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Influence of Simulated Early Lodging upon Soybean Seed Yield and its Components[1]

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ABSTRACT

Early lodging of soybeans [*Glycine max* (L.) Merr.] in highly productive environments has been observed throughout the midwestern United States. It has been established that soybean seed yields are decreased when severe lodging occurs sometime prior to physiological maturity. The objective of this 2-year field study was to examine the effect of plant growth stage at the time of lodging on soybean seed yield and its primary components; pods per plant, seeds per pod, and seed size.

The study was conducted at Tipton, Ind., in 1972 on a Crosby silt loam soil (member of the fine mixed mesic family of Aeric Ochraqualfs) and at Lafayette, Ind., in 1973 on a Chalmers silty clay loam soil (member of the fine loamy mixed mesic family of Typic Haplaquolls.) Two Group II soybean cultivars ('Wells' and 'Corsoy'), representing distinct degrees of lodging resistance, were subjected to a simulated lodging treatment at 2-week intervals in the early reproductive growth stages. Controls were: a) plants supported by a 10 × 10 cm plastic grid system, and b) no treatment or support which permited natural lodging to occur. Depending upon the time of simulated lodging, seed yields of both cultivars were reduced from 11 to 32% in 1972 and from 12 to 22% in 1973. The reproductive growth stage, R5, normally reached during the first 2 weeks of August in central Indiana, was found to be the most critical time for lodging to occur. Neither seeds per pod nor seed size was significantly reduced when lodging occurred at stage R5. The reduction in yield was due almost entirely to a reduced number of pods per plant, especially those on the central stem. When lodging occurred after flowering had commenced apical dominance was lost, resulting in lateral branches assuming central stem characteristics.

***Additional index words:* Glycine max (L.) Merr., Growth stages, Yield components, Apical dominance, Seed size, Seeds per pod, Pods per plant.**

PLANT breeders and production agronomists have long recognized the importance of the lodging phenomenon in soybeans. Lodging scores, based on visual observation at or near the time of physiological maturity, often appear in research reports. The recognition of lodging as a production problem has been traditionally associated with mechanical harvest loss and not as a factor affecting seed yield.

Only recently has attention been given to the hypothesis that lodging which occurs while the crop is still metabolically active may be influencing the expression of yield. Cooper (1, 2) reported yield reductions of 21 to 23% when natural lodging occurred in the early pod filling stage of plant development. Weber and Fehr (6) found a 13% increase in soybean seed yield when early lodging was prevented.

Simulated lodging techniques have been used previously in small grains (5). Although several methods have been employed to prevent lodging in soybeans, techniques used to simulate early lodging have not been reported.

The objectives of the present study were: a) to measure the influence of time of lodging during the reproductive growth stages on soybean seed yield, and b) to examine the effect of controlled early lodging on the primary components of yield, pods per plant, seeds per pod, and seed size.

MATERIALS AND METHODS

The experiment was conducted on a Crosby silt loam soil (member of the fine mixed, mesic family of Acric Ochraqualfs) near Tipton, Ind. in 1972 and on a Chalmers silty clay loam soil (member of the fine loamy, mixed mesic family of Typic Haplaquolls) at the Purdue Univ. Agronomy Farm near Lafayette, Ind. in 1973. Two cultivars representing distinct levels of lodging resistance were planted in a randomized complete block design with a split-plot arrangement of sub-treatments. Cultivars were the main plots, with lodging treatments, serving as subplots. Each treatment was replicated four times. Plots consisted of four rows 6.5 meters long with a 76 cm spacing between adjacent rows. All plots were seeded in excess and thinned to approximately 250,000 plants per ha 3 weeks after planting.

In order to control the time of lodging and measure its effect, a simulated lodging technique was employed. Lodging treatments were applied at approximately 2-week intervals corresponding to the early reproductive stages of development (Table 1) as described by Fehr et al. (3).

In 1972, plants were taller at growth stage R1 than plants at the same growth stage in 1973. Excessive stem breakage occurred when an attempt was made to lodge plants at stage R1 in 1973. Therefore no lodging treatments were made at stage R1 in 1973.

A 20-m aluminum bar weighing approximately 2.5 kg was used to guide individual rows of plants to a horizontal position 17 cm above the soil surface. A horizontal force great enough to achieve the 17-cm canopy height was applied to plants at a position halfway up the central stem. A strand of heavy duty baling twine was stretched across the top of the plants and tied to wooden stakes located in the middle and at both ends of each row prior to releasing tension on the aluminum bar.

Rows were planted in a north-south direction. The force used to lodge plants was applied in an easterly direction. The main objective was to simulate as closely as possible the results of a severe storm in accordance with prevailing southwesterly winds without the use of water.

It was important to have control plots containing erect plants. Control plots were supported by a plastic mesh consisting of 10 × 10 cm squares which was installed 1 m above the ground when plants were approximately 90 cm in height. The mesh was purchased from Vaughn's Seed Company, 5300 South Katrene, Downers Grove, Ill. The mesh was stretched between and tied to nine steel fence posts for each supported plot. Untreated plots were also included to compare the effect of any natural lodging that occurred.

Shortly before harvest each plot was trimmed to a 3.8-m length to eliminate border effects. Only the center two rows of each four-row plot were harvested for seed yield. Twelve plants from the harvest area of each plot were randomly selected prior to harvest for the purpose of estimating various seed yield characteristics of the whole plot. The weight of the seed from the 12-plant subsample plus the weight of the seed of the remaining plants in the harvest area comprised the seed yield of each plot.

Characteristics of the lateral branches were measured separately from those of the central stem. Branches of each plant in the subsample were detached from the central stem prior to threshing. All branches of each subsample were threshed to-

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Table 1. Description of lodging treatment codes.

Reproductive growth stage	Description
R1	One flower at any node.
R3	Pod 0.5 cm (¼-inch) long at one of four uppermost nodes with a completely unrolled leaf.
R5	Beans beginning to develop at one of the four uppermost nodes with a completely unrolled leaf. (A bean is considered "beginning to develop" when it can be felt when the pod is squeezed.)
R6	Pod containing full size green geans at one of the four uppermost nodes with a completely unrolled leaf.
Control treatments	
N	No treatment imposed, natural lodging.
S	Plants supported by plastic grid system.

gether. The total seed weight was divided by 12 in order to obtain seed yield per plant.

Pods per plant were counted directly using a hand counter. Seed size was expressed as the weight of 100 seeds. Seeds per pod was calculated using the formula:

$$\frac{\text{Total weight of seed on branches or stem}}{\frac{\text{Seed size}}{100} \times 12 \times \text{pods/plant on branches or central stem}}\,.$$

RESULTS AND DISCUSSION

Seed yields were significantly reduced both years as a result of simulated lodging (Fig. 1). There was no significant difference in seed yield between plots allowed to lodge naturally and those supported by the plastic grid system. The failure to detect a significant difference in yield between the untreated plots and supported plots can be explained by a negligible amount of natural lodging in both years of the study.

The stage of plant development when simulated lodging was imposed proved to be critical in determining the magnitude of yield reduction (Fig. 1). Yields were the lowest for both cultivars when lodging occurred as beans began to develop in pods located at one of the uppermost nodes with a completely unrolled leaf (stage R5).

Corsoy, although susceptible to lodging, consistently yielded more than Wells in other experiments with a high degree of early natural lodging. The same relationship existed in this study under simulated lodging. Corsoy had a consistently higher branch yield contribution for each lodging treatment than Wells (Fig. 2). A comparison of cultivars with respect to central stem yield and branch yield under simulated lodging conditions shows a much greater difference between branch yields than between central stem yields for both years. Therefore, the difference in yield levels between cultivars under simulated lodging conditions illustrated in Fig. 1, can be attributed mainly to variation in the branch contribution to seed yield.

Central stem yield response (based upon 12 randomly selected plants) to lodging treatment (Fig. 2) was very similar to the whole-plot yield response (Fig. 1). Branch yield response (based upon 12 randomly selected plants) to lodging treatment showed a much different pattern from the whole-plot yield response. The close relationship between the central stem and

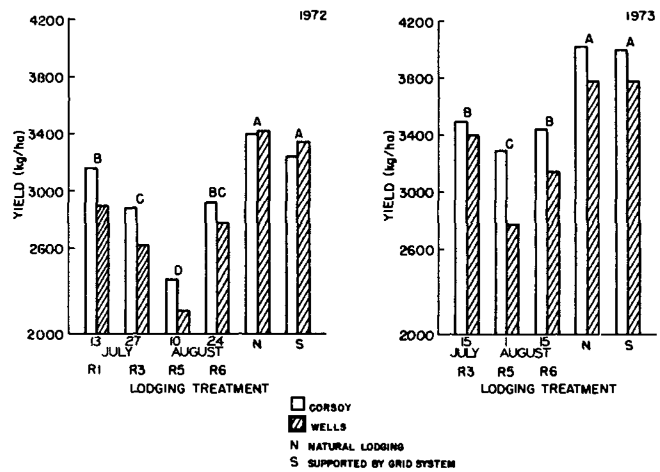

Fig. 1. Influence of lodging treatment on seed yield for 1972 and 1973. Treatments having the same letter above them are not significantly different from each other at the 5% level based on Duncan's Multiple Range Test.

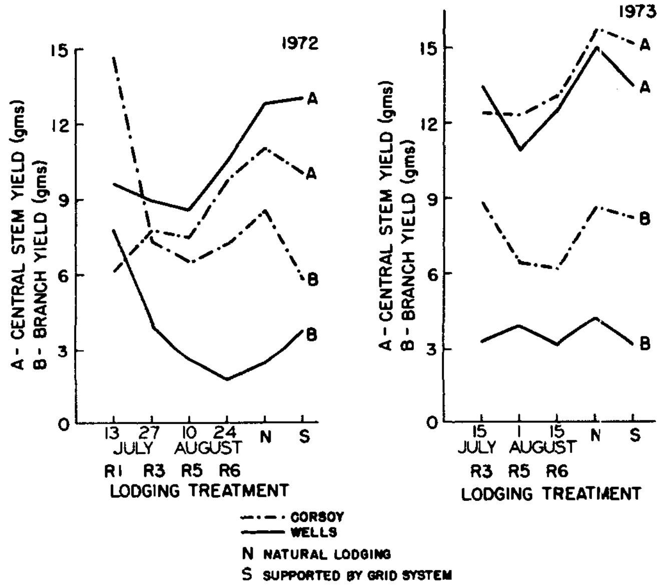

Fig. 2. Influence of lodging treatment on central stem and branch seed yields for 1972 and 1973.

whole-plot yield response patterns (Fig. 1 and 2) is evidence to show that yield reductions due to lodging were caused primarily by a reduction of central stem yield.

Apical dominance appeared to be lost in both cultivars when lodging occurred in the early reproductive growth stages. Branches of treated plants became much longer and had larger diameters as compared to supported and untreated plants. The altered canopy, as a result of lodging treatment, caused branches to assume a vertical orientation. Even the unrestricted portion of the central stem located above the lodging twine reassumed a vertical orientation approximately 2 days after lodging. The apparent loss of apical dominance may explain why increased branch yields were associated with the earliest lodging treatment in 1972

Table 2. Influence of lodging treatment on the primary yield components of Corsoy and Wells in 1972 and 1973.

Genotype	Yield component	Lodging treatment† R1	R3	R5	R6	N‡	S§
			Central stem 1972				
Corsoy	Seeds/pod	1.87 a*	1.92 a	1.91 a	1.85 a	1.99 a	1.96 a
	Seed size (g/100 seeds)	16.2 c	15.8 c	16.5 bc	17.4 ab	17.9 a	17.3 ab
	Pods/plant	20.2 c	25.6 bc	23.6 c	30.1 ab	33.2 a	31.6 a
Wells	Seeds/pod	2.21 a	2.09 a	2.18 a	2.11 a	2.24 a	2.17 a
	Seed size (g/100 seeds)	18.9 ab	16.8 c	18.0 b	18.0 b	19.3 a	18.5 ab
	Pods/plant	23.2 c	25.4 bc	21.8 c	27.7 abc	29.5 ab	32.6 a
			Branches 1972				
Corsoy	Seeds/pod	1.87 a	1.96 a	1.96 a	1.84 a	1.86 a	1.99 a
	Seed size (g/100 seeds)	16.8 ab	15.2 c	15.8 bc	16.2 abc	17.2 a	16.2 abc
	Pods/plant	46.4 a	24.5 b	20.9 b	24.3 b	26.6 b	17.8 b
Wells	Seeds/pod	2.19 a	2.14 a	2.12 a	2.20 a	2.16 a	2.13 a
	Seed size (g/100 seeds)	17.5 a	14.5 c	15.4 bc	15.6 bc	17.3 a	16.4 ab
	Pods/plant	20.5 a	12.8 ab	8.1 b	5.4 b	6.2 b	10.5 ab
			Central stem 1973				
Corsoy	Seeds per pod		2.39 a*	2.22 a	2.17 a	2.22 a	2.21 a
	Seed size (g/100 seeds)		14.9 b	15.8 ab	15.0 b	16.2 a	15.6 ab
	Pods per plant		35.1 b	35.0 b	39.9 ab	43.9 a	44.4 a
Wells	Seeds per pod		3.11 a	2.35 b	2.37 b	2.39 b	2.41 b
	Seed size (g/100 seeds)		15.4 a	15.7 a	14.3 b	15.7 a	15.3 a
	Pods per plant		31.4 b	29.8 b	36.9 ab	39.9 a	39.2 a
			Branches 1973				
Corsoy	Seeds per pod		2.04 a	2.05 a	2.02 a	2.06 a	2.06 a
	Seed size (g/100 seeds)		14.4 a	14.8 a	14.1 a	15.0 a	14.8 a
	Pods per plant		29.8 a	21.1 b	21.9 b	27.8 a	27.0 a
Wells	Seeds per pod		2.18 ab	2.22 a	2.18 ab	2.19 ab	2.10 b
	Seed size (g/100 seeds)		14.3 a	14.4 a	12.9 b	14.4 a	14.1 a
	Pods per plant		10.7 a	12.0 a	11.1 a	13.4 a	11.0 a

* Data within each horizontal row followed by the same letter are not significantly different from each other at the 5% level using Duncan's Multiple Range Test.
† Data represent a mean of four replications. ‡ Natural lodging. § Supported by grid system.

(Fig. 2). It is hypothesized that altered light relationships and canopy orientation occurring in the lower portion of the plant canopy as a result of lodging treatment were responsible for branches assuming central stem characteristics.

The primary components of seed yield; pods per plant, seeds per pod, and seed size influence yield variation to different degrees. Pandey and Torrie (4) used path coefficient analysis to show that pods per plant had the greatest influence in determining yield variability on a whole plant basis. Our work concentrated on keeping the primary yield components originating from branches separate from the same components originating from the central stem. A preliminary path coefficient analysis showed that pods per plant was the most influential yield component in determining seed yield variation on both the central stem and branches.

Corsoy had a greater number of pods per plant originating from branches than Wells for both years and over all lodging treatments (Table 2). The differential between cultivars with respect to the number of pods originating from branches explains why Corsoy made a greater branch contribution to seed yield than Wells.

Lodging treatment had the effect of reducing central stem pod numbers in both cultivars (Table 2). Lodging at stage R1 resulted in increased branch pod numbers for both cultivars in 1972. The loss of apical dominance when lodging occurred in the early reproductive growth stages could explain increased branch pod numbers.

Because of the great influence of pods per plant on seed yield variation one might expect the reduction in pods per plant due to lodging treatment to correspond closely to the yield response pattern obtained in Fig. 1. The lack of perfect correspondence between the two response patterns can be explained on the basis of subsampling error. The data for pods per plant was collected on 12 randomly selected plants per plot, whereas seed yields were based upon a much higher number of plants per plot. A larger number of plants in the subsample on which yield component data were collected might have shown lodging at stage R5 to result in a significantly lower number of central stem pods.

The primary yield component seeds per pod showed little response to lodging treatment. This was true for the central stem component as well as the branch component. Wells consistently produced more seeds per pod than Corsoy on both the central stem and branches. The difference between cultivars with respect to seeds per pod aided Wells in compensating for a low number of branch pods per plant.

Lodging had a greater influence on seed size than on seeds per pod. Although significant differences in seed size existed as a result of lodging treatment, no consistent patterns of response were observed.

In all of our work central stem seed size was larger than branch seed size. The same relationship between central stem and branch seed size has been found in the soybean cultivars 'Amsoy', Beeson', 'Calland', and 'Kent' (H. R. Koller, personal communication). A possible explanation for seed size differences between central stem and branches may involve a shorter period of pod filling for branch seeds as compared to central stem seeds. However, data to substantiate this hypothesis would require integrated growth curves for the entire pod-filling period.

SUMMARY AND CONCLUSIONS

A 2-year field study involving two cultivars of soybeans of group II maturity showed that early simulated lodging decreased seed yields. Lodging affected both cultivars in a similar manner. Seed yields were the lowest when lodging occurred at reproductive stages R5. When lodging occurred in the earlier reproductive stages of growth (R1 in 1972 and R3 in 1973) apical dominance was lost. The major effect of early simulated lodging was to reduce the number of pods originating from the central stem. Seeds per pod and seed size showed no response pattern to early simulated lodging. Central stem seed size was consistently larger than branch seed size.

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