

Improving the Harvestability of Dry Beans with Gibberellic Acid

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Abstract

Currently beans (*Phaseolus vulagris* L.) are commercially harvested in several operations. Initially mature plants are cut below the soil surface by a bean puller, swaths are later windrowed, then picked up and threshed. Attempts to improve the efficiency of bean harvesting, using straight cut harvesters have been problematic due and the proximity of the pods to the ground. Yield losses during straight cut harvesting can range from ~~25-~~ **90%**. Increasing stem length, thereby increasing the distance of pods from the ground, will permit the direct harvest of dry beans and reduce yield losses.

The effects of gibberellic acid (GA) on the canopy structure and harvestability of three cuitivars (Othello, UI 906, and Aztec (1995 only)) were examined in the field. Trials were conducted at two locations in 1994 and 1995. Five rates of GA (0, 12.5, 25, 37.5, and 50 ppm) were applied at three growth stages (1 st, 2nd, and 3rd trifoliolate leaf stages). Mechanically harvested yields were compared to hand harvested yields to determine if treatments improved the percentage yield recovery with straight cut harvesters.

Some cultivars were found to be more sensitive to GA treatment than others. GA stimulated internode elongation in all cultivars, stem length increases of 10% to 200% over control plants were recorded. One cultivar's (Othello) harvestability was improved by very high concentrations of GA.

Introduction

The largest hurdle to the acceptance and subsequent expansion of dry bean acreage, in Saskatchewan and around the world, are high equipment and production costs and the yield losses associated with direct harvesting (Park 1985, Cameiro 1991, Zyla 1993). Currently beans are harvested in several operations (Park 1985, Zyla 1993). The plants are initially cut below the soil surface by a bean puller when 50% of the pods are brown and mature. Swaths are later windrowed into larger swaths to ensure that the harvester is running at full capacity. This operation also aids in the drying of the swaths. Finally when all pods are mature, swaths are picked up with a combine fitted with the appropriate header. These multiple operations are time consuming and costly. Every time the crop is handled the potential for yield loss increases. Harrigan et al. (1991) estimated 50-70% of all yield losses stems from multiple harvesting operations. Yield losses increase dramatically when plants are dry.

Attempts to improve the efficiency of bean production with straight cut harvesters have been problematic (Zyla 1993). The difficulty stems from the bean plant's short growth habit combined with the low development of the pods. Pod length ranges from 7-15 cm, and pods are commonly found in contact with the soil. The plant's natural tendency to shatter when dry also contributes to yield losses. Advantages to direct harvesting are significant: reducing machinery costs, eliminating costly and time-consuming operations, reducing crop handling and therefore crop loss, simplifying the planning of harvest operations, reducing chance of weather damage, and reducing wear on harvesters (Sask. Ag. and Food 1996. Harrigan et al 1991). Harrigan et al. (1991) determined that 89% of yield loss during direct harvesting occurred at the header, because harvesters are unable to

pick up the low pods. The majority of yield loss, 67%, was attributed to pod shattering as a result of contact with the header. The remaining loss, was in the form of beans in missed pods, lying loose or still attached to the stem of unharvested plants.

Altering the bean plant's architecture, with growth regulators, should improve this crops harvestability (Harrigan et al. 1991). The ability of gibberelic acid (GA) to promote stem elongation has been well documented (Marth et al. 1956, Brian and Grove 1957, Salisbury and Ross 1992). *Phaseolus vulgaris* L. has been shown to be highly responsive to GA treatments (Dale 1969, Marth et al. 1956). GA can alter the bean plant's development from a dwarf bushy habit to a tall climbing habit (Brian and Grove 1957). The objective of this study was to use GA to alter the crop canopy of bean. By increasing stem length and therefore increasing the pod distance from the ground, the straight cut harvestability of this crop should be improved. This would remove a major constraint to the acceptance and expansion of this **crop** in Saskatchewan.

Materials and Methods

Field experiments were conducted in 1994 and 1995 at the Goodale experimental farm, at Floral, Sask. 20 Km E.S.E. of Saskatoon, and at the Preston field plots, in Saskatoon Cultivars examined were: Othello a vigorous, short, fairly upright, short vine pinto, type IIIA, UI 904 an upright, short vine, black, type IIA, and (in 1995) Aztec an upright, type 11 pinto (crop registrations, CIAT classification 1989). The plot area was disked in the fall, then cultivated and packed in the spring before seeding. Plots were seeded with a four row small plot seeder in the second last week of May in 1995 and the last week of May in 1994. All plots were 3.6 meters long and 8 seeded rows wide, 30 cm spacing. Seeds were treated with Agrox DL plus. Plots were seeded at approximately 100 kg/ha, at a depth of 3.5 to 5 cm, into good moisture in both years. At seeding *Rhizobium*, in a peat based self-stick form (Microbio Rhizo Corp.) combined with dead wheat, was applied in the seed row.

All experiments were laid out in a RCBD design. Othello and UI 906 were studied in 1994 and 1995 at both locations. The experiment consisted of three application timings (1st (T1), 2nd (T2), and 3rd (T3) trifoliolate leaf stage) and five rates of applied GA (0, 12.5, 25, 37.5, and 50 ppm), replicated four times (Ballard et al. 1959). An additional experiment on Othello was added in 1995 This experiment consisted of ten treatments, two application timings (1st and 2nd trifoliolate leaf stage) and five rates of GA (0, 50, 100, 200, and 300 ppm), replicated four times. Aztec was studied in 1995. the experiment consisted of two application timings (1st and 2nd trifoliolate leaf stage) and three rates of applied GA (0, 25, and 50 ppm), replicated three times.

The gibberellic acid used in this project was primarily GA3. KOH was used to facilitate the mixing and dissolving of GA (Marth et al. 1956). After all particles were dissolved solution pH was set to approximately 7.0 using HCl. A stock solution was created, from which GA was extracted to make up the spray solution the day prior to spraying. The same amount of KOH and HCl added to the stock solution of GA was added to a stock solution of water for the control. In 1994 a backpack boom sprayer was used to apply GA at the desired leaf stages on 23, 28 June and 4 July. In 1995 a bicycle sprayer was used to apply GA at the desired leaf stages on 21, 29 June and 4 July. A surfactant, Tween, was added to each spray solution to improve plant coverage (Maksymowych et al. 1984).

Sites were hand weeded, Copper sulfate was applied to plots to combat an infection of common bean blight. Plant samples were collected prior to harvest, after pod fill, for measurement and analysis Two rows per plot were hand harvested and threshed with a Wintersteiger harvester as a measurement of the possible yield potential. Two and three rows per plot, in 1994 and 1995 respectively, were direct harvested with a Wintersteiger small plot combine. Mechanically harvested yields were compared to the hand harvested yields for each plot to determine if the GA treatments improved the harvestability of the crop. Thousand kernel weight was determined from two 100 seed samples per plot.

Analysis of all data was completed using Minitab (1991, version 8.2), using ANOVA or GLM. Time and rate of application were considered fixed effects in all analysis, while all other factors were considered random. Treatments were compared to control by an LSD. Yield data was subjected to a combined ANOVA over years and locations. Bartlett's test determined the data to be heterogeneous (Steel

and Torrie 1980). The data was transformed ($\text{Log}(IO)$) prior to the combined analysis. GA application in the second season was delayed by rain, therefore the analysis of internode length for the experiments was separated by years. The analysis for the 1994 data determined the interaction between location*rate*timing to be significant, therefore the data was separated by location to identify treatment effects of GA application.

Results and Discussion

Internode lengths for each cultivar in each year have been presented separately because of differences in application timing in the two years. Internode lengths, for each cultivar, were presented for each location, in 1994, because crop growth differed significantly between the two locations. A cumulative internode length best represented the influence of the GA treatments.

The cumulative internode length examined on UI 906 plants, in 1994, extended between the unifoliate leaf and the 4th trifoliolate leaf node. Plants at both sites responded to GA treatment (Fig. 1). Plants at Saskatoon treated at the early growth stage increased in length on average 2-5% (ns), over control plants. Plants treated with GA at timing two demonstrated a 10-21% increase, significant ($p < 0.05$), in stem length over control plants. GA application at the third crop stage increased stem length 11% over control (ns). UI 906 plants from Goodale demonstrated a greater response to exogenous GA treatment (Fig. 1). The internode length examined increased, 8-33% over the control, in plants treated with GA at the earliest growth stage. Significant ($p < 0.05$) increases occurred with the higher GA rates. Plants treated at T2 with GA were 10-14% longer than control plants, a significant ($p < 0.05$) increase. Minimal (ns) increases in stem length were found in plants treated with GA at T3.

In 1995, UI 906 had a very similar crop growth at both sites. Increases in stem length, in 1995, in response to the GA treatments were small and not significant (data not presented).

The growth habit of the bush cultivar, UI 906, was not visibly altered by GA in either year. The response of UI 906 to GA treatment in 1994 varied with location. A greater response to GA occurred at Goodale where crop growth was vigorous, relative to Saskatoon where the crop growth was poor. Nutrient or moisture levels at the Saskatoon site may have limited growth. Development of UI 906 was not significantly altered by GA in 1995. A difference in growing conditions among 1994 and 1995 could have affected plant response to GA treatment. The individual applying GA changed between 1994 and 1995. It is possible that the speed of application changed as a result, decreasing in 1995. This would reduce the amount of GA applied to each plot. UI 906 also may not be sensitive to the rates of GA used in this experiment. Significant increases did occur in 1994 with the higher rates of GA supporting a theory that higher rates may be required to significantly and consistently stimulate stem elongation in this cultivar.

Othello's response to GA treatment was very different from UI 906. The cumulative internode length on Othello plants extended from the unifoliate to the 5th trifoliolate leaf node. Othello plants at Saskatoon in 1994 treated with GA at T1 had stem lengths 15-54% greater than the control plants (Fig. 2). Plants treated at T2 increased 53-100% over the control plants. Plants treated at T3 showed an increase of 39-65% over control plants. Highly significant ($p < 0.01$) increases were identified for all rates of GA and application timings. At Goodale, plants treated with GA at T1 increased in internode length 82-124% compared to control plants, which is dramatically greater than the increases found at Saskatoon (Fig. 2). Treatments with GA at T2 increased internode length by 46-87%. T3 treatments increased the internode lengths by 32-52% relative to control. Highly significant ($p < 0.01$) increases were identified for all rates of GA and application timings.

The same internodes were measured on Othello plants in 1995. Plants treated with GA at T1 increased 2-17% over control plants (Fig. 3). Only the 50 ppm rate resulted in a significant ($p < 0.05$) stem elongation (17%). All GA rates applied at T2 resulted in significant ($p < 0.01$) stem increases (26-58%) over the control. GA treatments at T3

resulted in no change in internode length. The effects of GA on Othello were not as apparent in 1995 as in 1994.

The growth habit of this cultivar changed, as a result of GA treatment, from an upright short habit to a very viney habit. Differences in stem elongation were not as dramatic in 1995 as in 1994, for T1 and T3. The change in the method of GA application, from backpack to bicycle sprayer, and the change in applicator may be responsible for the different results between the two years for both cultivars. Boom height of the backpack sprayer was not as reliable as with the bicycle sprayer. This could result in an increase in plant coverage with GA. Speed of application in the second season, with the bicycle sprayer, may have been faster, therefore reducing the amount of GA applied. Different growing conditions between years could have contributed to the differences in this cultivars response to GA treatment.

Aztec plants were treated with three rates of GA (0, 25, and 50 ppm), applied at two growth stages (1st and 2nd trifoliolate leaf stage) in 1995. The cumulative internode length examined extended between the unifoliate and the 5th trifoliolate leaf node. GA treatment at T1 with 25 and 50 ppm increased internode length by 14% and 43%, respectively, significant ($p < 0.05$) (Fig. 4). Treatment at T2 resulted in increases of 7% and 230%, significant ($p < 0.01$), for the 25 and 50 ppm rates respectively. GA treatments stimulated the development of a viney plant habit in this cultivar.

Othello was treated with very high rates of GA (0, 50, 100, 200, and 300 ppm), applied at two growth stages (1st and 2nd trifoliolate leaf stage) in an experiment in 1995. Treatment with GA at the early stage stimulated stem development by 12-200% (Fig. 5). Increases in internode length, at the 200 and 300 ppm rates of GA, were highly significant ($p < 0.01$). GA application at T2 resulted in an increase, over control, in internode length of 84232% significant ($p < 0.01$).

The measurement of % yield recovery was calculated from the comparison of hand and mechanically harvested yields and analyzed to determine if GA improved straight cut harvestability. The % yield recovery of UI 906 ranged between 83-93% for all GA treatments (data not presented). GA application did not alter 1000 kernel weight, compared to the control (data not presented). The harvestability of UI 906 was not significantly improved by GA treatments.

Hand harvested yields of Othello varied from 2716 to 3087 kg/ha, with no significant difference between GA rates or treatment timings. Percent yield recovery for Othello did not change with GA treatment (data not presented). Thousand kernel weight was not affected by the GA applications (data not presented). The harvestability of this crop was not changed with GA treatments, although stem length was significantly increased.

Similar yield data was collected and analyzed for Aztec. Hand and direct harvested yields varied between timings and GA rates, although not significantly (data not presented). The % yield recovery for T1 did not change with GA treatment. % yield recovery did increase in T2 (ns), but this was the result of a decrease in hand harvested yield and not the result of an improvement in straight cut harvestability. Thousand kernel weight was not affected by GA treatments. The harvestability of this variety was not improved with GA treatments, although stem length was increased.

Othello was treated with higher rates of GA (0, 50, 100, 200, 300 ppm) in a separate experiment in 1995. Hand harvested yields of GA treated plots were not significantly different from control plot yields (Table 1). Plots treated with GA at T1 produced, on average, 2-7% less than control plots. Treatment with GA at T2 yielded between 10% higher and 10% lower than control plots. Mechanically harvested yields increased significantly with GA treatment. Plots treated at T1 with GA generally out-yielded control plots by 10-34%. Plots treated at T2 with GA out-yielded the control by 47-68%. The resulting % yield recovery increased with GA rates, 63-77% at T1 and 60-90% at T2. The second application of GA resulted in the greatest improvement in harvestability. GA treatment did not affect seed weight (data not presented). Treated plants grew taller, improving the harvestability of Othello, in this experiment.

Conclusions

In general canopy development of the dry bean cultivars UI 906, Othello, and Aztec were affected by foliar applied GA. UI 906 internode length responded to GA treatment in one of the two years. The inconsistent response of UI 906 to GA suggests that this cultivar was not highly sensitive to the rates of GA used in this experiment. Higher rates may be required to consistently stimulate stem development in UI 906.

The cultivar Aztec responded positively to GA. GA significantly increased internode length of treated plants but % yield recovery was not improved.

In all Othello experiments, GA significantly increased internode length. Percent yield recovery was not significantly changed by the low rates (12.550 ppm) of GA. Very high rates (100-300 ppm) of GA, dramatically stimulated plant elongation in Othello, increasing internode length by up to 200%. As a result the % yield recovery of GA treated plots was significantly greater than the control. High rates of GA improved the straight cut harvestability of the cultivar Othello.

GA stimulated stem development of common bean plants. The very high rates of applied GA were found to improve the straight cut harvestability of one cultivar, Othello.

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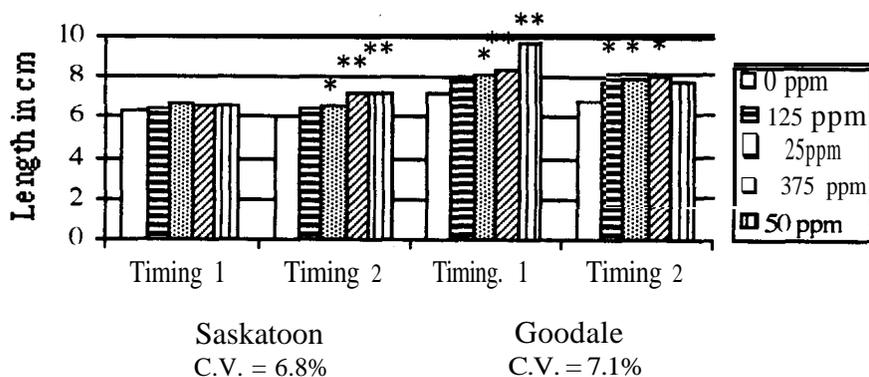


Figure 1. UI 906, 1994, internode length between the unifoliate and the 4th trifoliolate leaf node.

* Significantly different from control at $p < 0.05$, ** Significantly different from control at $p < 0.01$

GA application Timing 1 = 1st trifoliolate leaf stage, Timing 2 = 2nd trifoliolate leaf stage

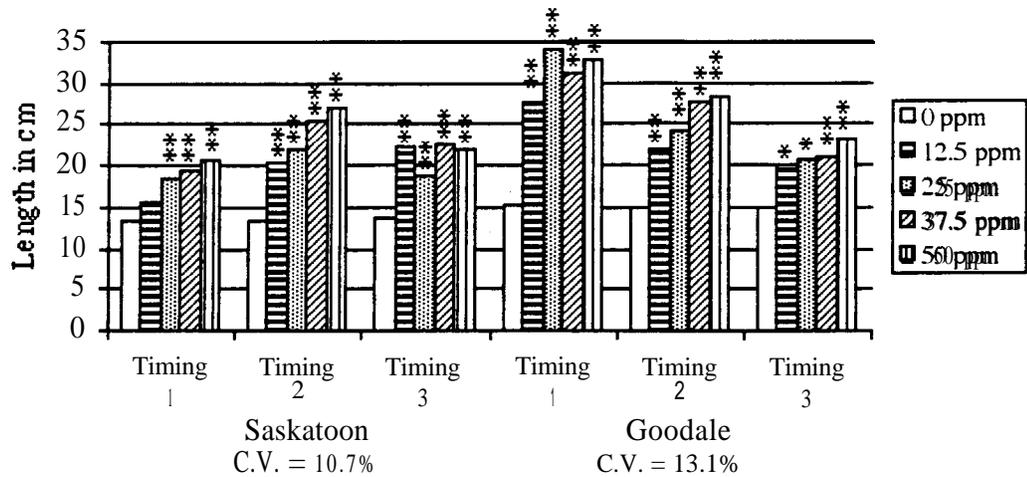


Figure 2. Othello, 1994, internode length between the unifoliolate and the 5th trifoliolate leaf node.
 * Significantly different from control at $p < 0.05$, ** Significantly different from control at $p < 0.01$
 GA application Timing 1 = 1st trifoliolate leaf stage, Timing 2 = 2nd trifoliolate leaf stage
 Timing 3 = 3rd trifoliolate leaf stage

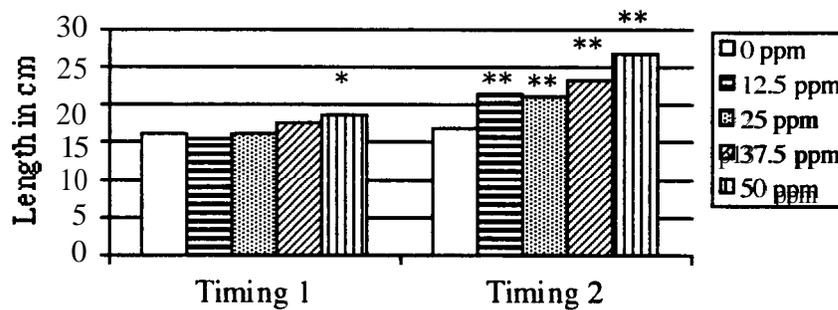


Figure 3. Othello, 1995, internode length between the unifoliolate and the 5th trifoliolate leaf node.
 * Significantly different from control at $p < 0.05$, ** Significantly different from control at $p < 0.01$
 GA application Timing 1=1st trifoliolate leaf stage, Timing 2=2nd trifoliolate leaf stage. c.v.=9.8%

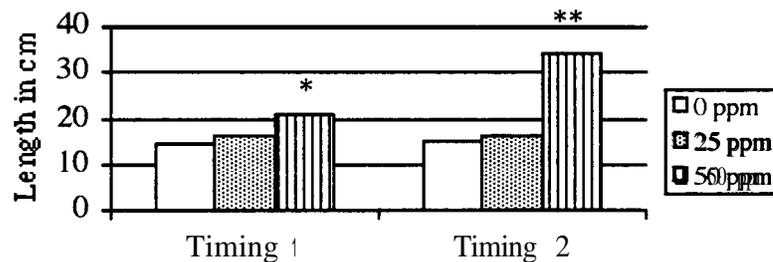


Figure 4. Aztec internode length between the unifoliolate and the 5th trifoliolate leaf node. c.v.=13%
 * Significantly different from control at $p < 0.05$, ** Significantly different from control at $p < 0.01$
 GA application Timing 1=1st trifoliolate leaf stage, Timing 2=2nd trifoliolate leaf stage.

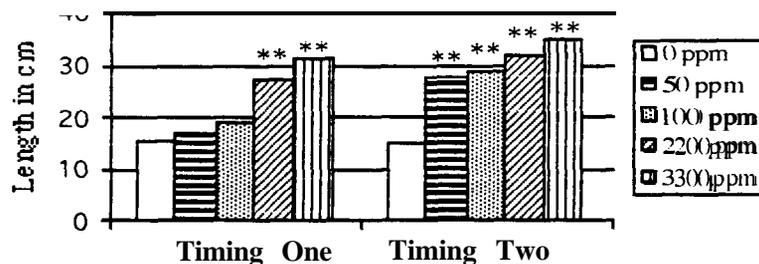


Figure 5. Othello high GA experiment, 1995. Internode length between the unifoliolate and 5th trifoliolate leaf node. GA application Timing 1=1st trifoliolate leaf stage, Timing 2=2nd trifoliolate leaf stage. ** significantly different from the control at $p < 0.01$. C.V.= 15%

Table 1. Othello yield data from the high rate GA experiment in 1995.

Rate of GA	Harvest Method	Timing One		Timing Two	
		Yield KG/Ha	% Yield Recovery	Yield KG/Ha	% Yield Recovery
0 ppm	Hand	2727	63	3799	60
	Mechanically	1618		1.556	
50 ppm	Hand	3538	58	2801	81 **
	Mechanically	1471		2309	
100 ppm	Hand	2681	66	2744	87 **
	Mechanically	1773		2291	
200 ppm	Hand	2616	77 **	3077	84 **
	Mechanically	2154		2613	
300 ppm	Hand	2611	77 **	2563	90 **
	Mechanically	2025		2300	

** Significantly different for control at $p < 0.01$ Hand harvested yield C.V.=10.4%, Mechanically harvested yield C.V.=12.9% % yield recovery C.V.=9.3%

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