Improving Bean Harvest with Gibberellic Acid

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SUMMARY. **The lowest pods on common bean (*Phaseolus vulgaris*) are on or near the ground. Yields may improve by raising these pods to reduce yield loss, especially with direct harvest. The objective of this field study was to use gibberellic acid (GA_3) to raise lower pods and increase yield. Seeds of cultivars Poncho (Type III, pinto) and Matterhorn (Type II, great northern) were dipped in GA_3 at 0, 125, 500, and 2000 ppm and planted in 30-inch rows (2005). Stem elongation was promoted, but emergence and yield were decreased especially for 'Poncho'. In foliar tests in 30-inch rows (2005 and 2006), GA_3 was applied to newly expanded unifoliolate leaves. Doses were 0, 0.5, 2, and 8 ppm for 'Poncho' and 0, 31.25, 125, and 500 ppm for 'Matterhorn'. The higher doses raised the low pod by 2 inches, and yields harvested conventionally were increased from 14% to 18%. In 2007, 'Poncho' and 'Matterhorn' unifoliolate leaves were treated with GA_3 at 0, 2, and 4 ppm, and 0, 62.5, and 125 ppm, respectively, and then portions of each plot were harvested either manually, conventionally, or directly. Planting was in 22- and 30-inch row spacing. Lower pods were raised by ≈1 inch by GA_3. Yields from conventional and direct harvest were increased by foliar GA_3 application for both cultivars and both row spacings. Yield from directly harvested GA_3-treated plots was comparable to that from untreated conventionally harvested plots. GA_3 may play a role in increasing yield from directly harvested common bean in conjunction with genetic and mechanical improvements.**

Indeterminate common bean cultivars may have one of two growth habits, erect or prostate. Growth habit is among the most important characteristics for classifying cultivars from an agronomic viewpoint (Kelly, 2001; Laing et al., 1984; Singh, 1982). The most common cultivars grown in the U.S. High Plains are Type III and Type II, which are indeterminate and prostrate, and indeterminate and erect, respectively (Singh, 1982). 'Poncho' (Type III) and 'Matterhorn' (Type II) are commonly grown in western Nebraska, and they produce pods low on the plant with the pod node usually being at the first or second trifoliolate node (Fig. 1) (unpublished data). These lower pods are very close to the ground, even lying on the ground. Therefore, the conventional harvest practice of first undercutting plants, then windrowing and threshing is used to minimize yield loss (Smith, 2004). An alternate method is direct harvest, which has advantages of lower operational costs, less soil disturbance, reduced exposure to deleterious weather, and fewer soil clods in delivered product resulting in less wear on combine. However, yield loss by harvesting directly may be greater than 10% in western Nebraska (Smith, 2004). In the Red River Valley, in a 2-year study at four North Dakota sites using several cultivars, seed yield was reduced on average from 2000 lb/acre for conventional harvest to 1260 lb/acre for direct harvest (Eckert et al., 2011a). The seed remaining on the ground after harvest indicated yield losses during harvest were 4.5% by conventional and 23.2% by direct harvests (Eckert et al., 2011a). Increasing the stem length of lower internodes, those below the node with the first flower and pod, may raise lower pods higher off the ground. This may allow the cutting blades on a direct harvester to cut the stem below those pods. Stem elongation may be promoted by the application of a growth-stimulating compound such as GA_3. Since the 1930s when a rice (*Oryza sativa*) disease was identified to be due to a pathogenic fungus *Gibberella fujikuroi* (Takahashi et al., 1991), GA_3 has been known to stimulate stem elongation (Davies, 2010; Marth et al., 1956). In greenhouse studies, elongation of the lower stem of common bean cultivars Poncho and Matterhorn was observed to be increased by the addition of GA_3 and a stimulation plateau was reached at 4 and 256 ppm GA_3, respectively (Pavlista et al., 2012). The objectives of this field study were to determine whether GA_3 would raise the lowest pods of 'Poncho' and 'Matterhorn' common bean plants higher off the ground, and whether this may result in improved yields comparing direct vs. conventional harvest methods.

Materials and methods

FIELD CONDITION AND OPERATIONS. Between 2005 and 2007, field trials were conducted on common bean cultivars Poncho and Matterhorn at the University of Nebraska's Panhandle Research and Extension Center, Scottsbluff (lat. 41.9°N, long. 103.7°W, elevation 3963 ft). Soil was a Tripp fine sandy loam at pH 7.9 to 8.2 and organic matter content of 0.8% to 1.0%. Planting was between 1 and 14 June depending on soil and air temperatures. Production

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
29.5735	fl oz	mL	0.0338
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
9.3540	gal/acre	$L \cdot ha^{-1}$	0.1069
2.54	inch(es)	cm	0.3937
16.3871	$inch^3$	cm^3	0.0610
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
28.3495	oz	g	0.0353
28,350	oz	mg	3.5274×10^{-5}
1.7300	$oz/inch^3$	$g \cdot cm^{-3}$	0.5780
1	ppm	$mg \cdot L^{-1}$	1
6.8948	psi	kPa	0.1450
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

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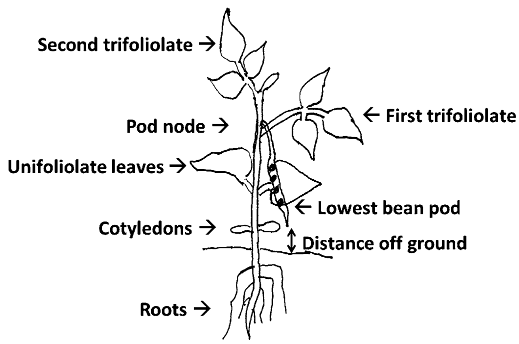

Fig. 1. Diagram of common bean seedling showing measurement of height of lowest pod's tip aboveground (clearance).

practices followed standard methods (Schwartz et al., 1993). Fertilization was applied preplant in May for a total of about nitrogen at 55 lb/acre, phosphate at 30 lb/acre, and sulfur at 15 lb/acre; no potash was added. Pesticides were applied using a carbon dioxide sprayer mounted on specially designed plot sprayer. Weed control was accomplished by preplant application of EPTC (Eptam 7E; Gowan, Yuma, AZ) plus alachlor (Lasso EC; Monsanto, St. Louis, MO) in late May. When mexican bean beetles (*Epilachna varivestis*) appeared in July each year, esfenvalerate (Asana XL; DuPont, Wilmington, DE) was applied. Rainfall from planting (June) to harvest (September) was ≈6 inches in 2005 and 2006, mostly occurring in June, and 2 inches in 2007. Seasonal rainfall was below normal 30%, 40%, and 80% for 2005, 2006, and 2007, respectively (Changnon et al., 1990). Trials were irrigated 11 to 13 inches, 2 inches applied in June, 6 to 7 inches in July, and 3 to 4 inches in August. Seasonal mean temperatures were near normal in 2005 and 2006, and 2.8 °F above normal in 2007. Plants were seeded to achieve a population of ≈80,000 plants/acre. Row spacing was 30 inches in 2005 and 2006, and both 22- and 30-inch row spacings were used in 2007. Plots consisted of six rows, 30 ft long, of which 25 ft of the center two rows were harvested conventionally in 2005 and 2006. Plots were harvested using the conventional practice of ditching in late May followed in September by undercutting, windrowing, and lifting (Smith, 2004). A combine manufactured by Wintersteiger (Ried im Innkreis, Austria) was used for the conventional harvest. For direct harvest, a sickle bar and reel were attached to the combine. In 2007, harvest methods were compared side-by-side in 10-row plots, of which four rows were harvested conventionally while two rows were harvested directly, and one row was harvested manually by cutting plants at the ground, bagging them followed by threshing and cleaning. Cultivars were evaluated in separate trials next to each other and analyzed independently. GA_3 treatments were replicated 4-fold and placed in a Latin square design in 2005 and 2006. In 2007, a randomized complete block design, with four replications, compared the three harvest methods within the same GA_3 treatment plots.

Plant material. Seeds of the common bean cultivars Poncho (pinto market class) and Matterhorn (great northern market class) were obtained through Kelley Bean Co. (Scottsbluff, NE). 'Poncho' is Type III, indeterminate, and prostate, and 'Matterhorn' is Type II, indeterminate, and erect (Kelly et al., 1999). They are commonly grown in western Nebraska and are representatives of their market class. Seeds were pretreated for bacterial and fungal pathogen suppression by Kelley Bean Co. using standard commercial practices.

Chemical preparation and applications. Gibberellic acid was applied as Release LC (Valent BioSciences, Long Grove, IL), a 4% (wt/wt) GA_3 formulation (1 g/fl oz GA_3). Release LC was diluted serially with water from 2000 to 0.5 ppm GA_3 depending on the trial. The rate ranges were determined from greenhouse studies (Pavlista et al., 2012). Seed treatment trials were conducted independently from foliar treatment trials in 2005. About 1000 seeds of cultivars Poncho and Matterhorn were dipped in 500 mL of an aqueous solution of GA_3 at 0, 125, 500, or 2000 ppm for ≈2 min after which the solution was drained and seeds were allowed to air dry. Foliar applications of GA_3 were tested in 2005, 2006, and 2007. GA_3 was applied to unifoliolate leaves at stage V2 (Schwartz et al., 1993) between 12 and 16 d after planting (DAP). Application of GA_3 to 'Poncho' was at 0, 0.5, 2, and 8 ppm in 2005 and 2006, and at 0, 2, and 4 ppm in 2007. 'Matterhorn' was treated with 0, 31.25, 125, and 500 ppm GA_3 in 2005 and 2006, and with 0, 62.5, and 125 ppm in 2007. A sticker-spreader type surfactant (X77; Loveland Products, Greeley, CO) at 0.125% was added to solutions applied to foliage in 2005 and 2006, but not in 2007 after greenhouse tests indicated a surfactant was not advantageous (unpublished data). GA_3 was applied in a 7.33-inch band at the level of the unifoliolate leaves. Earlier measurements indicated that the "wingspan" of two mature unifoliolate leaves averaged between 7 and 7.5 inches. The treatments were applied with a carbon dioxide sprayer mounted on a plot sprayer for uniform speed and direction control using 4001E nozzles (UniJet; Spraying Systems, Wheaton, IL) pressurized at 40 psi and positioned 10 inches above the unifoliolate leaves or 13 to 14 inches aboveground. Spray volume was equivalent to 21 gal/acre in the 7.33-inch treatment band thereby allowing for 0.5 to 1 mL of spray per plant.

Data collection and analysis. Emergence and seedling malformation were determined at 28 DAP in 2005. The height of the first and second trifoliolate nodes and the distance of the distal tip of the lowest pod aboveground (Fig. 1) were measured at 72, 75, and 99 DAP in 2005, 2006, and 2007, respectively. Seedling development was followed to 72 DAP, at which time the plant stand was counted. Yields from each plot were weighed, and seeds were sampled for moisture content and 100-seed weight. In 2007 shortly before harvest, six plant samples were taken from each plot. Pods were removed from each sample and counted. Pods were opened, and seeds were removed and counted. Seeds were weighed (fresh weight), placed in a graduated cylinder, and their volume (size) was determined. Seeds were then placed in an air drier and reweighed 1 week later to determine their dry weight. Seed moisture was calculated from the seed weights. Effects of GA_3 treatments were analyzed using PROC ANOVA (SAS version 9.1; SAS Institute, Cary, NC), and means were separated using least significant difference for each cultivar. In 2007, the analysis included harvest method for each row spacing of both cultivars.

Results

Seed treatment with GA_3 was field tested only in 2005. Dipping 'Poncho' seed in GA_3 lowered seedling emergence and stand (Table 1). Treated emerged seedlings also tended to be "bowed," that is the cotyledons remained buried while the hypocotyl was exposed (Fig. 2). Some of these seedlings snapped above the soil line from the pressure. Because of the poor stand and weak plants, yields likewise were reduced (data not shown). 'Matterhorn' also showed reduced emergence by 2000 ppm GA_3, but stand seemed unaffected later in the season (Table 1). However, treated plants lagged in development compared with checks. GA_3 did promote stem elongation below the unifoliolate (Table 1) and first trifoliolate nodes (data not shown) for cultivar Matterhorn; this could not be measured for cultivar Poncho because of the stem "bowing" effect. 'Poncho' and 'Matterhorn' yields were depressed by seed treatments (data not shown).

Since there were no year interactions, data from 2005 and 2006 were combined. 'Poncho' and 'Matterhorn' treated with GA_3 applied to unifoliolate leaves showed stem elongation. The distance from the ground to the first and second trifoliolate nodes was raised over 30% by GA_3 at 8 ppm applied to 'Poncho' and exceeded 50% higher when 125 or 500 ppm GA_3 was applied to 'Matterhorn' (Table 2). This stem elongation resulted in raising the lowest pods higher off the ground. The distal tip of the lowest pod of 'Poncho' treated with 8 ppm GA_3 was raised 5.7 cm (Table 2). The distal tip of the lowest pod of 'Matterhorn' was raised 4.7 and 7.6 cm when treated with GA_3 at 125 and 500 ppm, respectively (Table 2). Yields tended to increase with unifoliolate application of GA_3, presumably because of the elevation of the lowest pods. GA_3-treated 'Poncho' plants had yields 16% to 19% higher than the untreated

Table 1. Effect of gibberellic acid (GA_3) applied as a seed soak to common bean cultivars Poncho and Matterhorn on emergence and growth in 2005.

GA_3 applied (ppm)[z]	"Bowed" seedlings at 16 DAP (%)[y]	Emergence at 28 DAP (%)	Plant stand at 72 DAP (%)
	'Poncho'[x]		
0	2 c[w]	88 a	98 a
125	71 b	40 b	90 a
500	69 ab	22 c	32 b
2000	88 a	18 c	20 b
GA_3 applied (ppm)[z]	**Unifoliolate node ht at 16 DAP (cm)[z]**	**Emergence at 28 DAP (%)**	**Plant stand at 72 DAP (%)**
	'Matterhorn'[x]		
0	6.3 b	75 a	99
125	7.1 ab	68 a	99
500	7.2 a	67 a	98
2000	7.6 a	44 b	95

[z]1 ppm = 1 mg·L^{-1}, 1 cm = 0.3937 inch.
[y]"Bowed" seedlings refer to plants that emerged but the cotyledons were still buried giving a bowed appearance; a few of the hypocotyls broke from the strain; DAP = d after planting.
[x]'Poncho' is a Type III pinto cultivar. 'Matterhorn' is a Type II great northern cultivar.
[w]Mean separation for GA_3 dose (column) under each cultivar (block) by least significant differences at $P < 0.05$.

Fig. 2. "Bowed" common bean cultivar Poncho seedlings resulting from seed treatment with gibberellic acid at 2000 ppm (mg·L^{-1}) in 2005.

Table 2. Node and pod heights, and bean yield of common bean cultivars Poncho and Matterhorn after unifoliolate (V2 stage) treatment with gibberellic acid (GA_3) (means of 2005 and 2006).

GA_3 applied (ppm)[z]	Distance to node of first trifoliolate (cm)[z]	Distance to node of second trifoliolate (cm)	Distance to tip of lowest pod (cm)	Yield (lb/acre)[z]
		'Poncho'[y]		
0	6.2 b[x]	9.0 b	4.9 b	2862 b[w]
0.5	6.2 b	10.4 ab	8.2 ab	3319 a
2	7.8 ab	11.7 a	8.3 ab	3402 a
8	8.3 a	11.9 a	10.6 a	3398 a
		'Matterhorn'[y]		
0	5.6 b	7.6 b	5.8 c	2832 b
31.25	6.5 b	9.5 b	8.4 bc	2925 b
125	8.6 a	12.2 a	10.5 ab	3030 ab
500	9.3 a	13.1 a	13.4 a	3240 a

[z]1 ppm = 1 mg·L^{-1}, 1 cm = 0.3937 inch, 1 lb/acre = 1.1209 kg·ha^{-1}.
[y]'Poncho' is a Type III pinto cultivar. 'Matterhorn' is a Type II great northern cultivar.
[x]Mean separation for GA_3 dose (column) under each cultivar (block) by least significant differences at $P < 0.05$.
[w]Mean separation for GA_3 dose for each cultivar by least significant differences at $P < 0.1$.

'Poncho' plants (Table 2). 'Matterhorn' tended to have 14% higher yield when treated with 500 ppm GA_3 compared with untreated plants (Table 2).

In 2007, the ability of unifoliolate-applied GA_3 to raise the lowest pods of 'Poncho' and 'Matterhorn' was determined on row spacings of 22 and 30 inches. For 'Poncho' grown in 22- and 30-inch rows, the lowest pods were raised 3.7 and 1.8 cm by 4 ppm GA_3, respectively (Table 3). For 'Matterhorn', the pods were raised 2.1 and 2.9 cm by 125 ppm GA_3 at 22- and 30-inch row spacing, respectively (Table 3). The main purpose of this trial was to compare three harvest methods at two row spacings after unifoliolate treatment with GA_3. The irrigation trial conducted in 2006 suggested that GA_3 could improve yields from direct harvest. In 2007, when 'Poncho' was treated with 4 ppm GA_3, yield from direct harvest was raised to that of yields from untreated plants harvested manually or conventionally at both row spacings (Table 4). A similar yield promotion was observed with 'Matterhorn' when plants were treated with 125 ppm GA_3 (Table 5). There was no significant interaction ($P > 0.5$) between harvest method by GA_3 rate for either cultivar and row spacing.

In all foliar-treated trials, there was no effect of GA_3 treatment on seed moisture, weight, size, or density (data not shown). In 2007, six plant samples from each plot were removed, and GA_3 treatment did not affect pods per plant nor seeds per pod regardless of cultivar or row spacing. In 'Matterhorn', pod number and seed number/plant were unaffected by row spacing. Seed weight was little different, but seed size and moisture tended to be lower at 30-inch than at 22-inch row spacing; density tended to be higher (Table 6). In 'Poncho', pod and seed number per plant were higher at 30-inch compared with 22-inch row spacing (Table 6). Seed moisture was lower at 30-inch rows and density was higher.

Table 3. Effect of gibberellic acid (GA_3) applied to unifoliolate leaves at V2 stage on the clearance of the lowest pod from the ground of the common bean cultivars Poncho and Matterhorn planted at 22- and 30-inch (55.9 and 76.2 cm) row spacing in 2007.

'Poncho'[z]			'Matterhorn'[z]		
	Distance to tip of lowest pod (cm)[y]			Distance to tip of lowest pod (cm)	
GA_3 applied (ppm)[y]	22-inch row spacing	30-inch row spacing	GA_3 applied (ppm)	22-inch row spacing	30-inch row spacing
0	12.0 b[x]	9.3 b[w]	0	6.7 b	7.5 b
2	13.0 ab	9.9 ab	62.5	7.9 ab	9.5 ab
4	15.7 a	11.1 a	125	8.8 a	10.4 a

[z]'Poncho' is a Type III pinto cultivar. 'Matterhorn' is a Type II great northern cultivar.
[y]1 ppm = 1 $mg \cdot L^{-1}$, 1 cm = 0.3937 inch.
[x]Mean separation for GA_3 dose (column) under each cultivar by least significant differences at $P < 0.05$.
[w]Mean separation for GA_3 dose by least significant differences at $P < 0.1$.

Table 4. Comparing yields of common bean cultivar Poncho planted in 22- and 30-inch (55.9 and 76.2 cm) rows as influenced by gibberellic acid (GA_3) applied to unifoliolate leaves at V2 stage and harvested by three methods in 2007.

	Yield (lb/acre)[z]		
GA_3 applied (ppm)[z]	Manual harvest	Conventional	Direct harvest
		22-inch row spacing	
0	1360 bc[y]	1268 bcd	979 d
2	1616 ab	1638 ab	1196 cd
4	1501 abc	1861 a	1237 cd
		30-inch row spacing	
0	1992 bc	1826 cd	1469 e
2	2221 ab	2372 a	1604 de
4	2265 ab	2286 ab	1767 cde

[z]1 ppm = 1 $mg \cdot L^{-1}$, 1 lb/acre = 1.1209 $kg \cdot ha^{-1}$.
[y]Mean separation for GA_3 dose and harvest method under each row spacing by least significant differences at $P < 0.05$.

Table 5. Comparing yields of common bean cultivar Matterhorn planted in 22- and 30-inch (55.9 and 76.2 cm) rows as influenced by gibberellic acid (GA_3) applied to unifoliolate leaves at V2 stage and harvested by three methods in 2007.

	Yield (lb/acre)[z]		
GA_3 applied (ppm)[z]	Manual harvest	Conventional	Direct harvest
		22-inch row spacing	
0	1715 b[y]	1627 bc	1356 c
62.5	1755 b	1859 ab	1605 bc
125	1727 b	2110 a	1614 bc
		30-inch row spacing	
0	1346 bc	1424 ab	883 d
62.5	1398 ab	1550 ab	997 d
125	1414 ab	1655 a	1078 cd

[z]1 ppm = 1 $mg \cdot L^{-1}$, 1 lb/acre = 1.1209 $kg \cdot ha^{-1}$.
[y]Mean separation for GA_3 dose and harvest method under each row spacing by least significant differences at $P < 0.05$.

Discussion

Seed-applied GA_3 at 1000 and 2000 ppm stimulated stem elongation of cultivars Poncho and Matterhorn, respectively, in greenhouse tests (Pavlista et al., 2012). However, emergence could be negatively impacted. Although seed treatment with GA_3 may be less expensive than foliar treatment, there is a considerable amount of risk and uncertainties associated with seed applications. The deleterious and erratic effects observed both in the field trial (2005) and greenhouse tests may be associated with varying levels of GA_3 actually entering the seed because of irregularities such as cracks in the seedcoat. As a consequence, the authors do not recommend this form of application.

In greenhouse studies (Pavlista et al., 2012), 'Matterhorn', a Type II

Table 6. Comparing range of seed characteristics of six plant samples from 22- and 30-inch (55.9 and 76.2 cm) row-spaced plots of common bean cultivars Poncho and Matterhorn in 2007.

Cultivar row spacing (inches)	Pods (no./plant)	Seeds (no./plant)	Seed moisture (%)	Seed wt (mg/seed)[z]	Seed size (cm^3/seed)[z]	Seed density ($g \cdot cm^{-3}$)[z]
Poncho						
22	8–10	22–30	11.7–14.9	335–362	0.47–0.52	0.70–0.71
30	13–16	36–55	6.2–6.7	340–426	0.44–0.56	0.77–0.79
Matterhorn						
22	13–16	33–43	9.1–10.7	326–413	0.44–0.56	0.73–0.75
30	13–19	36–52	5.2–6.6	282–337	0.36–0.43	0.78–0.80

[z]1 mg = 3.5274×10^{-5} oz, 1 cm^3 = 0.0610 $inch^3$, 1 $g \cdot cm^{-3}$ = 0.5780 oz/$inch^3$.

cultivar, needed 64 times as much GA_3 applied to the unifoliolate leaves compared with 'Poncho', a Type III cultivar, to show maximum stimulation of elongation of the internode between the unifoliolate and first trifoliolate leaves. The field application of GA_3 to the foliage indicated the same levels of sensitivity. Much less GA_3 significantly raised the lowest pod off the ground for 'Poncho' compared with 'Matterhorn'. Increasing ground clearance of pods resulted in improved yields when conventional and direct harvest methods were compared in 2007. The yields from GA_3-treated 'Poncho' at either 22- or 30-inch row spacing harvested directly were comparable to the yields from untreated plants harvested conventionally or by hand. For 'Matterhorn', this was also the case at 22-inch, but not at 30-inch row spacing. Differences in the seed yield between direct harvest and conventional or hand harvest are presumed to represent seed loss mostly resulting from pods positioned too close or on the ground (Eckert et al., 2011a; Horn et al., 2000).

Eckert et al. (2011a) demonstrated that the two major factors governing seed yield and seed loss were the cultivar and the method of harvest. Using 30-inch row spacing with nine cultivars representing three market types, they tested two cultivars of Type III growth habit (prostate), and seven of Type II (erect). On average, beans harvested directly had 37% less yield and 5-fold greater seed loss than those harvested conventionally. Eckert et al. (2011b) then compared row spacings of 12, 18, and 30 inches under direct harvest of two Type II and one Type III pinto cultivars at a seeding rate of 70,000 plants/acre. Under direct harvest, beside the cultivar, row spacing was the main factor for seed yield and seed loss. They observed that by reducing row spacing from 30 to 18 inches, the highest yield was obtained. This observation was reported earlier for row spacing reduction from 30 to 15 inches (Grafton et al., 1988). On the other hand, Horn et al. (2000) reported that under direct harvest, seed yield was increased by increasing row spacing from 20 to 30 inches using cultivar Pampa, a Type II. In the 2007 trial reported here, yield increased when row spacing was changed from 22 to 30 inches for 'Poncho', a Type III pinto, but not for 'Matterhorn', a Type II great northern, that showed the reverse trend. Could the difference be related to growth habit, prostate vs. erect, or genetic variability between cultivars? Eckert et al. (2011b) did not report data on each cultivar at each row spacing but did report that cultivar was the most significant factor. 'Lariat', a Type II pinto, had the highest yield and lowest seed loss under direct harvest, which were associated with the greatest ground clearance of the lowest pod (2.3 cm). Seed loss was the greatest and the height of the lowest pod was highest at a row spacing of 12 inches, but there were no significant difference between 18- and 30-inch row spacings. Horn et al. (2000) observed that under direct harvest, reducing row spacing from 30 to 20 inches increased pod tip height from 2.1 to 3.7 cm, a 0.6-cm increase, and decreased the percentage of pods touching the ground from 28% to 11%. In the 2007 trial reported here, untreated 'Poncho' showed a 2.7 cm increase in ground clearance of the lowest pod when planting in 22- vs. 30-inch rows, but 'Matterhorn' did not show a significant difference between the two row spacings. Nevertheless, with the addition of GA_3, the difference in pod ground clearance showed a more dramatic difference between the two row spacings. 'Poncho' had more pod ground clearance in 22-inch rows, and 'Matterhorn' had more in 30-inch rows. The cultivar response comparing 22- and 30-inch row spacings may be related to growth habit, prostate vs. erect; however, differences in genetic variability between the cultivars and market class cannot be ruled out.

'Poncho' is a proprietary Type III pinto with a prostate or vining growth habit (Johnson et al., 2007), and 'Matterhorn' is a Type II great northern with an erect growth habit (Kelly et al., 1999). The genetic basis of growth habit or canopy architecture in common bean is not well characterized and is highly affected by the environment (Singh, 2001). GA_3 is a likely candidate contributing to the growth habit difference between 'Poncho' and 'Matterhorn' since its role in affecting internode length is well established. The climbing phenotype in common bean is due to the dominant gene *C1*, whereas the nonclimbing type is due to the recessive gene form (*c1*) that evolved from a natural mutation (Gepts, 1998; Kretchmer and Wallace, 1978). The differential sensitivity between 'Poncho' and 'Matterhorn' to GA_3 dose may be connected to the nature of this gene (*C1* or *c1* or other unknown genes). GA_3 response may be due to a mutation in its biosynthesis or signal transduction resulting in differences in sensitivity to externally applied GA_3 in those cultivars.

Conclusion

In this study, GA_3 increased the ground clearance of the lowest pod on the plant for the common bean cultivars Poncho and Matterhorn. This correlated with an increase in seed yield for both conventional and direct harvest methods. In addition, the trial in 2007 indicated that GA_3 did not decrease seed yield of direct-harvested beans from the level of untreated conventionally harvested 'Poncho' beans in both 22- and 30-inch row spacings, and of 'Matterhorn' beans in 22-inch row spacing. A key economic consideration is the relative cost of GA_3. For 'Poncho', as little as 2 ppm of GA_3 was needed for maximum effect, but for 'Matterhorn', at least 125 ppm is needed. Spray application was designed to deliver close to 1 mL of spray per plant, 80 L/acre on 80,000 plants/acre. The current cost of Release is ≈$1.15/fl oz, and 1 fl oz of Release contains 1 g GA_3. Therefore, for 'Poncho' an application of 8 ppm GA_3 would require GA_3 at 0.64 g/acre and cost ≈$0.74/acre. But 'Matterhorn', requiring at least 125 ppm GA_3, would use 10 g/acre GA_3 and cost ≈$12/acre. This is for the material only not for the cost of application. By no means do the authors wish to imply that GA_3 alone would solve the problem of seed loss due to direct harvest as harvest methods were compared only in 1 year. The authors do feel that GA_3, integrated with improvements in harvest machinery and cultivar architecture, could improve the yield from direct harvesting of common beans and thereby lowering production cost and reducing soil erosion.

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