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Spacing Pattern and End-Trimming Effects on Solid-Seeded Soybean Plot Comparisons

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ABSTRACT

Planting soybean [*Glycine max* (L.) Merr.] in solid stands increases grain yields for many producers. Testing techniques that simplify plot work but separate the effects of adjacent plots in solid-seeded soybean have not been described. This study was conducted to determine the influence of plot planting patterns and time of end-trimming on soybean cultivar comparisons in a solid-seeded system. The effects of three planting patterns and end-trimming at two stages of growth on yield, yield components, and agronomic characteristics of six cultivars were investigated in field studies conducted near Arlington, WI, from 1982 through 1984. All patterns had seven 0.18-m harvest rows plus a border row spaced 0.28 m from each of the outside harvest rows that created a tramline through the plot. Yields of cultivars were inflated 6% when the distance between border rows of adjacent plots was increased from 0.18 m in Pattern 1 to 0.48 m in Pattern 2; however, relative yield differences among cultivars were consistent. Adding an additional border row using a common cultivar (Pattern 3) increased the distance between harvest rows of adjacent plots without increasing the distance between their borders. Soybean planted using Pattern 3 performed more consistently with respect to lodging, plant height, and yield than when either of the other patterns was used. Plot yields were inflated an average of 10% when plot ends were not end-trimmed late in the season near plant maturity, as opposed to early season end-trimming only. Cultivars did not respond uniformly to end-trimming in 1983. Final plant density, pods per plant, and seed weight averaged 55, 60, and 6% more in the plot ends than in the middles, while the number of seeds per pod was unchanged. Response of pods per plant to end effects was greater for 'Hardin' and 'Corsoy 79' in 1982, and 'Hodgson 78' in 1984 than for the other cultivars. Techniques for solid-seeded soybean plot comparisons are improved by using additional border rows to separate plots and by end-trimming at or near harvest maturity.

In recent years a significant number of soybean growers have shifted from soybean production in wide rows to narrow rows (row spacings less than 0.76 m) and solid stands (row spacings less than 0.25 m) because of significant yield advantages (Cooper, 1977; Costa et al., 1980; Oplinger, 1982). It has been estimated that up to 40% of Wisconsin's soybean hectarage has been solid-seeded (Oplinger, 1982). Solid-seeded soybean plot evaluations can be difficult, particularly if plant lodging is significant. Philbrook and Oplinger (unpublished data) found that the use of tramlines in solid-seeded plot planting patterns was helpful in facilitating planting, spraying, and harvesting equipment without affecting whole-plot comparisons.

There are conflicting reports regarding the importance of border effects. It has been suggested that removal of border rows between adjacent plots is more important in southern states than in northern states (Garber and Odland, 1926; Hanson et al., 1961; Hartwig et al., 1951). Hartwig et al. (1951) concluded that multiple-row plots and the discarding of border rows were necessary to evaluate soybean cultivar performance in wide rows. Similar observations have been made by other investigators for other crops (Anderson, 1979; Arny, 1922; Hulbert and Remsberg, 1927). Hanson et al. (1961) reported that competition between yield rows and border rows is usually additive in nature, and that competition effects could be minimized with common border varieties. However, Thorne and Fehr (1970) showed nonequivalent competition from 'Hark' and 'Chippewa 64' soybean border cultivars in 0.96-m rows compared to bordering single-row plots of the same cultivar or strain. Barley (*Hordeum vulgare* L.) border rows were successful in controlling border effects from adjacent alleys in pea (*Pisum sativum* spp. *arvense* L. Poir) plots (Anderson, 1979). Discarding border rows to eliminate border effects was accepted as a standard technique by the American Society of Agronomy in 1933 (Kiesselbach, 1933).

End trimming soybean plots prior to harvest has long been used to control border effects from alleyways along the ends of plots (Garber and Odland, 1926; Hartwig et al., 1951). Probst (1943) demonstrated that border effects from 0.91-m end alleyways could inflate yields in the first 0.3 m of 0.76-m row plots, and all cultivars did not respond equivalently to these border effects. Wilcox (1970) reported that the effects of 1.8-m end alleyways could extend into the first 0.6 m of the plot ends for Maturity Group I to IV cultivars that were not trimmed after growth stage R6. Boerma et al. (1976) examined border effects in rows spaced 0.96 m apart from 0.91-m end alleyways. They removed 0.46 m of the plot ends at the V3, R2, R7, and R8 growth stages. Yield of soybean in the next 0.3-m segment of the remaining plot area was significantly inflated if the end-trimming occurred prior to physiological maturity. In a second study, Boerma et al. (1976) also demonstrated that failure to end-trim 0.61 m from soybean plots at maturity significantly changed cultivar yield comparisons within and among Maturity Groups V to VIII. They concluded that end-trimming 0.76 m from both ends of soybean plots at or after physiological maturity should provide reliable plot yields and avoid interactions among genotypes in the southern United States. End effects have been consistently shown to be greater with cultivars of later maturity within a region (Boerma et al., 1976; Probst, 1943; Wilcox, 1970). Wilcox (1970) and Boerma et al. (1976) attributed the majority of yield inflation from end effects to greater seed numbers, and the latter demonstrated a relationship between plant height and yield inflation.

Most of the literature on plot bordering and end-trimming is either outdated (Garber and Odland, 1926; Kiesselbach, 1933), applies to crops other than soybean (Anderson, 1979; Arny, 1922; Hulbert and Remsberg, 1927), or was conducted under lower yielding wide-row environments (Boerma et al., 1976; Garber and Odland, 1926; Hartwig et al., 1951; Probst,

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1943; Thorne and Fehr, 1970; Wilcox, 1970). This study was initiated to evaluate border and end-trimming techniques for solid-seeded soybean plots, in the northern soybean growing regions of the Midwest. The first objective was to determine the influence of spacing between plots and border row numbers on the harvest area in plots incorporating tramlines. A second objective was to determine the influence of early versus late-season end-trimming. A final objective was to determine if plot spacings or end-trimming techniques would change yield rank or otherwise influence cultivar comparisons.

MATERIALS AND METHODS

Field studies were conducted from 1982 to 1984 near Arlington, WI (43°20′N, 89°25′W), on a Plano silt loam soil (fine-silty, mixed, mesic Typic Argiudoll) that was high in fertility status. Plots were planted on 10 May 1982, 17 May 1983, and 12 May 1984, using a specially designed plot planter (Oplinger et al., 1983) and consisted of nine or 11 rows as discussed later. Plots were seeded at 11.7 seeds per meter of row, or approximately 656 500 seeds ha^{-1}. The seven center rows of all plots were harvested with an ALMACO[1] plot combine (Allen Machine Co., Nevada, IA).

[1] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the Wisconsin Agric. Exp. Stn., and does not imply its approval to the exclusion of other products that may also be suitable.

The experiment was designed as a split-split plot with four replications. Main plots consisted of varying the distance and number of border rows between adjacent plots, hereafter referred to as planting patterns. Three planting patterns (Fig. 1) were compared. All patterns had seven 0.18-m center harvest rows plus a border row spaced 0.28 m from each of the outside harvest rows. The wider spacings served as tramlines for equipment access through the solid-seeded plots. Plots in Planting Pattern 1 were planted on 1.8-m centers with 0.18 m between border rows of adjacent plots. Pattern 2 plots were identical to those of Pattern 1 except that they were planted on 2.1-m centers, which gave 0.48 m between adjacent plots. Pattern 3 plots were planted on 2.2-m centers with an additional border row added to both sides to spread out harvest rows of adjacent plots, but maintain 0.18 m between border rows of adjacent plots. The additional border row on each side of all plots in Pattern 3 was bulk planted using the cultivar Hodgson 78. Each main plot was bordered on each side by an additional plot of the same pattern to maintain uniform treatments between main plot levels.

Subplots consisted of six cultivars selected to provide a range of maturities, plant heights, lodging characteristics, and canopy types (Table 1). Sub-subplots consisted of two end-trimming treatments. All plots were planted 7.6 m long and were trimmed to 6.6 m when the soybean was between growth stages V1 and V3. Half of the plots received a second hand-end-trimming just prior to harvest that removed another 0.3 m from both ends of each harvest row, or 0.82 m^2 of the plot area. An equivalent area (0.82 m^2) was removed from the middle of each plot to compare yield components between the harvested (middle) segments and the end seg-

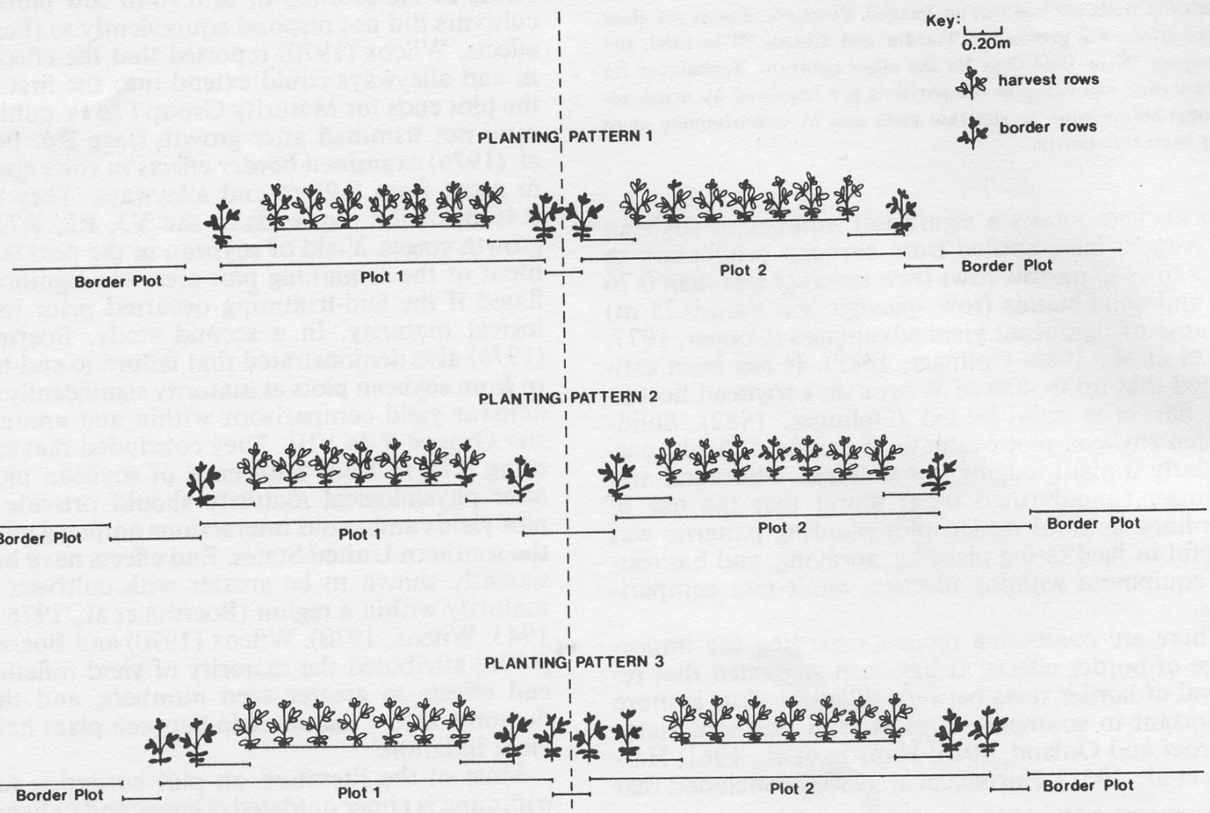

Fig. 1. Planting patterns diagrammed. In all plots there are seven harvest rows spaced 0.18 m apart, and a border row on each side of the harvest rows spaced 0.28 m. The wider spaces between the harvest and border rows serve as tramlines through the solid-seeded plots. In Planting Pattern 3, an additional common cultivar border row, spaced at 0.18 m, was added to each side of the plots. The spaces between the border rows of adjacent plots are 0.18, 0.48, and 0.18 m for Patterns 1, 2, and 3, respectively.

ments, hereafter referred to as middles and ends, respectively. Border plots were also included at both ends of each main plot so that alley width would not exceed 1.02 m throughout the season. Harvested area for plots end-trimmed early only were 8.98 m^2, and for plots end-trimmed early and late, 7.34 m^2 (also excluding the sampled area removed from the middle segments).

All plots in all years received a tank mixed application of alachlor [(2-chloro-*N*-(2,6-diethylphenyl)-*N*-methoxymethyl) acetamide] at 2.2 kg ha^{-1} plus chloramben [3-amino-2,5-dichlorobenzoic acid] at 2.2 kg ha^{-1} immediately after planting for weed control. Postemergence applications of bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-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.,[1] Sioux City, IA] at 2.4 L ha^{-1} (v/v) were made to achieve additional broadleaf weed control. Hand weeding was also performed when necessary to maintain a weed free environment.

Data collected from field plots included grain yield adjusted to 130 g kg^{-1} moisture, and plant height. Lodging was rated on a scale from 1 (all plants erect) to 5 (all plants prostrate). Seed weights were determined from the collected grain samples.

Yield components were measured from the plot segment samples to characterize the effects of alleyways on plants in the end segments as opposed to plot middles. Plants per hectare, pods per plant, seeds per pod, and seed weight were determined. Yield components were then analyzed, with main plots again as planting patterns, and cultivars as subplots, but sub-subplots were plot segments (ends versus middles) for the yield component analyses.

The maximum *F*-ratio test was used to determine homogeneity of variances for all variables across years. All data were subjected to the appropriate analyses of variance. Comparisons between treatment means were made using Fisher's protected LSD test. Correlations among yield components were determined. Yield components were also used to estimate plot yield.

Table 1. Description of cultivars based on average performance in Wisconsin's southern tests, 1980 and 1981.

Cultivar	Maturity group	Yield	Plant height	Lodging score†	Canopy type
		kg ha^{-1}	m		
Evans	0	3600	0.90	2.1	Thin line
Simpson	0	3940	0.84	1.9	Thin line
Hodgson 78	I	4150	0.97	2.5	Thin line
Hardin	I	4570	1.09	3.4	Thin line
Wells II	II	3970	1.04	1.8	Thin line
Corsoy 79	II	4370	1.13	3.6	Slightly branched
LSD (0.10)		340			

† 1 = Erect, 5 = prostrate.

RESULTS AND DISCUSSION

Agronomic Characteristics

Variances for nearly all traits were heterogeneous across years using the maximum *F*-ratio test. The data were therefore analyzed separately for each year (Tables 2 and 3).

Yields were higher in Pattern 2 than in the other two planting patterns in all 3 yr (Table 4), but in 1984, Pattern 2 was significantly different from Pattern 1 only at $P < 0.10$. Yield was inflated an average of 6% (228 kg ha^{-1}) when the space between adjacent border rows was increased from 0.18 m (Pattern 1) to 0.48 m (Pattern 2).

Philbrook and Oplinger (unpublished data) demonstrated that, in a planting pattern identical to Pat-

Table 2. Summary of analysis of variance for yield and agronomic characteristics sampled from the total plot area.

Year	Source	df	Yield	Plant height	Lodging	Seed size
1982	Replications	3	*	*	†	*
	Planting patterns (P)	2	**	NS	NS	NS
	Cultivars (C)	5	**	**	**	**
	P × C	10	NS	NS	NS	NS
	End trimmings (T)	1	**	NS	NS	NS
	P × T	2	NS	NS	NS	NS
	C × T	5	NS	NS	NS	†
	P × C × T	10	NS	NS	NS	NS
	CV, %		5.8	0.1	9.7	3.2
1983	Replications	3	**	NS	*	NS
	Planting patterns (P)	2	**	*	NS	NS
	Cultivars (C)	5	**	**	**	**
	P × C	10	NS	NS	NS	NS
	End trimmings (T)	1	*	NS	NS	NS
	P × T	2	NS	NS	NS	NS
	C × T	5	*	NS	NS	NS
	P × C × T	10	NS	NS	NS	NS
	CV, %		13.0	0.1	3.1	4.2
1984	Replications	3	NS	†	NS	NS
	Planting patterns (P)	2	*	NS	†	NS
	Cultivars (C)	5	†	**	**	**
	P × C	10	NS	NS	*	NS
	End trimmings (T)	1	**	NS	NS	NS
	P × T	2	†	NS	NS	NS
	C × T	5	NS	NS	NS	*
	P × C × T	10	NS	NS	NS	NS
	CV, %		5.4	4.6	26.3	3.2

*,** Significant at the 0.05 and 0.01 levels, respectively. NS = not significant.
† Significant at the 0.10 level.

Table 3. Summary of analysis of variance for yield components sampled from end versus middle plot segments.

Year	Source	df	Plants per hectare	Pods per plant	Seeds per pod	Seed size
1982	Replications	3	NS	*	NS	†
	Planting patterns (P)	2	NS	NS	NS	NS
	Cultivars (C)	5	*	**	*	**
	P × C	10	NS	NS	NS	NS
	Plot segments (S)	1	**	**	**	**
	P × S	2	NS	NS	NS	NS
	C × S	5	NS	*	NS	**
	P × C × S	10	NS	†	NS	†
	CV, %		24.1	17.9	5.2	2.8
1983	Replications	3	NS	NS	*	NS
	Planting patterns (P)	2	*	NS	NS	NS
	Cultivars (C)	5	NS	**	NS	**
	P × C	10	NS	NS	NS	NS
	Plot segments (S)	1	**	**	NS	**
	P × S	2	NS	NS	NS	NS
	C × S	5	NS	NS	NS	NS
	P × C × S	10	**	NS	NS	NS
	CV, %		29.3	35.2	8.3	4.5
1984	Replications	3	NS	NS	NS	NS
	Planting patterns (P)	2	NS	NS	NS	NS
	Cultivars (C)	5	NS	**	*	**
	P × C	10	NS	NS	NS	NS
	Plot segments (S)	1	*	**	NS	**
	P × S	2	NS	NS	NS	NS
	C × S	5	†	†	NS	*
	P × C × S	10	NS	NS	NS	NS
	CV, %		31.8	23.6	10.7	4.7

*,** Significant at the 0.05 and 0.01 levels, respectively. NS = not significant.
† Significant at the 0.10 level.

Table 4. Yield comparisons among three planting patterns and six cultivars at Arlington, WI, 1982, 1983, and 1984.

	Planting patterns											
	1982			1983			1984			Mean		
Cultivar	1	2	3	1	2	3	1	2	3	1	2	3
	kg ha^{-1}											
Hardin	4148	4622	4251	4031	4209	3912	4087	4333	4090	4089	4388	4085
Corsoy 79	4017	4297	4203	3689	4256	3868	4180	4067	3958	3962	4207	4010
Hodgson 78	3885	4065	3828	3757	3640	3188	4041	4318	3847	3894	4008	3621
Wells II	3599	4042	3781	3522	3604	3582	3770	3963	3886	3630	3870	3741
Simpson	3703	4045	3652	3348	3777	3232	3974	4047	3744	3675	3956	3543
Evans	3771	3859	3781	3334	3611	2890	4000	4210	3818	3702	3893	3496
Mean	3855	4155	3916	3614	3850	3446	4009	4156	3886	3826	4054	3749
LSD (0.05)†		238			172			207				
LSD (0.10)		133			97			116				

† For making yield comparisons among planting pattern means within a particular year.

Table 5. Lodging scores for six cultivars and three planting patterns in 1984.

	Planting pattern			
Cultivar	1	2	3	Mean
	Lodging score†			
Hardin	2.9a‡	1.9a	2.8a	2.5a§
Corsoy 79	2.0b	1.8a¶	2.0a¶	2.3ab
Hodgson 78	1.9bc	1.9a	2.0b	1.9b
Evans	1.4cd	1.5ab	1.4bc	1.4c
Wells II	1.4cd	1.0b	1.3c	1.2c
Simpson	1.0d	1.3ab	1.0c	1.1c
Mean	1.8	1.6‡	1.9	1.7

† 1 = Erect, 5 = prostrate.
‡ Values followed by the same letter are not significantly different within a pattern($P < 0.05$).
§ Values followed by the same letter are not significantly different across patterns ($P < 0.01$).
¶ Indicates patterns that are significantly different within a cultivar ($P < 0.05$).
# Indicates a significantly lower value among patterns ($P < 0.05$).

tern 1, a yield compensation equivalent to the area of the tramlines occurred in the first two adjacent harvest rows. However, when the space between adjacent plots was increased (Pattern 2) it was apparent from this study that the single border row could not prevent additional yield increases in the harvest rows. Although yields were inflated in Pattern 2, no interaction was identified between planting patterns and cultivars (Tables 2 and 4). In the absence of cultivar × pattern interactions, Hartwig et al. (1951) pointed out that yields could be mathematically adjusted. It was concluded that comparisons among cultivars would remain the same from one planting pattern to another, similar to the simple additive effects reported by Hanson et al. (1961).

Averaged over years, Pattern 1 outyielded Pattern 3 by 77 kg ha^{-1}, but in 1982 this trend was reversed. Patterns 1 and 3, however, significantly differed only at $P < 0.10$ in 1983 and 1984. The addition of a common cultivar border row (Pattern 3) spread the harvest rows of adjacent plots further apart but prevented yield inflations (Table 4). Differential competition or other influences from neighboring plot cultivars are another advantage for increasing the distance between harvest rows of adjacent plots. The common cultivar border row also standardized the influence of bordering rows on all plots. Although Thorne and Fehr (1970) reported differential yield responses from cultivars or strains to different bordering cultivars in wide rows, Hanson et al. (1961) concluded that common bordering cultivars provide equivalent competition. Additional border rows may provide even better control of nonuniform competition from neighboring plots. However, this requires additional land area and seed, and wider planting equipment, which is difficult to transport to outlying sites. The common cultivar border row added no additional seed to packets holding the cone-distributed portion of the seed, because a bulk ground-driven unit was used. Pattern 3, therefore, serves the purpose of widening the distance between harvest rows, providing more uniform competition, and maintaining a compact and convenient plot planting system. The use of a distinctive phenotype for the additional border row visually separates the plot, similar to Anderson's (1979) use of barley to border pea plots. Since soybean planted in Pattern 3 was similar in yield as that planted in Pattern 1, it can be assumed that individual row responses are also similar to those observed by Philbrook and Oplinger (unpublished data).

Significant plant height differences occurred in 1983 (Table 2) between Pattern 1, averaging 0.99 m, and Patterns 2 and 3, averaging 0.97 m (data not shown). In 1984, lodging was also influenced by planting patterns ($P<0.10$), and by an interaction among cultivars and planting patterns ($P<0.05$) (Tables 2 and 5). This occurred primarily because in Pattern 2, 'Hardin' and 'Corsoy 79', generally poor standing cultivars, had lodging scores similar to the other four cultivars, whereas in Patterns 1 and 3, they had average lodging scores of 2.9 and 2.5, respectively, as opposed to a range of 1.0 to 2.0 for the other four cultivars.

Plant height advantages measured in 1983 for Pattern 1 accompanied slightly higher yields over Pattern 3 ($P<0.10$). Boerma et al. (1976) also showed how plant height described a large portion of the yield inflation variation between some cultivars not receiving end-trimmings. This, along with lodging differences and interactions seen in 1984, presents difficulties with cultivar comparisons among planting patterns. Because some soybean growers place heavy emphasis on the ability of a cultivar to stand well through harvest, accurate evaluations of lodging and plant height are necessary. If cultivars were compared for lodging on the basis of performance in Pattern 2 in 1984, known differences in stem stiffness would not have been ap-

Table 6. Yield of six cultivars as influenced by developmental stage when end-trimmed in 1982, 1983, and 1984.

	Developmental stage at end-trimming											
	1982			1983†			1984			Mean		
Cultivar	V1-V3	V1-V3 + R8	Mean	V1-V3	V1-V3 + R8	Mean	V1-V3	V1-V3 + R8	Mean	V1-V3	V1-V3 + R8	Mean
	kg ha^{-1}											
Hardin	4501	4180	4341a‡	4374a¶	3728ab¶	4051	4370	3970	4170a§	4415	3959	4187
Corsoy 79	4403	3942	4173b	3794b	4083a	3939	4281	3855	4068ab	4159	3960	4060
Hodgson 78	4129	3724	3927c	3592bc	3465bc	3528	4341	3796	4069ab	4021	3662	3842
Wells II	4028	3587	3807c	3625bc	3514bc	3570	4040	3690	3865c	3898	3597	3747
Simpson	4030	3570	3800c	3628bc	3276c	3452	4113	3730	3922bc	3924	3525	3725
Evans	4127	3484	3806c	3323c	3233c	3278	4243	3776	4009abc	3898	3498	3698
Mean	4203¶	3748¶		3723	3550		4231¶	3803¶		4053	3700	

† A cultivar × end-trimming interaction occurred in 1983.
‡ Cultivars within a particular year, and within end-trimmings, followed by the same letter are not significantly different ($P < 0.05$).
§ Cultivars within a particular year, followed by the same letter are not significantly different ($P < 0.10$).
¶ Indicates end-trimming treatments within a particular year, and within or across cultivars, that are significantly different ($P < 0.05$).

Table 7. Plant population comparisons among six cultivars in plot middles and plot ends in 1982, 1983, and 1984.

	1982			1983			1984†		
Cultivar	Middles	Ends	Mean‡	Middles	Ends	Mean‡	Middles	Ends	Mean‡
	plants ha^{-1} (× 1000)								
Evans	565	883	594a§	471	977	518	452ab	515ab	457
Simpson	432	846	470b	448	1032	502	427ab¶	592a¶	442
Hodgson 78	465	722	489b	440	808	474	487a	442bc	483
Hardin	516	635	527ab	458	836	492	461ab	482bc	463
Corsoy 79	481	581	490b	413	932	461	388b	413c	390
Wells II	471	670	489b	456	930	500	430ab¶	523ab¶	439
Mean	488¶	723¶	510	448¶	919¶	491	441	495	446

† An interaction between cultivars and plot segments occurred in 1984 ($P < 0.10$).
‡ Weighted for the total plot area represented, i.e., 91% middles, 9% ends.
§ Values followed by the same letter are not significantly different in 1982 ($P < 0.05$), and in 1984 ($P < 0.10$).
¶ Indicate values for plot segments that are significantly different, across cultivars in 1982 ($P < 0.05$), and within cultivars in 1984 ($P < 0.10$).

parent. Thus, soybean in Pattern 3 performed more consistently with respect to lodging, plant height, and yield than soybean planted in either Pattern 1 or 2.

Although there were significant differences among cultivars for most traits (Tables 2 and 3), yield in 1984 differed only at the 10% level of significance (Table 2). Yield rank of the cultivars was similar each year (Table 6).

Yields were significantly lower when plots received an additional end-trimming just prior to harvest (Table 2). Plot ends, when not trimmed at harvest time, inflated yields 12, 5, and 10% in 1982, 1983, and 1984, respectively (Table 6). The range of yield inflation from plot ends was 7 to 16% and 9 to 13%, and was reasonably uniform among cultivars in 1982 and 1984, respectively. This uniform yield inflation, however, differs from previous reports of nonuniform end effects among cultivars (Boerma et al., 1976; Probst, 1943; Wilcox, 1970).

In 1983, yield was influenced by an interaction among cultivars and end-trimmings (Tables 2 and 6). Plot ends resulted in a 7% yield reduction for Corsoy 79 compared to a 17% yield increase for Hardin. Yield rank and relative differences among cultivars changed significantly (Table 6). No yield component exhibited a similar interaction in 1983.

Seed weights did not differ among end-trimmings from whole-plot seed samples, but cultivars interacted with end-trimmings in 1982 and 1984 (Table 2). Although no clear pattern for this interaction was elucidated, seed weight along with seed numbers may influence whole-plot comparisons, depending on the ratio of seeds from each plot segment obtained from random sampling.

Yield Components

Number of plants per hectare in 1983 was the only yield component to vary among planting patterns in any year (Table 3). In 1983, Pattern 2 had significantly fewer (447×10^3) plants per hectare than did Patterns 1 and 3 (average 512×10^3). This difference is difficult to explain, since each plot was planted in the same manner with the same number of seeds in the harvested rows. Damage during plot maintenance procedures, such as spraying postemergence herbicides, may have affected certain patterns more than others, but cultivars responded uniformly within patterns. In spite of lower populations, the yield of Pattern 2 still exceeded the yields of Patterns 1 and 3 in 1983, except for Hodgson 78, where Pattern 2 yielded less than Pattern 1 (Table 4).

Most yield components were different among cultivars (Table 3); however, seeds per pod differed only at $P < 0.11$ among the six cultivars in 1983. Plants per hectare also differed among cultivars in 1982, which was attributed to germination and emergence differences. However, all plot populations were considered adequate (Table 7).

On the average a greater number of plants survived in the plot ends than in the middles (Tables 3 and 7). In 1982, and especially in 1983, differences among plot

Table 8. Plot segment comparisons of seeds per pod, pods per plant, and seed weight for 1982, 1983, and 1984.

Year	Plot segments: Ends	Middles	LSD (0.05)
	Seeds pod^{-1}		
1982	2.8	2.7	0.1
1983	2.7	2.7	NS
1984	2.6	2.7	NS
	Pods plant^{-1}		
1982	45.8	23.4	3.6
1983	39.5	28.4	3.5
1984	41.0	26.9	2.3
	mg seed^{-1}		
1982	152.3	150.2	1.4
1983	144.3	131.7	2.1
1984	157.5	148.2	2.4

Table 9. Calculated yield estimates based on yield components from plot end versus middle segments, and actual whole plot yield in 1982, 1983, and 1984.

Year	Plot segment	Yield
		kg ha^{-1}
1982	Middles	4 410
	Ends	13 510
	Whole plot	3 975
1983	Middles	4 210
	Ends	12 110
	Whole plot	3 636
1984	Middles	4 360
	Ends	7 420
	Whole plot	4 017

segments for plants per hectare were due, in part, to an uneven distribution of seed in the planter cone. In spite of the higher populations, pods per plant and seed weight were also greater in the plot ends (Table 8 and Fig. 2), and seeds per pod increased in 1982 (Table 8) but remained the same in 1983 and 1984. Increases in pods per plant and plants per hectare represent large increases in seed numbers from the plot ends, as has been alluded to by others (Boerma et al., 1976; Wilcox, 1970). Linear correlations between pods per plant and plants per hectare over all group variables were only 0.18, 0.03, and −0.37 for 1982 through 1984, respectively. The 1982 and 1984 correlations were significant ($P < 0.05$ and 0.01, respectively). Within a plot area, however, linear correlations indicated that more plants per hectare were associated with fewer pods per plant, as would be anticipated. Pods per plant and plants per hectare were significantly correlated ($P<0.01$) in both the plot middles ($r = -0.61$, -0.68, and -0.60) and ends ($r = -0.35$, -0.34, and -0.67) for 1982 through 1984, respectively. However, end effects clearly are responsible for increasing or maintaining higher levels of all yield components. In 1984 when plant populations between plot segments were more comparable, other yield components still showed similar increases, and yield was inflated from end effects.

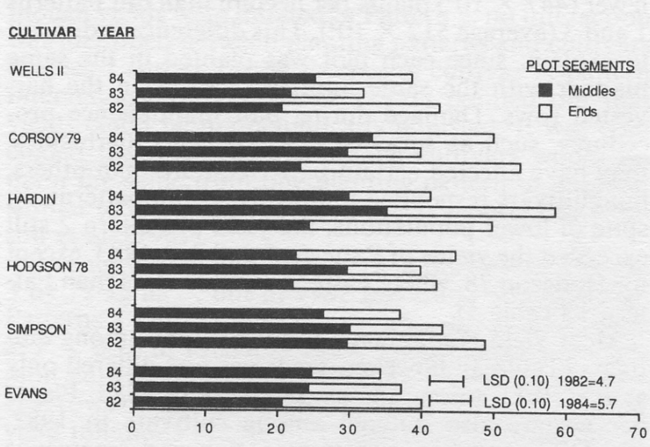

Fig. 2. Comparisons of pods per plant for six cultivars from plot middle and end segments in 1982, 1983, and 1984. LSDs apply to comparisons made among cultivars within a particular plot segment.

Plot segments interacted with cultivars for pods per plant in 1982 and 1984 (Fig. 2). In 1982, 'Simpson' had a much smaller increase in the number of pods per plant than did Hardin and Corsoy 79, which parallels previous indications that later maturing cultivars are more responsive to end effects (Boerma et al., 1976; Probst, 1943; Wilcox, 1970). In 1984, Hodgson 78 was the most responsive to end effects, but had not shown large responses in the previous 2 yr. However, interactions among cultivars and end-trimmings for yield occurred only in 1983 and not in 1982 or 1984. Therefore, number of pods per plant does not account totally for overall yield variation.

When yields were calculated from components obtained from plot middles, they were relatively close to the actual yield, while yields calculated from the ends were unrealistically high (Table 9). Plot ends represented only 9% of the total plot area but inflated total yield by an average of 10% (Table 6). The yield per unit area from the ends must therefore be 111% higher than that from the remainder of the plot area. The yield estimates indicate that yield inflation of this magnitude can be attributed to end effects in solid-seeded plots. With yield inflation of this magnitude in the first 0.3 m of the plot ends, also found by Probst (1943) in wide rows, the end effects may have extended further into the plot, as has also been reported previously (Boerma et al., 1976; Wilcox, 1970).

Harvested rows of solid-seeded soybean plots incorporating tramlines can be spaced further apart to reduce nonuniform competitions from neighboring plots, and to make plots more discernable for rating, measurement, and maintenance purposes. Pattern 3, as described in this study, met these requirements by the use of an additional border row. Interactions among cultivars in their responses to end effects cannot be anticipated for any single year, and could invalidate cultivar comparisons in some situations. Even though differential cultivar yield responses to end effects occurred in only 1 of 3 yr, other indications of differential responses to end effects occurred among cultivar yield components. End-trimming near cultivar maturity is therefore also necessary for controlling end effects from alleyways in solid-seeded soybean plots. Clearly more seeds per unit area were produced in the plot end segments than in middles, along with greater seed weights. Other alternatives for controlling border effects on plot ends may be to reduce the width of the alleyways, or to plant perpendicular rows into the alleyways and cut them out prior to harvest. In the interest of efficient field-plot testing, these alternatives may be worth further investigation. Care should be exercised so that mechanical end-trimming prior to harvest does not damage harvest plants at the ends of the harvested plot area and thus affect results. Inferences made from this study can be expanded to solid-seeded soybean plot techniques other than cultivar evaluations.

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