Tramlines, Row Orientation, and Individual Row Effects on Solid-Seeded Soybean Plot Comparisons.

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ABSTRACT

Evaluations of solid-seeded soybean [*Glycine max* (L.) Merr.] and other crops in solid-seeded research plots without damage to plants from equipment can be difficult. This study was conducted to determine how individual rows of solid-seeded soybean plots responded to the additional space of tramlines within the border rows, and if the effects varied with row orientation or cultivar. Cultivars Evans, Hodgson 78, and Hardin were planted in the field in seven 0.18 m harvest rows and two 0.28 m border rows as plots in north-south (N-S) and east-west (E-W) orientations near Arlington, WI from 1983 to 1985. The additional space between harvest and border rows served as tramlines through the plots, and imparted 28% more area to each of the two outside harvest rows than each of the other harvest rows. East-west row orientation had a lodging rating 0.4 units (0 to 5 scale) greater than N-S orientation in 1984, but no yield difference. In 1985 N-S orientation outyielded E-W by 410 kg ha^{-1}. Final plant stands in the rows next to tramlines averaged 10% less than the five center plot rows, but yields averaged 18% greater in compensation for the tramlines. The second rows from tramlines also yielded higher than three center rows, and contributed an additional 7% average yield. Performance estimates using seven rows between the tramlines were no different than those from the center three rows, which were guarded from the tramlines by two rows on each side. Cultivar yields varied, but relative performance was not influenced by tramlines or row orientations. We conclude that tramlines can be used in a plot planting system for accurately testing cultivars or treatments in solid-seeded soybean.

PERFORMANCE testing of crop cultivars in solid-seeding can be done using a planting pattern containing tramlines to facilitate planting, spraying, and harvesting equipment. Tramlines consist of additional space between two rows, but less than a complete row, at specific intervals to accommodate wheel traffic through the planted crops. Tramlines are commonly used in intensive cereal grain management to prevent driving on plants, to allow more precise postemergence pesticide and fertilizer applications, and to aid traveling through the field (Oplinger et al., 1985). Skip row planting patterns have been used in soybean production for similar purposes (Beuerlein, 1987). With skip rows a double width row spacing between adjacent rows is left unplanted at specific intervals to accommodate wheel traffic through the planted crop. In both systems growth and yield responses of plants next to the tramlines or skipped rows compensate for the open space, resulting in yields comparable to solid-seeded stands.

Response to non-uniform row spacing may be affected by cultivar growth habit. In Iowa, soybean rows adjacent to a skipped row had 34% yield increases and all nonadjacent rows averaged an additional 4% (Wilkens and Whigham, 1986). In this same study, rows bordering the skipped row had 5 to 20% higher yields depending on the developmental stage when adjacent soybean plants received traffic. In Wisconsin, Temba (1983) found that rows adjacent to wheel traffic lanes in solid-seeded soybean compensated for most of the yield lost from the rows that were damaged from the wheel traffic.

Yield compensation occurs due to an increase in the number of pods plant^{-1}. When skips were introduced within soybean rows, adjacent rows compensated for yield depending on how much of the row was missing and by cultivar maturity (Pepper and Walker, 1988; Stivers and Swearingin, 1980). In a Wisconsin study yields of solid-seeded soybean cultivars were inflated 6% when the distance between border rows of adjacent plots was increased from 0.18 m to 0.48 m, however this did not influence relative yield differences among cultivars (Philbrook and Oplinger, 1988).

Row orientation influences light penetration into the crop canopy. However, reports of yield increases for a particular row orientation are contradictory. For many crops, N-S oriented rows usually have a yield advantage (Austenson and Larter, 1969). The advantage for N-S rows has been attributed to greater penetration and more uniform distribution of light throughout the crop canopy at solar noon (Santhirasegaram and Black, 1968). However, soybean has not shown a yield response to row orientation (Beuerlein, 1987). Leaf distribution in soybean is, however, influenced by row orientation and row width, and other factors which influence light penetration into the canopy (Blad and Baker, 1972). Shibles and Weber (1966) reported that soybean planting pattern did not influence the arrangement of leaves, that the most efficient plant arrangements present the greatest total canopy surface during the growing cycle. They also found that maximum yields required complete interception of solar radiation prior to reproductive stages. The interruption of a uniform soybean canopy surface by mod-

Dep. of Agronomy, 1575 Linden Dr., Univ. of Wisconsin-Madison, Madison, WI 53706. Contribution from the Dep. of Agronomy, Univ. of Wisconsin-Madison. Supported by Hatch project 1890. Received 15 April 1988. *Corresponding author.

Published in Agron. J. 81:498–502 (1989).

erate lodging increased light penetration, light interception, and yield (Shaw and Weber, 1967).

This research was conducted to evaluate the influence of tramlines on individual rows in a solid-seeded soybean research plot to determine if the non-uniformly spaced rows affect the entire plot yield, and to determine if comparisons of soybean cultivars are influenced by tramlines or by row orientation.

MATERIALS AND METHODS

Field studies were conducted from 1983 to 1985 at Arlington, WI (43°20′N, 89°25′W) on a Plano silt loam (fine-silty, mixed, mesic Typic Argiudoll) soil of high fertility status. Soybean was planted on 2 June 1983, 30 May 1984, and 7 May 1985 using a specially designed tractor-mounted planter (Oplinger et al., 1983) with nine rows. The center seven rows were spaced 0.18 m apart and a border spaced 0.28 m. With this arrangement rows on either side of the tramlines have 28% more area than those in the center of the plot. Soybean was seeded at 10.5 viable seeds m^{-1} of row. Plots were 7.6 m long and trimmed to 6.6 m when the soybean was between stages V1 and V3. Weeds were controlled with alachlor [2-chloro-2′,6′-diethyl-N-(methoxymethyl)acetanilide] at 2.2 kg ha^{-1} plus chloramben [3-amino-2,5-dichlorobenzoic acid] at 2.2 kg ha^{-1} applied immediately after planting, bentazon [3-(1-methylethyl)-(1H)-2,1,3 benzothiadiazin-4(3H)-one 2,2-dioxide] at 1.1 kg ha^{-1} plus crop oil concentrate (COC) [17% polyol fatty acid esters and polyetoxylated derivatives in mineral oil; Riverside Chemical Co., Sioux City, IA] at 2.4 L ha^{-1} (v/v) applied postemergence, and hand weeding when necessary. Individual rows of a plot were harvested using hand clippers and threshed with a stationary plot thresher.

In 1983 the experiment was designed as a split plot with four replications. Main plots, oriented north-south (N-S), were Evans, Hodgson 78, and Hardin cultivars selected to provide a range of plant maturities (90, 100, and 105 RM or maturity group 0, I, and II, respectively). Sub-plots consisted of row position. The first position (Row 1) was the border row on the western side of the plot. The second position (Row 2) was the first adjacent row on the inside of the tramline, and so on to the ninth position (Row 9), which was the border row on the eastern side of the plot. In 1984 and 1985 N-S and E-W row orientations were added as main plots. Cultivars were the sub-plots and row positions were sub-sub plots. For E-W oriented rows, Row 1 was the border row on the southern most side of the plot.

Data collected from field plots included early plant stands determined just after end trimming (between GS V1 and V3), late plant stands (determined between GS R7 and R8), grain yield adjusted to 130 g kg^{-1} moisture, and plant height at maturity. Lodging was rated at plant maturity on a scale from 1 (all plants erect) to 5 (all plants prostrate). Plant survival was calculated as the percentage of plants at harvest remaining from early plant stands.

All data were subjected to analyses of variance. Comparisons between treatment means were made using Fisher's protected LSD test and single degree of freedom comparisons. Data from 1983 were analyzed separately, whereas 1984 and 1985 data were combined. Further statistical analyses were completed to determine how cultivar comparisons were affected when evaluations were made using the seven center harvest rows, the center five rows, and the center three rows.

RESULTS AND DISCUSSION

The combined analyses of variance indicated that most variables differed between years (Table 1). Except for plant survival, most values were higher in 1984 than in 1985.

A row orientation effect was found for lodging and row orientation interacted with years for grain yield and lodging (Table 1). In 1984 E-W orientation had a lodging rating of 2.3 vs. 1.9 for N-S orientation, but lodging did not differ with row orientation in 1985 (data not shown). Average yield of N-S oriented rows was greater in 1985 than E-W rows (Table 2). This differs from the results reported by Beuerlein (1987).

Cultivars differed for grain yield, plant height, and lodging (Table 1) in each year. Hardin was taller and

Table 1. Summary of significance levels for cultivars and row position data in 1983, and for row orientation, cultivars, and row position in 1984 and 1985.

Year	Source	Grain yield	Plant height	Lodging	Stand: Early	Stand: Late	Plant survival
1983	Replicaion	NS	NS	**	NS	NS	NS
	Cultivar (C)	**	**	**	*	**	NS
	Row Position (P)	**	NS	NS	**	**	NS
	C × P	NS	NS	NS	NS	NS	NS
	CV (%)	14.7	3.6	9.5	13.9	13.7	7.4
1984 to 1985	Year (Y)	*	**	*	*	NS	*
	Replication	NS	NS	NS	NS	NS	NS
	Row Orientation (O)	NS	NS	*	NS	NS	NS
	Y × O	*	NS	**	NS	NS	NS
	Cultivar (C)	**	**	**	NS	NS	*
	Y × C	NS	NS	**	NS	NS	NS
	O × C	NS	NS	NS	NS	NS	NS
	Y × O × C	NS	NS	NS	NS	NS	NS
	Position (P)	**	**	*	**	**	**
	Y × P	*	**	**	**	**	**
	O × P	NS	NS	**	*	*	NS
	Y × O × P	*	NS	NS	NS	NS	NS
	C × P	NS	*	NS	NS	NS	NS
	Y × C × P	NS	NS	NS	NS	NS	NS
	O × C × P	NS	NS	NS	NS	NS	NS
	Y × O × C × P	NS	*	NS	NS	NS	NS
	CV (%)	20.2	5.1	24.5	15.8	15.9	13.0

*,** Significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

Table 2. Yield, early and late plant stand, and lodging as influenced by row position and row direction in 1984 and 1985.

Row position	Yield 1984 N–S‡	Yield 1984 E–W§	Yield 1985 N–S	Yield 1985 E–W	Plant stand Early N–S	Plant stand Early E–W	Plant stand Late N–S	Plant stand Late E–W	Lodging† N–S	Lodging† E–W
	g row⁻¹				plants row⁻¹					
1	371	506	521	418	52	52	50	47	1.8	1.8
2	480	431	403	375	55	52	53	50	1.8	2.2
3	397	434	407	333	57	57	57	54	1.7	2.1
4	433	433	407	343	64	60	64	58	1.9	2.3
5	389	384	371	332	59	55	60	53	1.9	2.2
6	389	421	351	315	56	62	53	57	2.0	2.1
7	453	458	427	367	59	55	59	58	1.8	2.3
8	384	475	424	412	54	53	53	53	2.2	2.2
9	462	469	506	438	56	50	57	50	2.0	1.9
Mean	418	446	424¶	370¶	57	55	56	53	1.9¶	2.1¶
LSD (0.05)#	36	36	36	36	5	5	5	5	0.2	0.2

† Lodging score 1 = all plants erect to 5 = all plants prostrate.
‡ North-south oriented rows.
§ East-west oriented rows.
¶ Values are significantly different from each other at the 0.05 level of probability.
# LSD comparisons between rows within years and orientations.

yielded more in all year, and lodged more in 1983 than the other cultivars. Hodgson 78 yielded more than Evans in all years. Except for plant height in 1984 and 1985, cultivars did not influence the row position response for measured characteristics in any of the three years (Table 1). Therefore, we conclude that cultivar comparisons are not significantly affected by row position or row orientation, and data are combined over the three cultivars for this discussion.

Grain yield was affected by row position in all years of the study (Table 1). Average yield for plants in rows adjacent to tramlines (Row 1, 2, 8, and 9) was 18% higher than in the center five rows in all years (Fig. 1 and Table 3). The magnitude of this compensation is similar to that reported by Pepper and Walker (1988) where rows adjacent to within row skips had 19% higher yields. Row 1 and 9 (border rows) in 1984 and 1985 had higher yields than Row 2 to 8, and Row 2 and 8 had higher yields than the center five (Row 3 to 7) or the center three (Row 4 to 6) rows in all years (Fig. 1 and Table 3). In 1984 and 1985, plants in the second row in from the tramline (Rows 3 and 7) also had 7% higher yields when compared with the center three rows. Temba (1983), and Wilkens and Whigham (1986) also found that yield compensation extended beyond the rows adjacent to wheel traffic.

Grain yield of plots did not differ when yield was determined using different numbers of harvest rows in 1983 (Table 4), but in 1984 and 1985 yield determined using the center five rows was higher than when all seven or the center three rows were used. Yields were inflated when calculated from only the center five rows because of the higher yields of Row 3 and 7, which were not assessed any additional area. Rows 2 and 8 dilute yield when the additional area of the tramlines are considered, because full compensation for the

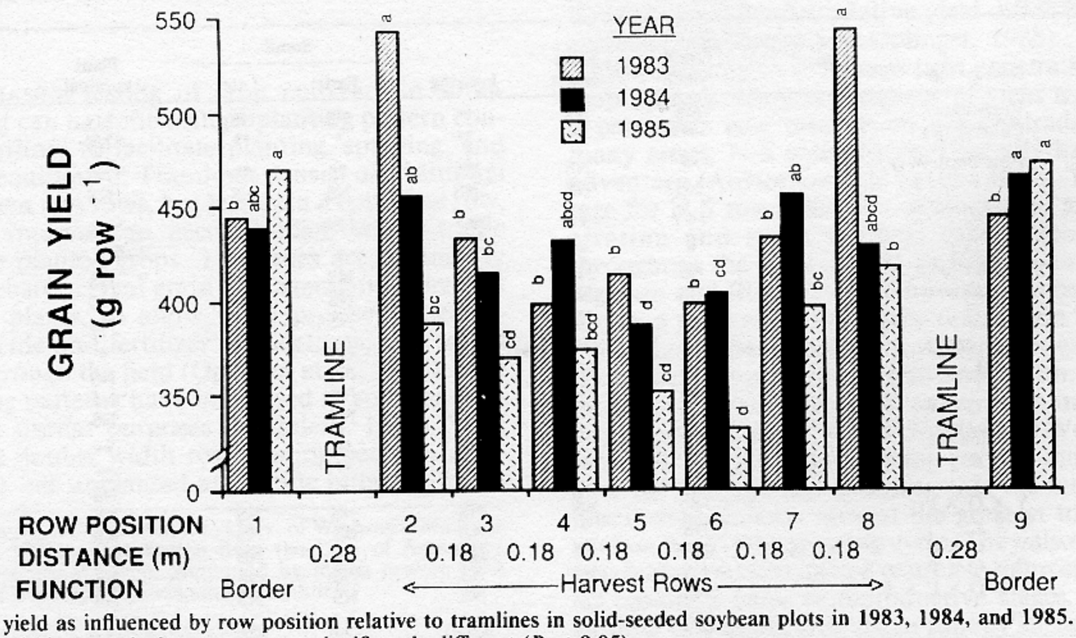

Fig. 1. Grain yield as influenced by row position relative to tramlines in solid-seeded soybean plots in 1983, 1984, and 1985. Bars with the same letter within a particular year are not significantly different ($P < 0.05$).

Table 3. Single degree of freedom comparisons for row positions.

Comparison of rows	Year	Grain yield 83	Grain yield 84–85	Plant height 84–85	Lodging 84–85	Stand Early 83	Stand Early 84–85	Stand Late 83	Stand Late 84–85	Plant survival 84–85
1 and 9 vs. 2 to 8		NS	+**†	+**	−**	−**	−**	−**	−**	NS
1, 2, 8, and 9 vs. 3 to 7		+**	+**	+**	NS	NS	−**	NS	−**	NS
2 and 8 vs. 3 to 7		+**	+**	+**	NS	NS	−**	NS	−**	NS
2 and 8 vs. 4 to 6		+**	+**	+**	NS	NS	−**	NS	−**	NS
3 and 7 vs. 4 to 6		NS	+*	NS	−*	−*	−*	NS	NS	NS
error mean squares (1983 df = 36, 1984–85 df = 288)		4329	6971	0.002	0.2	93	78	86	75	163

*,** Significant at the 0.05 and 0.01 level of probability, respectively. NS = Non-significant.
† The sign indicates whether the first comparison category was less than (−) or greater than (+) the second.

Table 4. Effect of harvest row number on selected variables.

Number of rows inside tramlines	Year	Grain yield 83	Grain yield 84–85	Plant height 83	Plant height 84–85	Lodging†‡ 83	Lodging†‡ 84	Lodging†‡ 85	Plant population Early‡ 83	Early‡ 84	Early‡ 85	Late‡ 83	Late‡ 84	Late‡ 85	Plant survival 83	Plant survival 84–85
		kg ha^{-1}		m					plants × 10^{-3} ha^{-1}						%	
All seven		3552	3202	0.89	0.81	2.0	2.2	1.9	577	499	418	564	483	415	98	98
Center five		3539	3337	0.89	0.81	2.0	2.1	2.0	603	544	450	590	527	446	98	98
Center three		3460	3238	0.88	0.80	2.1	2.1	2.0	625	557	453	606	534	448	97	98
LSD (.05)		NS	37	NS	NS	NS	0.1	0.1	15	9	9	18	9	9	NS	NS
CV (%)		3.8	2.8	1.4	1.1	9.7	6.1		2.9	3.3		3.6	3.5		1.6	2.1

† Lodging score 1 = all plants erect to 5 = all plants prostrate.
‡ A row number × year interaction occurred for these variables in 1984 to 1985, therefore data is presented separately by years.

additional 28% area is not made by these rows alone. Therefore, yield estimates from the center seven rows adjusted for the extra area provided by the tramlines were not different from those obtained using the center three harvest rows only. The center three rows are guarded from the tramlines by two rows on either side and do not significantly differ from one another (Fig. 1).

Early and late plant stands were affected by row position in all years of the study, and row position affected plant survival in 1984 and 1985 (Table 1). Comparisons for early plant stands indicated that the rows next to the tramlines had fewer plants than the center five rows in 1984 and 1985, but not in 1983 (Table 3). Late plant stands averaged 10% fewer plants per row in rows bordering the tramlines (56) than any of the center five rows (62). Beuerlein (1987) suggested that on a field scale using a skip row system, rows adjacent to the skip should be seeded at a slightly higher rate to take advantage of the additional area. In our study, seeding rate was constant at 10.5 seeds m^{-1} of row. However, since rows next to the tramlines (Row 1, 2, 8, and 9) had more area, seeding density in these rows was 28% less than in the center five rows. Late plant populations in the center seven rows averaged 7% less than in the center five rows when compared on an area basis (Table 4). In our study, yield compensation occurred even though plant stands were lower in rows next to tramlines.

Differences in plant height among row positions were found in 1984 and 1985, but not in 1983 (Table 1). In 1984 and 1985 plants in rows next to the tramlines were taller than plants in all other rows (Table 3). Evans had the tallest plants in Row 1 and 2, while Hardin had the tallest plants in Row 8 and 9, resulting in the significant cultivar × row position interaction for plant height in 1984 and 1985.

Border rows lodged less than the harvest rows in 1984 and 1985, but Row 2 and 8 were not different from Row 3 to 7 (Table 3). Row 3 and 7 also had less lodging than the center three rows. However, when data from individual rows are combined and lodging comparisons made across the entire plot, lodging scores did not differ by more than 0.1 units using the 1 to 5 scale (Table 4).

Row orientation by row position interactions occurred in 1984 and 1985 for early plant stand, late plant stand, and lodging (Table 1). Early and late plant stands varied to a small extent in rows next to tramlines, but were higher and nearly uniform in the center five rows regardless of row orientation (Table 2). Rows on the east side of the plots next to the tramline (Row 8 and 9) in the N-S orientation lodged to a greater extent than most other rows. Row 7, which was the highest yielding row not adjacent to tramlines (Fig. 1), may have benefited from the extra light penetration resulting from the moderately higher lodging of the adjacent border rows. This supports previous observations by Shaw and Weber (1967). Plants in Row 1 and 9 had less lodging than plants in Row 2 to 8 in E-W orientations, but not in N-S orientations (Table 2).

CONCLUSIONS

Results from these studies illustrate that presence of tramlines may influence the performance of soybean plants in rows bordering the tramlines. Plants in rows adjacent to tramlines generally were taller and had higher yields. Slight breaks in a uniform canopy from differential row lodging around tramlines also helped impart yield compensation to the second rows inside the tramlines. Yield compensation from the adjacent rows was not equivalent to the additional 28% area allocated to them, but the yield compensation from the first two rows on the inside of tramlines did fully compensate. Total yield on an area basis of all seven center rows was equivalent to that of the center three rows, which were guarded by two rows on each side of the tramlines. Yield determinations using the center five harvest rows were inflated by the undiluted yield compensation provided by the second harvest rows in from the tramlines. Plants in N-S rows demonstrated a yield advantage over E-W rows in 1985, but not in 1984. Row orientation affected lodging and a related grain yield response from certain rows, but was not different for the three cultivars tested. Cultivar yield comparisons due to row position or orientation were not demonstrated even though there were some differences in plant heights. The effects of row position on measured agronomic characteristics were not present when data was averaged over all harvest rows. Since this is the normal procedure used for testing performance of cultivars or other treatments, we conclude that tramlines can be used effectively in a plot planting system for evaluating solid-seeded soybean.

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