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Soybean Response to Gibberellic Acid Treatments

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Abstract. Early-maturing soybean lines (*Glycine max* (L.) Merr.) grown in subtropical areas during short days can produce economic seed yields. However, the plants are short, and many of the pods are produced close to the soil, making commercial harvest difficult. The feasibility of increasing the lengths of the first three internodes by growth regulator application was evaluated at two locations over a 3-year period using separate plots of Amsoy 71 (Maturity Group (MG) II) and Williams (MG III) soybean by spraying each cultivar with 0, 25, or 50 g (a.i.) ha^{-1} of gibberellic acid (GA) in 280 L ha^{-1} water when the hypocotyl was cracking the soil. The 25 g ha^{-1} treatment increased ($p < .05$) the length of the hypocotyl and first internode 60% and 25% in 1979 and 36% and 17%, respectively, in 1980. Increasing the GA application to 50 g ha^{-1} had no additional effect on hypocotyl elongation, but the length of the first internode continued to increase linearly. Gibberellic acid treatment did not stimulate elongation of internodes above the first two, and internodes above the fifth tended to be shorter, causing total plant height at maturity to be the same as untreated plants. The overall effect of GA application at cracking time on harvestable seed yield was about nil, since GA decreased yields by 8–11%, but it increased stem elongation, so a greater portion of seeds were produced above 80 mm that were accessible to commercial combining. The application of GA generally did not affect ($p < .05$) seed quality. Seed weight was reduced significantly at both locations in 1979 but not in 1980. These data indicate that elongation of the lower stem portion of early-maturing soybean cultivars grown in subtropical areas during short days can be increased significantly by GA to improve commercial harvesting, but the treatments appear to have little net effect on seed yield.

Planting soybean (*Glycine max* (L.) Merr.) cultivars at earlier than optimum dates may subject the plants to short days, which result in early flowering, reduced height, pod production near the soil surface, and increases in harvest loss. Boote (1977; 1981) reported on the planting of Maturity Group (MG) II and III cultivars at Gainesville, Florida (29° 40′ N) during mid-March for harvest in June. Good seed yield was obtained with Amsoy 71 (MG II) and Williams (MG III). Unfortunately, these cultivars flowered early and produced a short plant with pod clusters at or near the soil surface. Because gibberellic acid (GA) can increase stem elongation, we hypothesized that appropriate rates of GA application might increase length of internodes 1–3 and elevate the height of lower pods to improve harvestability.

Gibberellic acid has been used as a seed treatment. Seedling height increases were reported for soybean (Howell et al. 1960) and cotton (*Gossypium hirsutum* L.) (Bird and Ergle 1960, Bradford and Ewing 1958). Howel et al. (1960) treated soybean seed with GA at 73 or 294 mg kg^{-1} of seed and evaluated the effect of GA on stand, height, and final yield at nine locations across the United States. Although treated plants were taller in the seedling stage, the final height was reduced, and seed yields were significantly reduced with both treatments. Major stand reductions of 25% and 40% were caused by seed treatment with GA at 73 and 294 mg kg^{-1} of seed, respectively. Howell et al. (1960) stated that poor stands induced by GA treatment were caused by hypocotyl breakage and other injuries during germination and emergence. Stand reduction was also demonstrated to be a problem after GA treatment of cotton seed (Bradford and Ewing 1958). We suspected that the soybean yield reductions reported by Howell et al. (1960) were associated with the major stand reduction caused by GA and not necessarily with the GA effect on subsequent growth. For this reason, we hypothesized that treating seedlings with GA during emergence might eliminate the stand reduction and better test the true effect of GA on seed yield and lower stem elongation. The effect of GA on final height also needed to be reevaluated, because final height is also highly dependent on plant population.

The objective of this experiment was to study the effect of three levels of GA treatment on lower stem internode length, seed yield, and agronomic characters of early-maturing soybean cultivars.

Materials and Methods

Ona Experiment

This study was conducted over a 2-year period, on Ona fine sand (sandy, siliceous, hyperthermic, Typic Haplaquod) soil located at the Agricultural Research and Education Center, Ona, Florida (27° 25′ N; 81° 55′ W). The field plot design consisted of four replicates of a split-plot arrangement with the main plots being soybean cultivar (Amsoy 71 and Williams) and subplots being GA treatments of 0, 25, and 50 g active ingredient (a.i.) ha^{-1}.

Soybeans were seeded on March 6 and 10 with a resulting final population density of 22 and 8 plants m^{-1} row in 1979 and 1980, respectively. Row spacing during both years was 0.25 m. Seeds were inoculated with *Bradyrhizobium japonicum* in granular form during planting.

Fertilizer N, P, and K was applied preplant at 56, 49, and 186 kg ha^{-1}, respectively in 1979 and at 56, 49, and 178 kg ha^{-1} in 1980. Soil Ca and Mg content was adequate by soil test and averaged 2020 and 213 kg ha^{-1}, respectively. Irrigation was applied as needed, totaling 84 and 74 mm in 1979 and 1980, respectively. Alachlor (2-chloro-N-(2,6-diethylphenyl)-N-methoxymethyl) acetamide was applied preemerge at 2.2 kg a.i. ha^{-1} in 280 L ha^{-1} water to control annual grasses.

Gibberellic acid as an aqueous spray was applied at 25 and 50 g ha^{-1} in 280 L ha^{-1} of water when the soybean hypocotyls overall were at the "cracking stage" (hypocotylary arch breaking through the soil; a few cotyledons beginning to open).

Measurements of hypocotyl length above the soil surface, length of the first internode, and length of the second internode was determined 60 days after seeding on eight randomly preselected plants at cracking stage per plot. Seed yield was obtained by harvesting 0.75 m^2 (two middle rows) and oven-drying to constant weight.

To estimate combine harvestability, a 0.5-m section of row per plot was categorized into two segments; soil surface to 80 mm, and above 80 mm. The individual segments were threshed, and percentage of total seed yield below 80 mm was determined.

Gainesville Experiment

Williams cultivar was planted on March 12, 1980, on a Kendrick sand (loamy, siliceous, hyperthermic Arenic Paleudult). The GA treatments were repeated four times in a randomized complete block design. The row spacing was 0.25 m, and intrarow plant population was 20 plants m^{-1} of linear row. The field was fertilized on March 5 with 56, 45, and 175 kg ha^{-1} of N, P, and K, respectively. Aldicarb (2-methyl-2-(methylthio)propinoaldehyde-0-(methylcarbanoxyl)oxime) was incorporated at 5.3 kg a.i. ha^{-1} for nematode control. The selective preemergence herbicides benefin (N-Butyl-N-ethyl-a,a,a-trifluoro-2,6-dinitro-p-toluidine) were incorporated into the soil at 1.3 kg a.i. ha^{-1} on March 6, and Alachlor at 2.6 kg ha^{-1} and naptalam (sodium 2-(1-naphthalenylamino)carbonyl benzoate) at 2.6 kg a.i. ha^{-1} on March 17. Irrigation as applied as needed totaling 132 mm to supplement 274 mm of rainfall from March 12 to June 18 (planting to maturity). The GA treatments were 0, 5, and 50 g a.i. ha^{-1} in 280 L ha^{-1} of water. The treatment was applied on March 19, 7 days after planting. The "cracking" stage had occurred on March 18, so plants may be considered emerged by the date of GA treatment.

Measurements of internode length were made at maturity on 10 randomly selected plants per treatment in each replicate. Combine harvestability was estimated as explained in the Ona experiment. Seed yield at oven dry weight was based on three bordered rows each 4.9 m long. Seed quality (subjective evaluation) and seed weight were also determined at both locations.

Seed yield, stem elongation, plant height at maturity, seed quality, seed weight, and percentage seed yield from lower stem (soil surface to 80 mm) from both experiments were all subjected to analyses of variance, and treat-

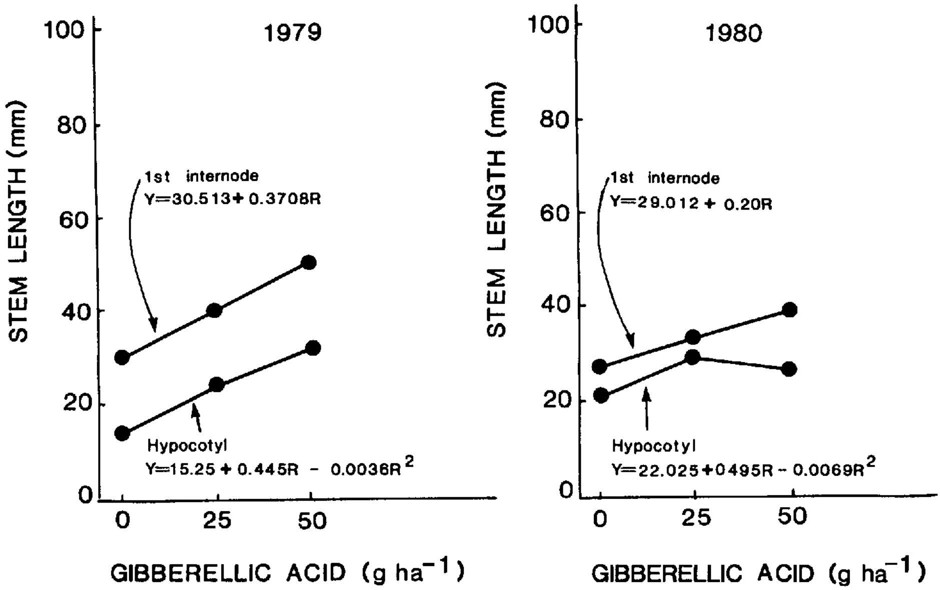

Fig. 1. Effect of gibberellic acid (GA) treatments applied at emergence on soybean hypocotyl and first internode length in 1979 and 1980 at Ona. R = GA treatments.

ment means were compared by the Duncan's Multiple Range Test. For 1979 yield at Ona, there was a significant GA × cultivar interaction. For several other responses the best-fitting regression equation was fitted to the rate means. Therefore, with the exception of 1979 yield, the two cultivars reacted similarly to the GA treatments.

Results and Discussion

Stem Length

The application of 25 and 50 g ha^{-1} GA to soybean hypocotyls at emergence (cracking) resulted in significantly greater hypocotyl and first-internode length in both 1979 and 1980 for both Amsoy 71 and Williams cultivars at Ona (Fig. 1). A significant difference in first-internode length but not in hypocotyl length also resulted from GA treatments on the Williams cultivar in 1980 at Gainesville (Fig. 2). In the Ona experiment, GA applied at 25 g ha^{-1} increased the length of the hypocotyl and first internode 60% and 23%, respectively, in 1979 and 36% and 17%, respectively, in 1980. Further increases in the GA treatment to 50 g ha^{-1} increased hypocotyl length in 1979 at Ona but caused no additional increase in hypocotyl length over the 25-g treatment in 1980. In all years and locations, first-internode elongation response to GA treatments up to 50 g ha^{-1} was linear.

Length of the first internode for the control (0 g ha^{-1} GA) plots at Ona was about equal in 1979 and 1980, averaging 31 and 29 mm, respectively. The value

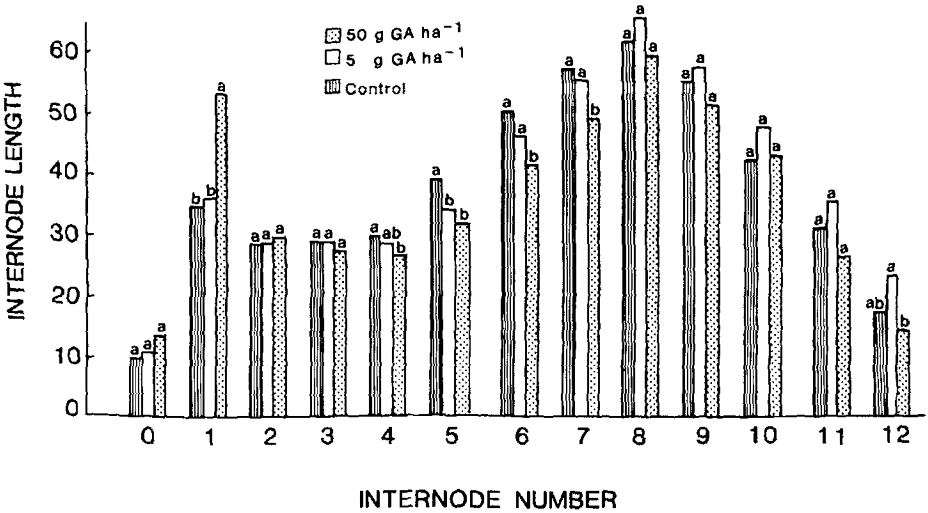

Fig. 2. Effect of gibberellic acid (GA) treatments at emergence on length of hypocotyl (0) and the first 12 internodes of Williams soybean in 1980 at Gainesville. Means between columns for each internode number followed by the same letter are not significant at the .05 level of probability according to Duncan's Multiple Range Test.

at Gainesville was 34 mm. However, in 1979 the plant population density at Ona was about threefold greater than the population density obtained in 1980. This greater population density in 1979, along with the addition of 50 g ha^{-1} GA, resulted in a 61% increase in first-internode length over the control. The Gainesville plant population density was even higher, and GA at 50 g ha^{-1} produced a 53% increase in length of the first internode compared to the control. With the lower population density at Ona in 1980, the length of the first internode was increased by only 34% with the highest GA treatment. Therefore, there is some evidence that GA tended to enhance stem length more when applied to a dense population of plants, or the dense population tended to enhance the effect of GA.

The application of GA at the ground-cracking stage increased ($p < .05$) the elongation of the hypocotyl (Ona) and the first internode (Ona and Gainesville) only. The GA stimulus did not appear to be translocated to the second internode, or perhaps GA was metabolized by the time the second internode was ready to expand. There were no increases to internode elongation above the first internode (Gainesville) (Fig 2). In fact the application of 50 g ha^{-1} GA resulted in similar lengths ($p > .05$) for internodes 2, 3, and 4 and even resulted in significant reductions in lengths of internodes 4–7 (Gainesville only). Because of the antagonistic effect of GA on elongation of upper internodes, the net effect of GA application at Gainesville was a slight reduction in final plant height irrespective of the GA-induced increases in the elongation of the hypocotyl and first internode. The reason for the delayed effect of GA on the upper internode lengths is not known, but the effect on overall plant development may be worthy of further study.

Table 1. Effect of gibberellic acid on seed yield of two soybean cultivars seeded in separate plots in 1979 and 1980, Ona.

	1979		1980	
Gibberellic acid[a] (g ha^{-1})	Total yield (kg ha^{-1})	Yield[b] below 80 mm (%)	Total yield (kg ha^{-1})	Yield below 80 mm (%)
0	3293	8	2554	25
25	3024	8	2353	20
50	3025	7	2352	19
	NS	NS	NS	NS
Cultivar				
Amsoy 71	3091	11	2218	20
Williams	3226	4	2688	22
	NS	*	NS	NS

* Means within a column followed by * are significantly different at the .05 level of probability. NS = not significant.
[a] Values for GA treatments are an average of two cultivars seeded in separate plots.
[b] Percentage of total seed yield obtained from the basal 80 mm of the soybean plants.

Hypocotyl length of soybean cultivars (Ona) differed significantly only in 1979. The greater hypocotyl length of Williams may be confounded with the higher plant density in that year, although Williams is also later maturing. Cultivars at Ona did not differ significantly in elongation of the first internode in 1979 or in hypocotyl length in 1980.

Seed Yield

The application of 25 or 50 g ha^{-1} of GA reduced the average seed yields from entire plants for both years at Ona by 8% ($p > .05$) when averaged over both cultivars (Table 1). Gibberellic acid at 50 g ha^{-1} significantly reduced yield by 11% at Gainesville in 1980 (Table 2). The 5 g ha^{-1} rate had no effect on yield at Gainesville. The fraction of total seed yield located on the lower 80-mm stem portion was obtained to estimate combine harvestability. The control plants produced 8%, 25%, and 20% of total seed yield below 80 mm in 1979 and 1980 at Ona and in 1980 at Gainesville, respectively (Tables 1, 2). The application of GA to the hypocotyl had no significant effect on the percentage yield below 80 mm in any of the tests. However, under an increased population in 1979 at Ona, the yield below 80 mm was decreased from 25% to 8% of the total yield compared to 1980. Yields on the lower stems were decreased from 25% (control) to 19% (50 g ha^{-1} GA) and from 20% (control) to 14% (50 g ha^{-1} GA) ($p >$ .05) at Ona and Gainesville, respectively, in 1980, indicating that soybean pod clusters developed higher up the stem (above 80 mm) because of the stem elongation effect of GA. However, since the addition of GA lowered total yield 8% (Ona) to 11% (Gainesville) in 1980 and increased yield above 80 mm by 5% to 6%, the overall effect on harvestable yield was about equal to that from the control plots.

Table 2. Effect of gibberellic acid treatments, applied at the cracking stage, on yield and agronomic characteristics of Williams soybean in 1980 at Gainesville.

GA level (g ha^{-1})	Height (mm)	Seed yield (kg ha^{-1})	Yield below 80 mm (%)	Seed weight (mg seed^{-1})	Seed quality[a]
0	430a	2500a	19.7a	174a	1.8a
5	430a	2510a	20.4a	173a	1.9a
50	400a	2220b	14.4a	170a	1.8a

Means within a column followed by different letters are significantly different at the .05 level of probability according to Duncan's Multiple Range Test.
[a] 1 = Excellent; 5 = poor.

Table 3. Effect of gibberellic acid treatments on seed yields in kg ha^{-1} of two soybean cultivars in 1979, Ona.

Cultivar	Seed yield (g ha^{-1})			F Test
	0	25	50	
Amsoy 71	3427	2822	2957	*
Williams	3226	3293	3091	NS
	NS	*	NS	

* Means within a column followed by * are significantly different at the .05 level of probability. NS = Not significant. Means in a row followed by * are significantly different at the .05 level of probability. Since these values represent continuous variables, they must be expressed by the following estimated regression equation.
Fitted equation for Amsoy 71 soybeans over rates (R) of gibberellic acid: $Y = 50.55 - 0.5914 R + 0.00935 R^2$.

Soybean cultivars differed in lower stem yield in 1979 (Table 1). Williams, being of somewhat later maturity than Amsoy 71, produced only 4% of its total yield below 80 mm. A similar effect was observed by Boote (1981), who reported that the proportion of seed yield below 80 mm was 11% and 16% for Williams and Amsoy 71, respectively. High plant population plus GA appeared to stimulate hypocotyl and first-internode elongation and thus reduced the proportion of lower stem yield of Williams (Table 1). Lack of difference in lower stem yield between cultivars at Ona in 1980 can be partially attributed to a sparse population. The GA × cultivar interaction was significant (Table 3).

The generally higher yield of Williams is related to its later maturity (MG III) compared to Amsoy 71 (MG II).

Agronomic Characteristics

Plant height, seed quality, and percentage shriveled seed were generally not affected ($p < .05$) by GA or either cultiver (Tables 2, 4). In 1979, seed weight was significantly ($p < .05$) reduced by GA treatments. However, seed weight was not affected by GA in 1980 at Ona or Gainesville. The trend for smaller

Table 4. Effect of gibberellic acid treatments and soybean cultivars on agronomic characteristics during 1979 and 1980, Ona.

	1979		1980		
Gibberellic acid[a] (g ha^{-1})	Seed weight (mg seed^{-1})	Plant height (mm)	Seed weight (mg seed^{-1})	Seed quality[b]	Shriveled seeds (No. 100^{-1})
0	183a	510	182	1.6	10
25	175b	480	179	1.6	10
50	168c	500	178	1.6	8
		NS	NS	NS	NS
Cultivar					
Amsoy 71	173	460	170a	1.7	12
Williams	177	530	190b	1.5	6
	NS	NS		NS	NS

Means within a column followed by the same letter are not significant at the .05 level of probability according to Duncan's Multiple Range Test.
* .01% level.
[a] Values for GA treatments are an average of two cultivars seeded in separate plots.
[b] Seed quality: 1 = Excellent; 5 = poor.

seed size in 1980 and lower ($p < .05$) seed weight in 1979 suggests that smaller seed size may be one of the reasons for reduced yields of GA-treated plants.

These data indicate that early-maturing soybean cultivars (MG II and III) seeded in subtropical areas during short days of early March will produce dry seed yields ranging from 2200 to 3200 kg ha^{-1}. The application of GA to the hypocotyl along with a high plant population may elevate the lower internodes of the plant enough to improve combine harvesting of lower pod clusters. There is some indication, however, that yield and seed size are reduced by GA treatment, so the net benefit of harvestable seed yield may be negligible. Additional research is needed to determine the flexibility in timing of the GA application and to elucidate causes for the delayed effect of GA on reduced upper internode length and seed yield reduction.

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