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Gibberellic Acid Sensitivity among Common Bean Cultivars (Phaseolus vulgaris L.)

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Additional index words. dry edible bean, plant growth stimulant, gibberellin, GA3

Abstract. To lower seed yield loss from directly harvested common bean or dry bean, height of the lower pod-bearing nodes needs to be raised. The objective of this greenhouse study was to stimulate lower stem elongation by gibberellic acid (GA3) of dry bean cultivars. Seeds of cv. Matterhorn, erect indeterminate Type II, and cv. Poncho, prostate indeterminate Type III, were dipped in GA3 at 62.5 to 16,000 ppm and planted. After 14 d, the height of the unifoliate and first trifoliate nodes showed maximum stimulation of stem elongation by 1000 ppm GA3 for ‘Poncho’ and by 2000 ppm for ‘Matterhorn’. Application of 1 mL of GA3 at 0.031 to 2048 ppm to newly expanded unifoliate leaves showed cultivar differences. Whereas ‘Matterhorn’ was promoted at 64 ppm and reached a maximum height by 512 ppm GA3, ‘Poncho’ was promoted at 0.25 ppm and reached a maximum height by 8 ppm GA3. Flowering of ‘Matterhorn’ was unaffected by GA3; flowering of ‘Poncho’ was completely inhibited by 128 ppm. The sensitivity differential of cultivars was verified with other cultivars. Type I cultivars, which are all determinate, showed a full range of GA3 sensitivity. Dry bean cultivars may be regrouped based on the GA3 dose to which they respond. Individual response to GA3 rates of dry bean cultivars needs to be predetermined using a short-term, 2–3 weeks, greenhouse bioassay before field use of GA3.

In dry bean (Phaseolus vulgaris L.), growth form, i.e., determinate vs. indeterminate, and growth habit, i.e., upright/erect/bushy vs. viny/prostrate, are among the most important characteristics for classifying cultivars from an agronomic viewpoint (Kelly, 2001; Laing et al., 1984; Singh, 1982). Dry bean is morphologically classified as determinate or indeterminate growth forms depending on whether the terminal meristem is reproductive (determinate) or vegetative (indeterminate) (Miklas and Singh, 2007). This characteristic is genetically controlled by the gene Finfin or unaffected by the environment (Koinange et al., 1996). Having a determinate terminal meristem was the result of FinFin or Finfin that is dominant over an indeterminate type (finfin) and this probably evolved through natural mutation of the wild-type Fin gene (Gepts, 1998). Indeterminate agronomic cultivars were classified into Type II and Type III based on vine growth extension and climbing ability. Determinate cultivars were classified as Type I and subdivided by their climbing ability. North American-grown commercial dry bean cultivars are described by Singh (1982) as:

Type I = determinate, erect (bushy). Further classified into Ia (no climbing ability) and Ib (some climbing ability);
Type II = indeterminate, erect (bushy). Further classified into Iia (no climbing ability) and Iib (some climbing ability = semiclimbing); and
Type III = indeterminate, prostate (viny). Further classified into IIIa (some climbing ability = semiclimbing) and IIIb (strong climbing ability = climbing).

Vine length is highly affected by environment conditions, especially light (Kelly, 2001; Singh, 2001). The climbing phenotype of dry bean may be the result of a dominant gene, C1, whereas the nonclimbing types may be the result of a recessive gene, c1, that has evolved through natural mutation of C1 (Gepts, 1998; Kretschmer and Wallace, 1978).

Type II and III dry bean cultivars are the most common ones grown in the U.S. High Plains. The lower pods of common dry bean grown in the field are very close to the ground. Because of this, the conventional practice in dry bean production in the U.S. High Plains is to harvest by first undercutting plants, conventional harvest, to minimize yield loss (Smith, 2004). The alternate method of harvest is direct harvesting but the yield loss in the Nebraska Panhandle may be greater than 10% even with the addition of lifters (Smith, 2004). In the Red River Valley, the mean of nine cultivars grown in four North Dakota locations over 2 years, seed yield was reduced from 2240 for conventional harvest to 1410 kg ha−1 for direct harvest or 27% (Eckert et al., 2011). Most of the yield reduction was the result of seed loss during harvest, 4.5% by conventional harvest vs. 23.2% by direct harvest (Eckert et al., 2011).

One possible method of reducing yield loss is to stimulate growth of lower internodes, those below the node with the first flower and pod, to raise lower pods higher off the ground and allow the cutting blades on a direct harvester to cut the stem below those pods. This may be accomplished by application of a growth-stimulating compound such as GA3.

The ability of gibberellins to promote stem growth was known since the 1930s when a rice disease was identified to be the result of a pathogenic fungus Gibberella fujikuroi (Takahashi et al., 1991). Since then, there have been more than 130 gibberellins identified. Gibberellic acid, a key gibberelin, is highly active and well known to stimulate stem elongation (Davies, 2010; Marth et al., 1956). A greenhouse bioassay for GA3 applied to fully opened unifoliate leaves of snap bean cultivars (P. vulgaris) was developed showing a dose–response for stimulating stem elongation and exposure between 2 and 10 μg GA3/plant for maximum effect (Knoche et al., 1998, 2000).

The objective of this study was to compare the GA3 dose–response of indeterminate dry bean cultivars with an erect, upright (Type II) growth or a prostate (Type III) growth habit and determinate cultivars (Type I).

Materials and Methods

Greenhouse conditions. Experiments were conducted in March and April of 2005, 2006, and 2007 in a greenhouse at the Panhandle Research & Extension Center of the University of Nebraska in Scottsbluff (lat. 41.9° N, long. 103.7° W, elevation 1208 m). The maximum daytime temperature was ≈35 °C, and minimum nighttime temperature was ≈23 °C. Metal halide lamps were used to supplement sunlight to maintain a 14-h photoperiod. Lamps were kept 1.5 m above plants. Pots were watered at planting and checked three times weekly and watered as needed to maintain a full water profile throughout the experiments.

Plant material. Dry bean cultivars, i.e., common bean and dry edible bean, listed in Table 1, were obtained from various seed programs such as the University of Idaho, University of Saskatchewan, and Michigan State University and purchased through Kelley Bean Co., Scottsbluff, NE. Type II, indeterminate and upright, and Type III, indeterminate and prostate, cultivars are commonly grown in western Nebraska. The cv. Matterhorn and cv. Poncho were chosen as to initially represent Type II and Type III cultivars, respectively, because they are major cultivars grown in this area. Type I, determinate, cultivars are not commonly grown in this area, but as a result of the range of responses to GA3, application of Type II and III cultivars, Type I cultivars

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Table 1. Dry bean cultivars, their market class and type, used in greenhouse studies, and a summary of the GA$_3$ concentration applied to the unifoliate leaves that resulted in the maximum stimulation of internode elongation (combination of 3 years’ data).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Market class</th>
<th>Type</th>
<th>GA$_3$ concn for maximum response (ppm)</th>
<th>Relative GA$_3$ foliar sensitivity level*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poncho</td>
<td>Pinto</td>
<td>III*</td>
<td>2</td>
<td>High</td>
</tr>
<tr>
<td>Marquis</td>
<td>Great Northern</td>
<td>III</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>Frigate</td>
<td>Navy</td>
<td>II</td>
<td>0.5</td>
<td>High</td>
</tr>
<tr>
<td>Vision</td>
<td>Pinto</td>
<td>II</td>
<td>32</td>
<td>Medium</td>
</tr>
<tr>
<td>Matterhorn</td>
<td>Great Northern</td>
<td>II</td>
<td>512</td>
<td>Medium</td>
</tr>
<tr>
<td>Ensign</td>
<td>Navy</td>
<td>II</td>
<td>512</td>
<td>Medium</td>
</tr>
<tr>
<td>Agate</td>
<td>Pinto</td>
<td>I</td>
<td>0.125</td>
<td>High</td>
</tr>
<tr>
<td>Amber</td>
<td>Pinto</td>
<td>I</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>CDC Pintium</td>
<td>Pinto</td>
<td>I</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>Dory</td>
<td>Pinto</td>
<td>I</td>
<td>0.125</td>
<td>High</td>
</tr>
<tr>
<td>Early Ray</td>
<td>Pinto</td>
<td>I</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>G2883</td>
<td>Great Northern</td>
<td>I</td>
<td>0.125</td>
<td>High</td>
</tr>
<tr>
<td>Nordic</td>
<td>Great Northern</td>
<td>I</td>
<td>512</td>
<td>Medium</td>
</tr>
<tr>
<td>Newport</td>
<td>Navy</td>
<td>I</td>
<td>512</td>
<td>Medium</td>
</tr>
<tr>
<td>Seafarer</td>
<td>Navy</td>
<td>I</td>
<td>512</td>
<td>Medium</td>
</tr>
<tr>
<td>Foxfire</td>
<td>Light Red Kidney</td>
<td>I</td>
<td>512</td>
<td>Medium</td>
</tr>
<tr>
<td>Pink Panther</td>
<td>Light Red Kidney</td>
<td>I</td>
<td>512</td>
<td>Medium</td>
</tr>
<tr>
<td>Rog 776</td>
<td>Light Red Kidney</td>
<td>I</td>
<td>512</td>
<td>Medium</td>
</tr>
<tr>
<td>Moldova-104</td>
<td>Large White Kidney</td>
<td>I</td>
<td>2048</td>
<td>Low</td>
</tr>
</tbody>
</table>

*Relative sensitivity was based on the concentration of foliar-applied GA$_3$ that resulted in the maximum stimulation of internode elongation: high = 8 ppm or less, medium = 32–512 ppm, low = 2048 ppm or greater.

**Matterhorn** and **Poncho** were the standards for Type II and Type III cultivars and for medium and high GA$_3$ sensitivity, respectively.

Type III cultivars are prostate (viny) and indeterminate. Type II cultivars are bushy (erect) and indeterminate. Type I cultivars are determinate and bushy. GA$_3$ = gibberellic acid.

were also tested for their foliar response. Seeds were treated with streptomycin for pathogen suppression by Kelley Bean Co. using standard commercial practices.

In the 2005 rate tests, seeds were planted in durable molded fiber pots that were 20 cm in diameter and 20 cm deep. In the tests conducted in 2006 and 2007, seeds were planted in plastic pots, 15 cm in diameter by 15 cm deep, because of acceptability, availability, and bench space limitation. Seeds were planted 2 cm deep in Fafard Superfine Germination Mix (American Clay Works, Denver, CO). In the seed application tests in 2005, emergence of all planted seeds and bench space limitation. Seeds were treated with streptomycin for pathogen suppression by Kelley Bean Co. using standard commercial practices.

In 2006, the cultivars were chosen based on the 2006 results. Apical height was measured at 7 DAT. Apical height was measured at 7 DAT.

Results

Seed application (2005). Emergence from pots in the greenhouse of ‘Matterhorn’ seed treated with 16,000 ppm GA$_3$ was 25%, significantly less than for both water-treated checks (75%) and seed treated with 63 to 4000 ppm GA$_3$ (67% to 83%). In contrast, ‘Poncho’ did not show a significant effect of GA$_3$ seed treatment on emergence at any treatment level (67% to 75%). At 14 DAP, the height of the unifoliate and first trifoliate nodes was measured. Stem elongation promotion by GA$_3$ was highly significant (Fig. 1). ‘Poncho’ grew more than ‘Matterhorn’ and its nodes were higher. Significant height promotion was obtained between 250 and 1000 ppm GA$_3$. Maximum stimulation by GA$_3$ was reached at 1000 ppm for ‘Poncho’ and 2000 ppm for ‘Matterhorn’, indicating a possible difference in sensitivity.

Foliar application (2005). The rate response of ‘Matterhorn’ and ‘Poncho’ to GA$_3$ applied to unifoliate leaves at V2 was tested also in 2005. Initially, GA$_3$ was applied at 2 to 2048 ppm in 2x increments (Fig. 2). ‘Matterhorn’ showed significant height promotion of the first trifoliate node after 1 week exposure to 64 ppm GA$_3$ or greater and the response reached a plateau at 256 ppm GA$_3$. ‘Poncho’ was much more sensitive to GA$_3$ than ‘Matterhorn’ (Fig. 2). Within 7 DAT, it was clear that ‘Poncho’ was affected by 2 ppm. The rate response was repeated with lower doses, 0.031 to 4 ppm GA$_3$. Significant height promotion of the first and second trifoliate nodes at 7 DAT was observed with 0.25 ppm
GA$_3$ applied to unifoliate leaves and the response reached a plateau at 4 ppm GA$_3$ (Fig. 2). When ‘Poncho’ plants were held to 21 and 35 DAT to observe floral and subsequent pod development, GA$_3$ at 32 ppm and greater had a significant inhibiting effect on flowering and pod formation (Fig. 3). No flowers or pods were present on ‘Poncho’ plants exposed to 128 ppm GA$_3$ and greater. A similar effect was not observed with ‘Matterhorn’ (data not shown); floral and pod development showed no significant difference between water-treated checks and plants treated with up to 2048 ppm GA$_3$.

**Cultivar sensitivity (2006, 2007).** Because results in 2005 showed that GA$_3$ applied to the unifoliate leaves at V2 affected the internode length above the unifoliate node (Fig. 2), new growth, i.e., difference between the plant height at treatment and at 7 DAT, should be indicative of a GA$_3$ effect. In 2006, nine cultivars were used, some of Type I, Type II, or Type III with three cultivars being in one of three market classes, ‘Great White Northern’, ‘Pinto’, or ‘Navy’ market class (Table 1). Cultivars Marquis and Poncho, both Type III, and Type II cultivar Frigate reached a plateau in the amount of new growth when exposed to GA$_3$ at less than 8 ppm (Table 2). ‘Frigate’ is a Type IIB cultivar that can be viny, behaving similar to a Type IIIA cultivar in the environment of western Nebraska. The Type II cultivar Vision attained a plateau in new growth with GA$_3$ at 32 ppm, whereas the other two Type II cultivars, Ensign and Matterhorn, attained a plateau in new growth response with GA$_3$ at 512 ppm (Table 2). Cultivar Poncho’s higher sensitivity and cv. Matterhorn’s lower sensitivity to GA$_3$ was at the same level as observed in 2005 (Fig. 2). The three Type I cultivars, CDC Pintium, Nordic, and Seafarer
showed a sensitivity plateau between 8 and 32 ppm (Table 2). Although a statistical comparison was not possible, market class, which is based on seed characteristics, did not show a pattern to GA₃ sensitivity. In 2007, 13 Type I cultivars (Table 1) were tested. Type I cultivars reacted to GA₃ doses in three groupings classified by the degree of cultivar sensitivity to GA₃ (Table 3). Cultivars Agate, Amber, CDC Pintium, Doray, Early Ray, and G2883 reached a sensitivity plateau at or below 8 ppm GA₃ similar to Type III cultivars and the Type II cultivar Frigate. Cultivars Nordic, Newport, Seafarer, Foxfire, Pink Panther, and Rog 776 reached a plateau between 8 and 512 ppm GA₃ similar to ‘Matterhorn’, ‘Vision’, and ‘Ensign’ (Table 3). The cultivar Moldova 104 did not reach a maximum elongation stimulation until exposed to 2048 ppm GA₃ or greater indicating a lower level of sensitivity than the other cultivars (Table 3).

Discussion

Gibberellic acid dose–response. A cultivar-specific stem elongation response to GA₃ was first observed with seed treatments. ‘Poncho’, a Type III cultivar, showed elongation of the stem below the first trifoliate internode with one-fourth to half the concentration needed by ‘Matterhorn’, a Type II cultivar, to reach maximum effect. Foliar GA₃ application resulted in a similar effect but with lower GA₃ doses and showing a greater difference in dose–response between the two cultivars. Much lower GA₃ rates applied to foliage significantly stimulated stem elongation for ‘Poncho’ compared with ‘Matterhorn’ (Fig. 2). On snap bean (P. vulgaris), the GA₃ exposures of unifoliate leaves at V₂ that resulted in maximum elongation of the internode above the unifoliate within 1 week after exposure were between 2 and 10 μg/leaf or 1 mL of a 10 ppm solution (Bukovac et al., 1958; Knoche and Bukovac, 1999; Knoche et al., 1998, 2000;
The genetics of gibberellin sensitivity in common bean cultivars seemed to be highly variable and may be grouped into at least two categories based on their sensitivity to GA3. Type I cultivars showed a mixed response to GA3, from low to high doses. Unlike indeterminate cultivars, Type I cultivars (determinate) are loosely described as bushy. Based on their GA3 response, some Type I cultivars may be less sensitive to GA3, similar to the Type II cultivar Matterhorn; other Type I cultivars may be more sensitive to GA3, similar to the Type III cultivar Poncho. In the present study, significant differences in response to GA3 doses were observed among cultivars regardless of their growth habit, e.g., erect/upright vs. prostate/viny, determinate vs. indeterminate. Dry bean cultivars with a similar sensitivity to GA3 dose may have similar genetics related to gibberellin response.

### Table 2. New growth of Type I, II and III cultivars 1 week after exposure of unifoliate leaves to gibberellic acid (2006).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Type</th>
<th>GA3 exposure (ppm)</th>
<th>New growth (mm)</th>
<th>GA3 exposure (ppm)</th>
<th>New growth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poncho</td>
<td>III</td>
<td>0</td>
<td>0.125</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>Marquis</td>
<td>III</td>
<td>109 D</td>
<td>222 B</td>
<td>294 B</td>
<td>447 A</td>
</tr>
<tr>
<td>Frigate</td>
<td>II</td>
<td>380 BC</td>
<td>262 C</td>
<td>294 B</td>
<td>447 A</td>
</tr>
</tbody>
</table>

*a New growth was calculated as the plant height 7 d after treatment minus the plant height at time of treatment.

**Fig. 3.** Floral stage of dry bean cultivar Poncho 3 and 5 weeks after treating (WAT) unifoliate leaves with gibberellic acid (GA3; 2005). Reproductive scale indicates presence of no flowers (0), closed flowers (1), open flowers (2), small pods, less than 2.5 cm (3), and large pods, greater than 2.5 (4). Means separated between GA3 doses for each WAT (curve) by least significant difference at P < 0.05.

### Conclusion

This study showed that stem elongation of common bean cultivars responds to different doses of GA3 and that this difference may be categorized in at least two groups, high and medium GA3 sensitivity. GA3 sensitivity could not be correlated to determinate vs. indeterminate, growth habit, e.g., erect/upright/bush vs. prostate/viny, or to market class. Individual cultivars would need to be evaluated in a short-term foliar bioassay for their specific GA3 sensitivity before applying GA3 in the field to raise lower pods and improve direct harvest.

### Literature Cited


Table 3. New growth of Type I cultivars 1 week after exposure of unifoliate leaves to gibberellic acid (2007).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Market class</th>
<th>GA3 exposure (ppm)</th>
<th>New growth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0.125</td>
</tr>
<tr>
<td>Agate</td>
<td>Pinto</td>
<td>488 B</td>
<td>593 AB</td>
</tr>
<tr>
<td>Amber</td>
<td>Pinto</td>
<td>487 BC</td>
<td>444 C</td>
</tr>
<tr>
<td>CDC Pintium</td>
<td>Pinto</td>
<td>309 C</td>
<td>505 B</td>
</tr>
<tr>
<td>Doray</td>
<td>Pinto</td>
<td>520 B</td>
<td>669 A</td>
</tr>
<tr>
<td>Early Ray</td>
<td>Pinto</td>
<td>396 B</td>
<td>429 B</td>
</tr>
<tr>
<td>G2883</td>
<td>Great Northern</td>
<td>424 B</td>
<td>567 AB</td>
</tr>
<tr>
<td>Nordic</td>
<td>Great Northern</td>
<td>210 C</td>
<td>177 C</td>
</tr>
<tr>
<td>Newport</td>
<td>Navy</td>
<td>33 C</td>
<td>31 C</td>
</tr>
<tr>
<td>Seafarer</td>
<td>Navy</td>
<td>89 C</td>
<td>115 C</td>
</tr>
<tr>
<td>Foxfire</td>
<td>Light Red Kidney</td>
<td>131 C</td>
<td>143 C</td>
</tr>
<tr>
<td>Pink Panther</td>
<td>Light Red Kidney</td>
<td>279 C</td>
<td>288 C</td>
</tr>
<tr>
<td>Rog 776</td>
<td>Light Red Kidney</td>
<td>155 C</td>
<td>211 C</td>
</tr>
<tr>
<td>Moldova 104</td>
<td>Large White Kidney</td>
<td>217 D</td>
<td>361 C</td>
</tr>
</tbody>
</table>

GA3 = gibberellic acid.

*New growth was calculated as the plant height 7 d after treatment minus the plant height at time of treatment.

*Mean separation for each cultivar (rows) by least significant difference at P < 0.05.