$, $r = -0.518$) suggests that BSR is a significant factor in the reduction of yield of soybean grown in NT. Previous research conducted in Wisconsin (Mengistu and Grau, 1987) has shown a similar negative correlation between BSR severity and grain yield.

While other researchers have shown the influence of crop rotation (Kennedy and Lambert, 1981; Dunleavy and Weber, 1967) and BSR-resistant cultivars (Mengistu et al., 1986) on severity of BSR and soybean yield, this data is the first to show the influence of tillage on severity of BSR. While the use of residue management to control BSR has not been reported, residue management has been recommended to control other residue-borne plant pathogens of soybean such as: *Pseudomonas syringae* pv. *glycinea* Young, Dye, and Wilkie (bacterial blight), *Col-*

*letotrichum truncatum* Andrus and W.D. Moore (anthracnose), *Septoria glycines* Hemmi (brown spot), and *Diaporthe phaseolorum* var. *sojae* Wehm. (pod and stem blight) (Sinclair and Backman, 1989). The effect NT has on the survival of *P. gregata* and potential inoculum of the fungus is not known.

Concerns of soil erosion control and the restrictions on tillage require the examination of other means to reduce the inoculum of residue-borne plant pathogens other than CT with the moldboard plot. Use of resistant cultivars to reduce inoculum of *P. gregata* could be a potential disease management strategy that could be integrated with tillage and crop rotation. The incidence and severity of BSR was reduced and yields of BSR-susceptible cultivars increased following 4 yr of BSR-resistant soybean (Tachibana et al., 1989). This phenomenon maybe related to lower numbers of colony forming units of *P. gregata* isolated from straw of BSR 101 collected in the spring than from BSR-susceptible cv. Hardin (Mengistu et al., 1991). This strategy also has been demonstrated by growing a cultivar resistant to soybean cyst nematode, *Heterodera glycines* Ichinohe, which reduces the number of soybean cyst nematode cysts in the soil (Epps et al., 1981).

*Rotation*. First-year soybean after 5 yr of corn had 44% less severity of BSR, 11% greater yield, and 5% greater seed weight than soybean that had been annually alternated with corn for 6 to 9 yr (Table 2). The severity of BSR increased, and yields and seed weight of soybean decreased with an increase in frequency of soybean in the rotation. Plant height and lodging of soybean decreased with an increase in soybean frequency.

Longer crop rotations, such as a 3-yr corn/soybean/wheat (*Triticum aestivum* L.) cropping system, may be more advantageous than annually alternated corn and soybean when BSR is a limiting factor for soybean yield (Lund et al., 1993). Dunleavy and Weber (1967) reported a yield advantage of 9.2 bu/acre for soybean grown after 3 yr of corn compared with 2 yr, and the incidence of BSR symptomatic plants was 45 and 83%, respectively.

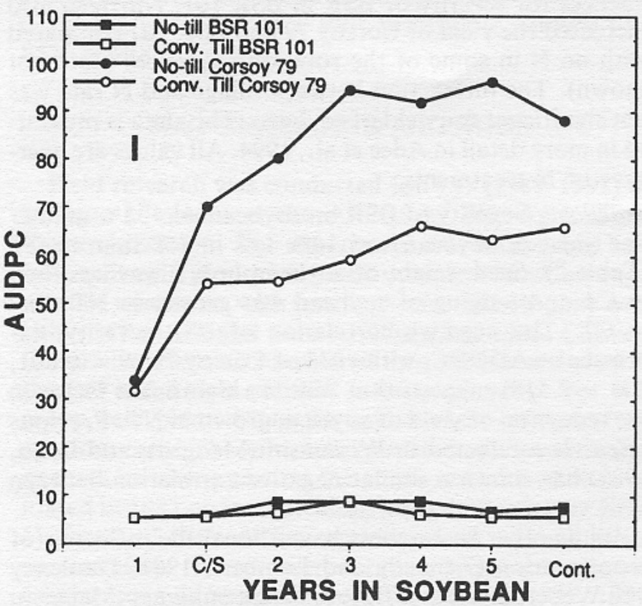


**Fig. 2. Severity of brown stem rot as influenced by rotation, tillage, and cultivar, averaged over two N rates and 4 yr. Years in rotation of soybean are: 1 = first-year soybean after 5 yr of corn; C/S = soybean alternated annually with corn; 2, 3, 4, 5 = second-, third-, fourth-, and fifth-year soybean, respectively; Cont. = seventh-, eighth-, ninth-, and 10th-year soybean in 1989, 1990, 1991, and 1992, respectively. An area under disease progress curve (AUDPC) was calculated to present the severity and progress of foliar symptoms of BSR for each year. Vertical bar represents FLSD (0.10).**

*Cultivar*. The severity of BSR in cv. Corsoy 79 was almost 10 times greater, yield was 19% lower, and seed weight was 10% lower than for cv. BSR 101 (Table 2). Corsoy 79 also had greater plant height and more lodging than BSR 101. The height and lodging of Corsoy 79 is typically greater than for BSR 101 when symptoms of BSR are not present (Oplinger et al., 1991).

The negative correlation between AUDPC of BSR and seed weight of Corsoy 79 ($P < 0.001$, $r = -0.61$), and the positive correlation between seed weight and yield of Corsoy 79 ($P < 0.001$, $r = 0.72$) confirms BSR reduces the yield of BSR-susceptible cultivars partially by decreasing seed weight, however, previous work has shown that most yield loss can be attributed to lower seed number (Dunleavy and Weber, 1967; Kennedy and Lambert, 1981; Mengistu et al., 1986).

### Interactions of Factors

*Disease Severity*. There was an interaction between tillage, rotation, and cultivar for the severity of BSR ($P < 0.001$) (Fig. 2). Tillage type did not have an effect on the severity of BSR in first-year soybean. Severity of BSR was greater with NT than with CT, starting with annually alternated soybean, and the difference increased with more consecutive years of soybean in the susceptible cultivar Corsoy 79. The severity of BSR in Corsoy 79 was more than 100% greater in NT and 70% greater in CT in annually alternated soybean than in first-year soybean following 5 yr of corn. Severity of BSR in Corsoy 79 was 30 to 60% greater in NT than in CT with annually alternated soybean and rotation sequences of two or more consecutive years of soybean. Severity of BSR was extremely low in BSR 101 and was not affected by tillage system in any of the rotation sequences. Across all rotation sequences, the overall trend for severity of BSR was least with BSR 101 in either tillage system, followed by Corsoy 79 in CT, and Corsoy 79 in NT.

Effectiveness of CT and longer crop rotations in reducing the severity of BSR supports the concept that *P. gregata* survives primarily in crop residue (Gray, 1972b). The use of CT and crop rotation as a means of residue management is effective in reducing the inoculum of other residue-borne plant pathogens (Cook et al., 1978). Burying crop residue with tillage operations and longer durations between a crop are two methods of reducing the amount of crop residue remaining when the crop is planted again (Christensen, 1986; Parker, 1962).

*Yield*. The interaction between tillage, rotation, and cultivar for yield was significant at $P = 0.005$ (Fig. 3). Yields of Corsoy 79 were not influenced by tillage in the first-year soybean, but in NT were 15 to 25% lower than in CT for rotation sequences after the first-year soybean. With annually alternated soybean, yield of Corsoy 79 was

20% lower in NT and 6% lower in CT than Corsoy 79 as first-year soybean following 5 yr of corn. Yield of BSR 101 in both tillage systems was 8 to 53% greater than yields for Corsoy 79 across all rotation sequences. Soybean yield was greatest across all rotation sequences with BSR 101 in CT, followed by BSR 101 in NT, Corsoy 79 in CT, and Corsoy 79 in NT. The severity of BSR can partially explain the reduction in yield of susceptible soybean cultivars grown in reduced tillage systems with shorter crop rotations. The reduction in yield of BSR 101 in rotation sequences after first-year soybean with NT and CT cannot be attributed to increased severity of BSR.

There are several possible explanations for the decline in yield of BSR 101 in NT compared with CT. Several other pathogens of soybean that survive in soybean residue, such as bacterial blight and brown spot, were observed on soybean in the plots. However, the incidence of bacterial blight was very low, and brown spot occurred late in the season on both cultivars. Symptoms caused by *Phytophthora sojae* (Kaufmann and Gerdemann) and *Pythium* spp., which are favored by cooler and wetter soils, were not observed in this experiment. Both cultivars are resistant to specific races of *P. sojae* common to the region, and there were no significant stand problems associated with *Pythium* in the plots. The health of roots was not determined in this study, but could be another factor influenced by crop rotations. Nickel et al. (1992) found that roots of corn and soybean grown in monoculture had lower health scores and higher numbers of total root pathogen colony forming units from *Fusarium* spp., *Rhizoctonia* spp., and *Pythium* spp. on roots than when grown in rotation.

Reduced yields of BSR 101 after first-year soybean in both tillage systems could be related to microbial activity in the soil. Mycorrhizal fungi could have an important role in the yield of crops grown in different crop rotations. Numbers of spores of mycorrhizal fungi predominant in soils that had been continuously cropped to corn and soybean were negatively correlated with yield of the respective crops (Johnson et al., 1992). Rotation of burley tobacco and sod crops reduced root colonization and severity of stunting of tobacco plants by the mycorrhizal fungus *Glomus macrocarpum* Tul and Tul (Hendrix et al., 1992).

*Seed Weight.* There was an interaction between tillage, rotation and cultivar for seed weight ($P = 0.099$). Seed weight of Corsoy 79 was 7 to 12% lower than seed weight of BSR 101 across all rotation sequences (Fig. 4). There was a trend for seed weights of Corsoy 79 to be lower in NT than in CT for all but first-year soybean. Seed weights of BSR 101 were not significantly different between tillage systems across all rotation sequences. Both cultivars, however, had higher seed weights under both tillage systems in first-year soybean than in all other rotations.

*Conclusions.* Results from this study on the effect of crop rotation on yield loss to BSR confirm previous reports by Dunleavy and Weber (1967) and Kennedy and Lambert (1981), while disagreeing with the conclusions of Whiting and Crookston (1993). The absence of visible foliar symptoms of BSR reported by Whiting and Crookston (1993) could explain the lack of a rotation effect with BSR. Mengistu and Grau (1987) reported that yield loss was greater when both stem and foliar symptoms of BSR were present and that severity of foliar symptoms was more closely correlated with yield loss than severity of stem symptoms. Severity of symptoms and yield loss to BSR can be affected by environmental factors. Low soil moisture, as in 1988 (Whiting and Crookston, 1993), reduces the severity of BSR stem and foliar

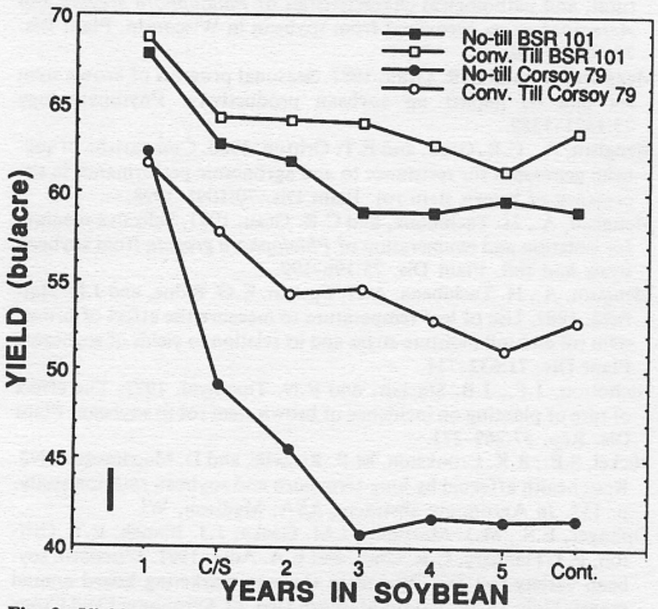


**Fig. 3. Yield of soybean as influenced by rotation, tillage, and cultivar, averaged over two N rates and 4 yr. Years in rotation of soybean are: 1 = first-year soybean after 5 yr of corn; C/S = soybean alternated annually with corn; 2, 3, 4, 5 = second-, third-, fourth-, and fifth-year soybean, respectively; Cont. = seventh-, eighth-, ninth-, and 10th-year soybean in 1989, 1990, 1991, and 1992, respectively. Vertical bar represents FLSD (0.10).**

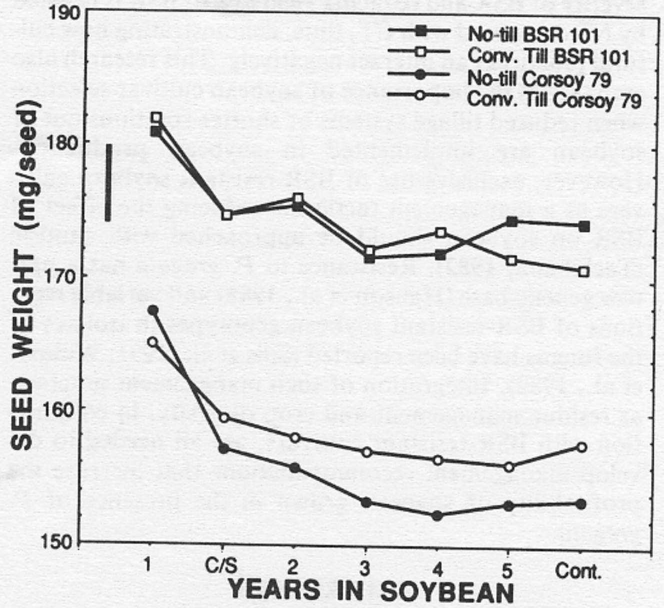


**Fig. 4. Seed weight of soybean as influenced by rotation, tillage, and cultivar, averaged over two N rates and 4 yr. Years in rotation of soybean are: 1 = first-year soybean after 5 yr of corn; C/S = soybean alternated annually with corn; 2, 4, 5, 5 = second-, third-, fourth-, and fifth-year soybean, respectively; Cont. = seventh-, eighth-, ninth-, and 10th-year soybean in 1989, 1990, 1991, and 1992, respectively. Vertical bar represents FLSD (0.10).**

symptoms, as well as yield loss due to BSR (Mengistu and Grau, 1987; Mengistu et al., 1987). The lack of foliar symptoms could also be attributed to the pathotype of *P. gregata* present in the field (Gray, 1972a; Mengistu and Grau, 1986).

Whiting and Crookston (1993) measured no yield differences between Hodgson 78 and BSR 101. The choice of BSR-susceptible cultivar may have masked the effects of BSR in this study. Cultivars of shorter relative maturity escape the yield reducing effects of BSR compared with longer maturity cultivars for a geographic region (Weber et al., 1966). The maturity of Hodgson 78 is 100 d and maturity group 1.4 (used by Whiting and Crookston, 1993) compared with 110 d and maturity group 2.1 for Corsoy 79 (used in this study) (Oplinger et al., 1993). BSR 101 (BSR-resistant), used in both studies to determine yield loss estimates, has a relative maturity of 105 d (maturity group 1.9). To accurately assess the influence of cultural practices on severity of BSR, comparisons must be between cultivars of similar maturity and yield potential.

We do agree with Whiting and Crookston (1993) that other factors can be contributing to the rotation effect. As mentioned previously in this paper, the yield of BSR 101 declines with an increased frequency of soybean in a rotation. However, severity of foliar symptoms expressed by BSR 101 were not correlated with the yield decline as they were with the BSR-susceptible cultivar (Corsoy 79). As suggested by Crookston et al. (1991), we believe yields of soybean would benefit from crop rotations with a minimum of 2 yr between soybean crops. As shown by our data and that of others, fields with a BSR history could benefit from crop rotation primarily due to a reduction in severity of BSR (Dunleavy and Weber, 1967; Kennedy and Lambert, 1981).

The effectiveness of crop rotation in lowering the severity of BSR and reducing yield loss to BSR is negated by NT compared with CT, thus, demonstrating how cultural practices can interact negatively. This research also emphasizes the importance of soybean cultivar selection when reduced tillage systems or shorter rotations out of soybean are implemented in soybean production. However, exclusive use of BSR-resistant soybean cultivars as a management tactic for reducing the effect of BSR on soybean should be approached with caution (Tachibana, 1982). Resistance to *P. gregata* has a narrow genetic base (Hanson et al., 1988) and variable reactions of BSR-resistant soybean genotypes to isolates of the fungus have been reported (Sills et al., 1991; Willmot et al., 1989). Integration of such management practices as residue management and crop diversity, in conjunction with BSR-resistant cultivars, are all needed to develop management recommendations that increase the profitability of soybean grown in the presence of *P. gregata*.

## REFERENCES


Adee, E.A., E.S. Oplinger, and C.R. Grau. 1994. Effect of nitrogen on severity of brown stem rot and yield of soybean. Proc. Wisconsin Fertilizer, Aglime, and Pest Manage. Conf. 33:287–294.

Allington, W.B., and D.W. Chamberlain. 1948. Brown stem rot of soybean. Phytopathology 38:793–802.

Christensen, B.T. 1986. Barley straw decomposition under field conditions: Effect of placement and initial nitrogen content on weight loss and nitrogen dynamics. Soil Biol. Biochem. 18:523–529.

Cook, R.J., M.G. Boosalis, and B. Doupnik. 1978. Influence of crop residues on plant diseases. p. 147–163. *In* W.R. Oschwald (ed.) Crop residue management systems. ASA Spec. Publ. 31. ASA, CSSA, and SSSA, Madison, WI.

Crookston, R.K., J.E. Kurle, P.J. Copeland, J.H. Ford, and W.E. Lueschen. 1991. Rotational cropping sequence affects yield of corn and soybean. Agron. J. 83:108–113.

Dunleavy, J. 1966. Factors influencing spread of brown stem rot of soybeans. Phytopathology 56:298–300.

Dunleavy, J., and C.R. Weber. 1967. Control of brown stem rot of soybeans with corn-soybean rotations. Phytopathology 57:114–117.

Epps, J.M., L.D. Young, and E.E. Hartwig. 1981. Evaluation of nematicides and resistant cultivar for control of soybean cyst nematode race 4. Plant Dis. 65:665–666.

Fehr, R., C.E. Caviness, D.T. Burmood, and J.S. Pennington. 1971. Stages of development descriptions for soybeans, *Glycine max* (L.) Merrill. Crop Sci. 11:929–931.

Gray, L.E. 1972a. Effect of *Cephalosporium gregatum* on soybean yield. Plant Dis. Rep. 56:580–581.

Gray, L.E. 1972b. Recovery of *Cephalosporium gregatum* from soybean straw. Phytopathology 62:1362–1364.

Hanson, P.M., C.D. Nickell, L.E. Gray, and S.A. Sebastian. 1988. Identification of two dominant genes conditioning brown stem rot resistance in soybean. Crop Sci. 28:41–43.

Hendrix, J.W., K.J. Jones, and W.C. Nesmith. 1992. Control of pathogenic mycorrhizal fungi in maintenance of soil productivity by crop rotation. J. Prod. Agric. 5:383–386.

Johnson, N.C., P.J. Copeland, R.K. Crookston, and F.L. Pfleger. 1992. Mycorrhizae: Possible explanation for yield decline with continuous corn and soybean. Agron. J. 84:387–390.

Kennedy, B.W., and J.W. Lambert. 1981. Influence of brown stem rot and cropping history on soybean performance. Plant Dis. 65:896–897.

Lund, M.G., P.R. Carter, and E.S. Oplinger. 1993. Tillage and crop rotation affect corn, soybean, and winter wheat yields. J. Prod. Agric. 6:207–213.

Meese, B.G., P.R. Carter, E.S. Oplinger, and J.W. Pendleton. 1991. Corn/soybean rotation effect as influenced by tillage, nitrogen, and hybrid/cultivar. J. Prod. Agric. 4:74–80.

Mengistu, A., and C.R. Grau. 1986. Variation in morphological, cultural, and pathological characteristics of *Phialophora gregata* and *Acremonium* sp. recovered from soybean in Wisconsin. Plant Dis. 70:1005–1009.

Mengistu, A., and C.R. Grau. 1987. Seasonal progress of brown stem rot and its impact on soybean productivity. Phytopathology 77:1521–1529.

Mengistu, A., C.R. Grau, and E.T. Gritton. 1986. Comparison of soybean genotypes for resistance to and agronomic performance in the presence of brown stem rot. Plant Dis. 70:1095–1098.

Mengistu, A., H. Tachibana, and C.R. Grau. 1991. Selective medium for isolation and enumeration of *Phialophora gregata* from soybean straw and soil. Plant Dis. 75:196–199.

Mengistu, A., H. Tachibana, A.H. Epstein, K.G. Bidne, and J.D. Hatfield. 1987. Use of leaf temperature to measure the effect of brown stem rot and soil moisture stress and its relation to yields of soybeans. Plant Dis. 71:632–734.

Nicholson, J.F., J.B. Sinclair, and P.N. Thapliyal. 1973. The effect of rate of planting on incidence of brown stem rot in soybean. Plant Dis. Rep. 57:269–271.

Nickel, S.E., R.K. Crookston, M.P. Russelle, and D. Macdonald. 1992. Root health affected by long-term corn and soybean rotation study. p. 152. *In* Agronomy abstracts. ASA, Madison, WI.

Oplinger, E.S., M.J. Martinka, J.M. Gaska, J.J. Blanch, E.T. Gritton, P.J. Flannery, C.R. Grau, and E.A. Adee. 1991. Wisconsin soybean variety test and Wisconsin soybean marketing board annual report. Univ. of Wisconsin-Madison Dep. of Agronomy Field Crops 27.33.

Oplinger, E.S., M.J. Martinka, J.M. Gaska, E.T. Gritton, P.J. Flannery, C.R. Grau, and E.A. Adee. 1992. Wisconsin soybean variety test and Wisconsin soybean marketing board annual report. Univ. of Wisconsin-Madison Dep. of Agronomy Field Crops 27.33.

Oplinger, E.S., M.J. Martinka, J.M. Gaska, G.C. Mayne, E.T. Gritton, P.J. Flannery, C.R. Grau, and E.A. Adee. 1993. Wisconsin soybean variety test and Wisconsin soybean marketing board annual report. Univ. of Wisconsin-Madison Dep. of Agronomy Field Crops. 27.33.

Parker, D.T. 1962. Decomposition of the field of buried and surface-applied cornstalk residue. Soil Sci. Soc. Am. Proc. 26:559–562.

Sills, G.R., E.T. Gritton, and C.R. Grau. 1991. Differential reactions of soybean genotypes to isolates of *Phialophora gregata*. Plant Dis. 75:687–690.

Sinclair, J.B., and P.A. Backman (ed.) 1989. Compendium of soybean diseases. 3rd ed. Am. Phytopathological Soc., St. Paul, MN.

Tachibana, H. 1982. Prescribed resistant cultivars for controlling brown stem rot of soybean and managing resistant genes. Plant Dis. 66:271–274.

Tachibana, H., A.H. Epstein, and B.J. Havlovic. 1989. Effect of four years of continuous cropping of maturity group II soybeans resistant to brown stem rot on brown stem rot and yield. Plant Dis. 73:846–849.

Tachibana, J., B.K. Voss, and W.R. Fehr. 1987. Registration of 'BSR 101' soybean. Crop Sci. 27:612.

Weber, C.R., J.M. Dunleavy, and W.R. Fehr. 1966. Influence of brown stem rot on agronomic performance of soybeans. Agron. J. 58:519–520.

Whiting, K.R., and R.K. Crookston. 1993. Host-specific pathogens do not account for the corn-soybean rotation effect. Crop Sci. 33:539–543.

Willmot, D.B., C.D. Nickel, and L.E. Gray. 1989. Physiologic specialization of *Phialophora gregata* on soybean. Plant Dis. 73:290–294.