

CULTIVAR, ROW SPACING, AND SOIL MOISTURE EFFECTS ON SNAP
BEAN YIELD AND MORPHOLOGICAL RESPONSE TO TIBA APPLICATIONS
AT EARLY BLOOM

by

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Chapter I

INTRODUCTION

Various morphological responses occur in legumes following foliar treatment with the antiauxin, 2,3,5-triiodobenzoic acid (TIBA). In soybean, Glycine max L., TIBA produces apical bud abscission with subsequent loss of apical dominance, plant height reduction due to shorter internodes and plant dry weight reduction (3). Greer and Anderson (4) also reported increased seed yields with TIBA treatment, which was attributed to production of smaller but more numerous seeds. This apparently related directly to a previously observed increase in floral bud numbers when TIBA was applied to photoinduced soybeans (3).

Similar responses have been observed in snap beans, Phaseolus vulgaris L., with increased yields also occurring as a result of increased floral bud number and pod set (5). However, the yield increase with TIBA treatment was variable. Such responses probably relate to differences in TIBA absorption which may be determined by varying environmental factors. Vegetative and fruiting responses to TIBA have been reported to vary with temperature (9) and cultural practices, such as spacing (6) and fertilization (11).

The cultural and environmental influences on snap bean response to TIBA treatment were the focus of the research reported herein. Primary factors in these studies were cultivar, spacing and the effects of TIBA rates on snap bean growth under field conditions and differing soil moisture regimes under greenhouse conditions.

Chapter II

MATERIALS AND METHODS

2.1 FIELD STUDY.

A 36 m x 12 m plot arranged in a split-split plot design was used for the field trial. The main plot factor was row spacing using 3 m-long single and double rows. Single rows were 1 m apart and double rows were spaced 0.75 m apart with 0.25 m separating the paired rows. A uniform planting rate of 20 seeds/m within each row was employed. Cultivars, the split factor, were 'Sprite', a white-seeded bean requiring 50 days for maturity, and 'Dark-Seeded Provider', a dark-seeded bean requiring 45 days for maturity. TIBA levels of 0 (control), 1, 2, 4, 5 and 12 g/ha were the split-split treatments.

The clay loam plot was fertilized (27 kg 10-4.4-8.3) and limed (454 kg dolomitic) according to soil test recommendations and planted June 23, 1981. Trifluralin (pre-plant incorporated) was applied for weed control, and Diazinon at recommended rates was used for Mexican bean beetle control.

A stock TIBA solution was made by dissolving 240 mg of TIBA in 1 liter of ethanol. A unit of 5 ml treated an experimental plot equivalent to 1 g/ha of TIBA. Multiples of

the basic unit were used to provide rates of 2, 4, 5, and 12 g/ha of TIBA.

Thirty-eight days after seeding, the plants were at 1-5% bloom, the development stage designated by Greer and Anderson (4) for TIBA application to legumes. The appropriate amount of stock solution, 2 liters of tap water and 0.05% Tween 20 were added to a small, hand-pumped stainless steel sprayer for each 3 m row treated (i.e. 4 liters total spray applied to the double row units). The total spray volume selected was sufficient to give thorough coverage without excessive runoff. Plants were sprayed until the sprayer was empty. Drift to adjoining rows was controlled by large fiberglass panels held on either side of the row being treated.

Harvests were at 51 and 65 days after seeding with morphological data recorded at the second harvest.

2.2 GREENHOUSE MOISTURE EXPERIMENT.

Six raised greenhouse beds, 30 cm deep and filled with a soil-peat-sand mix (1:2:1), were divided into 3 equal 102 cm x 120 cm sections using 6 ml black polyethylene film strips embedded in the soil. This separated the bench media for different moisture regimes. Thermocouples were placed in

the middle of each section to record soil temperature and at bench ends to record air temperature.

Two double rows of 'Sprite', 30 cm apart with 10 cm between row pairs and 102 cm long, were planted January 8, 1982 in each bench section. All plots were fertilized January 25 with water-soluble N-P-K (20-8.7-16.6) fertilizer at recommended rates and three weeks later with an equivalent analysis fertilizer also containing micronutrients.

Water treatments were begun 19 days after seeding when plants had developed 2 sets of fully expanded leaves. The initial application was equivalent to 2.5 cm applied to all sections with subsequent applications of 2.5 cm of water:

1. every 2 days for the high treatment,
2. every 3 days for the medium treatment, and
3. every 5 days for the low water treatment.

Soil water levels were measured gravimetrically before and after irrigation treatment with allowance for drainage time. Soil and air temperatures also were recorded at each irrigation.

The 1-5% bloom stage for TIBA treatment was reached 38 days after planting. Using the TIBA stock solution previously described, the single 2 g/ha TIBA treatment was supplied as 10 ml of stock solution plus 300 ml of tap water.

Application was by a pressurized stainless steel mister with the total sprayer volume applied to the paired treatment rows. Adjoining control rows were protected by covering with polyethylene film during the spraying. Following TIBA application, all plants were irrigated daily to maintain optimum soil moisture.

A second experiment identical to the first was started April 2, with the soil moisture regimes initiated 24 days later. TIBA application was begun on May 5, and harvests were made on May 28 and June 15. Morphological measurements also were made on June 15. A water-soluble micronutrient fertilizer (STEM) was given once to alleviate a micronutrient problem; a water-soluble N-P-K (18-7.8-16.8) fertilizer also was supplied weekly.

2.3 COROLLARY GROWTH ANALYSIS STUDY.

A single greenhouse bench 360 cm x 102 cm x 30 cm was planted April 5 with 'Sprite' in 12 double rows spaced 25 cm on center and 5 cm between paired rows. Plants were watered daily, and when two sets of fully expanded leaves had developed, all plants were fertilized with a water-soluble N-P-K (18-7.8-16.8) fertilizer at recommended rates.

On May 14 four plant samples from each plot were harvested at the soil surface and separated into leaves, stems, and flowers. Leaf area was measured with a leaf area meter. All parts were oven dried 24 hours at 70°C and weighed immediately.

TIBA was applied at 2 g/ha on May 15 using a stock solution and spray dilution prepared as previously described for the greenhouse studies. On May 27 the second set of four-plant samples were harvested for calculation of:

1. leaf area ratio (LAR), the ratio of assimilatory material to the plant material present.
2. relative growth rate (RGR), the increase of plant material per unit of material present per unit of time.
3. net assimilatory rate (NAR), the increase of material per unit of assimilatory material per unit of time over the treatment to harvest period.

Chapter III

RESULTS AND DISCUSSION

3.1 FIELD STUDY.

Double row spacings yielded significantly greater pod weights in the first, second and total harvests as compared to the single rows. This difference was directly due to the higher plant population in these plots (Table 1). 'Sprite' outyielded 'Dark-Seeded Provider' in the second harvest, which was consistent with its later maturity rate. Total yield differed little between the cultivars under these experimental conditions.

Row spacing affected plant height according to plant population and competition factors (Table 2). Canopy width differences were directly related to single row versus a double row width, with single rows (lower population pressure) producing slightly greater dry weights. Cultivars were virtually identical in plant height and canopy width. Vegetative dry weights did differ between cultivars as 'Sprite' had a tendency to be larger than 'Dark-Seeded Provider'.

Although not significant, TIBA-treated plants tended to yield less than control plants (Table 1). Dry soil condi-

TABLE 1

Row spacing, cultivar and TIBA effects on yield and 50-pod subsample weights of field-grown snap beans.

Treatment	First harvest		Second harvest		Total yield (MT/ha)
	Yield (MT/ha)	50 pods (g)	Yield (MT/ha)	50 pods (g)	
<u>Row spacing</u>					
Single	0.46	b ^z 265 a	0.30	b 243 a	0.74 b
Double	0.94	a 286 a	0.49	a 284 a	1.42 a
<u>Cultivar</u>					
'Sprite'	0.56	a 256 b	0.49	a 285 a	1.04 a
'Dark-Seeded Provider'	0.84	a 295 a	0.29	b 242 a	1.12 a
<u>TIBA rate (g/ha)</u>					
0	0.83	a 284 a	0.45	a 259 a	1.28 a
1	0.63	a 287 a	0.37	a 250 a	1.00 a
2	0.76	a 250 a	0.40	a 262 a	1.16 a
4	0.65	a 300 a	0.34	a 253 a	0.99 a
5	0.68	a 275 a	0.42	a 278 a	1.09 a
12	0.63	a 256 a	0.36	a 281 a	0.99 a

^zMeans separated within columns and treatment groups by F-test and Duncans Multiple Range (5%).

TABLE 2

Row spacing, cultivar and TIBA effects on snap bean plant height, canopy width and total plant dry weight.

Treatment	Height (cm)	Width (cm)	Dry weight (g/plant)
<u>Row spacing</u>			
Single	34.13 a ^z	30.73 b	6.70 a
Double	38.33 a	53.33 a	5.55 a
<u>Cultivar</u>			
'Sprite'	36.35 a	41.77 a	7.62 a
'Dark-Seeded Provider'	36.10 a	42.29 a	4.63 b
<u>TIBA rate (g/ha)</u>			
0	40.63 a	45.63 a	7.23 a
1	35.63 b	42.50 ab	5.82 a
2	36.56 ab	41.25 b	5.76 a
4	35.63 b	41.25 b	7.01 a
5	35.50 b	40.94 b	5.49 a
12	33.44 b	40.63 b	5.41 a

^z Means separated within columns and treatment groups by F-test and Duncans Multiple Range (5%).

tions present in the field prior to TIBA application may have resulted in lowered yields due to reduced plant growth and flower and pod abortion. Yield reductions have been reported when TIBA was applied under low soil moisture (7). Other researchers have reported yield improvements through TIBA application (1). Weights of 50-pod subsamples did not differ between treated and control plots, indicating TIBA treatment had no effect on pod development (Table 1).

TIBA application tended to produce a shorter plant than the control, except for the 2 g/ha rate (Table 2). No differences were observed among treatment levels. Canopy width also was reduced by all TIBA treatments. Control plants were wider, except for the 1 g/ha treatment, but no significant differences occurred among TIBA treatments. Whole plant dry weights did not differ with TIBA treatment.

A significant TIBA treatment - row spacing interaction occurred. This mainly was due to the 2 g/ha rate, associated with the highest double-row yield and poorest single-row yield (Appendix A).

The results of this study are in partial agreement with the literature. Treated plants were shorter than nontreated plants, as reported by other researchers (2,9). Yield increases reported by some workers (1) were not observed in

this experiment. Hume, et al. (7) reported that TIBA application following a dry preflower period decreased plant height more than with a wet preflower period. In this experiment, soil moisture content measured gravimetrically at the time of TIBA application was 10-16%. These moisture levels were in the soil moisture tension range of 5 to 15 bars, as reported by Kovach (8) for a neighboring plot area with similar soil characteristics. In addition, low soil moisture could have reduced dry weight and canopy expansion, regardless of growth regulator use.

3.2 GREENHOUSE MOISTURE STUDY.

Moisture stress is reported to reduce TIBA yield response and to act synergistically with TIBA to further reduce plant height (7). A greenhouse study was initiated to examine the TIBA - soil moisture interaction under more controlled conditions than was found in the field.

TIBA treatment produced significant yield differences in both first and second harvests over both crops (Table 3). Treated plants outyielded control plants in the first harvest, with 50-pod subsample weights showing no difference, indicating yield increases from increased numbers rather than increased weight. Nontreated plants out yielded treated plants in the second harvest, again numbers of pods

TABLE 3

TIBA rate, soil moisture and cropping time effects on yield and subsample weight of greenhouse-grown 'Sprite' snap beans.

Treatment	First harvest		Second harvest		Total yield (MT/ha)
	Yield (MT/ha)	50 pods (g)	Yield (MT/ha)	50 pods (g)	
<u>Moisture level^z</u>					
High	9.78 a ^y	166 a	4.19 a	151 a	13.97 a
Medium	8.22 a	162 a	4.47 a	140 a	12.69 a
Low	6.05 a	131 b	3.75 a	111 a	9.81 b
<u>TIBA rate (g/ha)</u>					
0	7.61 b	154 a	4.48 a	136 a	12.09 a
2	8.42 a	152 a	3.79 b	132 a	12.22 a
<u>Cropping time</u>					
First	9.71 a	153 a	5.35 a	137 a	15.06 a
Second	6.31 b	116 b	2.92 b	81 b	9.25 b

^zPre-TIBA-treatment moisture levels were 2.5 cm water applied every 2 days (high), 3 days (medium) or 5 days (low).

^yMeans separated within columns and treatment groups by F-test and Duncans Multiple Range (5%).

increased rather than weight. Total yield, however, showed no treatment differences, which indicates that TIBA induces early pod set in snap beans, as suggested in the literature (9). Morphological differences were not indicated in this study (Table 4), and the growth analyses study confirmed morphological similarities between treated and nontreated plants (Table 5).

Significant yield differences occurred with moisture effects in the first and total harvests (Table 3). In the initial harvest, the low-water treatment yielded significantly less than the high or medium, which did not differ. Reduced yields in the low-water treatment resulted from flower abortion and incomplete pod filling. The second harvest yield showed no yield response to moisture levels. The total harvest also showed differences between the moisture treatments through losses in the initial yield by the stressed plants.

Moisture level showed some significant effects on plant height and width (Table 4). Low-water treatment plants were smaller than medium or high-water treatment plants. Generally, height decreased with decreasing moisture levels. The high-water treatment plants' canopy widths were significantly larger than low-water treatment plants. Medium-water treatment plants were intermediate in size. No significant

TABLE 4

TIBA rate, moisture level and cropping time effects on 'Sprite' snap bean plant height, canopy width and dry weight.

Treatment	Height (cm)	Width (cm)	Dry weight (g/plant)
<u>Moisture level</u>			
High	35.00 a	49.50 a	10.10 a
Medium	32.20 a	46.50 a	7.70 a
Low	28.30 b	43.90 a	7.80 a
<u>TIBA rate</u> (g/ha)			
0	32.50 a	46.00 a	9.10 a
2	31.20 a	47.20 a	7.90 a
<u>Cropping Time</u>			
First	33.83 a	51.25 a	11.37 a
Second	29.86 b	42.00 b	5.72 b

Pre-TIBA-treatment moisture levels were 2.5 cm water applied every 2 days (high), 3 days (medium) or 5 days (low).

Means separated within columns and treatment groups by F-test and Duncans Multiple Range (5%).

TABLE 5

Growth analysis parameters between TIBA-treated and nontreated 'Sprite' snap bean plants under greenhouse conditions.

TIBA rate (g/ha)	NAR (mg/dm ² /day)	LAR (cm ² /day)	RGR (g/100 g/day)
0	0.00125	41.26	0.140
2	0.0013	47.83	0.144

differences in dry weight occurred among the water treatments. Finally, no significant TIBA-moisture interaction was found.

Yield and morphological differences occurred between the crops due to environmental differences. Stresses were the most severe for the second greenhouse crop, with the low moisture treatment reaching 7% at one point, and air temperatures exceeding 38°C. In addition, a severe magnesium deficiency occurred during the second greenhouse crop. Moisture in the first study reached only 10% in the low moisture treatment, and air temperatures averaged 23°C. Moisture levels in the medium and high treatments remained in the 20-30% and 30-40% range, respectively, in both studies. These factors would contribute to the reduced plant size and yield in the second crop.

Although positive yield results were obtained from TIBA application, the primary effect seen in this experiment was environment. Significant experimental crop differences illustrate this most clearly, since the first crop (good environment) produced larger, better yielding plants than the second (poorer environment). Under these conditions, TIBA treatment only induced earliness, rather than promoting overall yield increases. TIBA had no morphological effect on

the plants, yet environmental factors did, just as environmental factors affected overall yield where TIBA treatment had failed.

Environmental parameters defined the growth and production of the plants in this experiment; TIBA acted in some way as a catalyst to speed initial production. Although no TIBA treatment - moisture level interaction occurred here, other workers (7,10) have reported such an interaction. Environmental conditions, then, must be known to define TIBA action as a synergist, a catalyst, or to say it had no effect at all.

Chapter IV

CONCLUSIONS

Earlier workers reported a TIBA treatment - soil moisture interaction which was found in the field study, yet not in the greenhouse study. Under optimum soil moisture conditions, TIBA is reported to act as a yield synergist, significantly enhancing yield (7). Synergism was not confirmed in this study; in fact, no yield reaction could be discerned in the field study. However, plant height already reduced by moisture stress was further reduced by TIBA action, as noted in the literature (7). In the greenhouse, TIBA acted not as an overall yield synergist, but as a catalyst promoting early maturity and improving initial yield in concurrence with previous reports (9). The growth analysis experiment indicated there were no morphological changes.

Environmental conditions are apparently the limiting or defining parameters determining whether TIBA will produce a yield reaction, acting as a yield synergist or as a yield catalyst. Environmental conditions, then, should be reported with future TIBA yield results, in order to define parameters for use of this chemical to achieve a desired result. Without such data, the information is not interpretable.

Chapter V

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Appendix A

TABLE 6. TIBA RATE - ROW SPACING INTERACTION
EFFECT ON MEAN YIELDS FOR TWO FIELD-GROWN SNAP
BEAN CULTIVARS.

Table 6

TIBA rate - row spacing interaction effect on mean yields for two field-grown snap bean cultivars.

TIBA rate (g/ha)	Harvest Yields (MT/ha)					
	First		Second		Total	
	Single rows	Double rows	Single rows	Double rows	Single rows	Double rows
0	.28	.82	.20	.39	.48	1.21
1	.35	.48	.23	.27	.58	.75
2	.26	.75	.17	.36	.43	1.11
4	.28	.58	.17	.28	.45	.86
5	.28	.62	.22	.33	.50	.95
12	.35	.48	.19	.29	.54	.77

Appendix B

TABLE 7. GREENHOUSE MOISTURE STUDY YIELD DATA
FOR EACH MOISTURE LEVEL AND TIBA RATE.

Table 7

Greenhouse moisture study yield data for each moisture level and TIBA rate.

Rep	Moisture level	TIBA (g/ha)	Pod yield (MT/ha)			
			First crop		Second crop	
			Harvest 1	Harvest 2	Harvest 1	Harvest 2
1	high	0	13.6	3.3	8.6	2.3
2	high	0	13.2	4.3	6.2	2.3
3	high	0	10.9	6.6	5.3	5.4
4	high	0	3.8	9.5	7.1	4.4
5	high	0	14.2	4.2	6.5	2.6
6	high	0	8.2	8.9	12.6	1.1
Mean			10.6	6.1	7.7	3.0
1	high	2	14.2	5.7	10.1	1.7
2	high	2	14.9	3.3	7.7	2.6
3	high	2	14.5	4.1	3.5	2.1
4	high	2	6.0	6.4	5.4	4.5
5	high	2	18.1	3.9	8.3	2.4
6	high	2	9.2	7.1	12.4	1.9
Mean			12.9	5.1	7.9	2.6
1	medium	0	11.0	5.4	7.9	5.0
2	medium	0	14.4	7.6	5.0	1.8
3	medium	0	4.9	8.5	4.8	2.6
4	medium	0	3.7	8.9	4.8	2.4
5	medium	0	9.5	7.9	4.8	3.6
6	medium	0	11.5	5.3	9.5	1.9
Mean			9.2	7.3	6.2	2.9
1	medium	2	9.8	3.7	5.9	3.2
2	medium	2	12.9	4.6	7.6	0.6
3	medium	2	9.7	8.0	6.5	1.4
4	medium	2	7.3	6.0	3.6	2.9
5	medium	2	13.9	4.4	4.2	6.0
6	medium	2	11.2	3.4	12.9	2.1
Mean			10.8	5.0	6.8	2.7

Table 7 (continued)

Rep	Moisture level	TIBA (g/ha)	Pod yield (MT/ha)			
			First crop		Second crop	
			Harvest 1	Harvest 2	Harvest 1	Harvest 2
1	low	0	11.9	4.7	8.2	2.7
2	low	0	8.9	6.5	3.0	0.9
3	low	0	7.7	4.7	5.1	6.4
4	low	0	3.6	2.9	3.2	4.4
5	low	0	7.4	7.9	3.9	3.6
6	low	0	6.5	5.3	2.4	1.7
Mean			7.7	5.3	4.4	3.3
1	low	2	11.9	5.3	3.9	0.9
2	low	2	6.0	6.5	5.7	2.7
3	low	2	9.1	4.8	4.2	4.5
4	low	2	4.5	2.4	3.9	4.8
5	low	2	3.9	3.7	3.9	4.8
6	low	2	7.6	3.0	8.3	3.2
Mean			7.2	4.3	5.0	3.2

Appendix C

TABLE 8. RESPONSE OF GREENHOUSE-GROWN SNAP BEANS TO TIBA TREATMENT AND NODULATION BACTERIUM INOCULATION.

TIBA effects on root nodulation were examined in this experiment. A 6 x 2 factorial arrangement in a 5-replication randomized complete block was employed. Sixty 6-inch plastic pots were filled with a soil mix of soil, peat and web-lite (1:1:1). Two seeds were planted in each pot May 8, 1982; one-half of the pots were planted with seed inoculated with Rhizobium phaseoli. A water-soluble 18N-7.8P-16.6K fertilizer was applied to all pots when two sets of fully expanded leaves appeared, at which time the pots also were thinned to single plants.

On June 16 the plants were treated with TIBA. The stock solution contained 7.4 mg TIBA per liter in 95% ethanol with each 5-ml aliquot equivalent to applying 1 g/ha to the treated container spacing area. Multiples of the basic unit were mixed with 300 ml of tap water and sprayed as previously described to give rates of 1, 2, 4, 5, and 12 g/ha.

Plants were harvested June 26, July 6 and July 20 with total and graded pod weights recorded. At the final harvest, plants were cut at the soil line for dry weight determinations, and roots were washed for root dry weights.

Table 8

TIBA treatment level and Rhizobia phaseoli inoculation effects on 'Sprite' snapbean yields and shoot and root dry weights.

Treatment	<u>Pod yield by harvest (g/plant)</u>				<u>Dry weight (g/plant)</u>	
	First	Second	Third	Total	Shoot	Root
<u>TIBA rate</u>						
<u>(g/ha)</u>						
0	12.0 a ^Z	11.1 a	11.4 a	34.5 a	17.5 b	16.0 a
1	17.2 a	12.7 a	5.7 a	35.7 a	17.6 b	14.2 a
2	7.3 a	13.0 a	11.1 a	31.4 a	17.7 b	16.0 a
4	9.3 a	9.6 a	11.7 a	30.7 a	18.4 a	15.8 a
5	9.6 a	10.0 a	14.2 a	33.8 a	17.0 b	15.2 a
12	5.6 a	10.9 a	12.5 a	29.0 a	17.3 b	15.2 a
<u>Inoculation</u>						
Yes	7.0 a	12.1 a	13.5 a	32.6 a	17.4 a	15.4 a
No	3.4 a	10.4 a	8.6 a	32.4 a	17.7 a	15.4 a

^ZMeans separated within columns and treatment groups by F-test and Duncan's Multiple Range (5%).

Appendix D

LITERATURE REVIEW

TIBA (2,3,5-triiodobenzoic acid) is classified as an anti-auxin and is mobile within the plant (1,11,14,18,20,25). The mode of action is believed to be competitive inhibition of auxin binding sites (20), which results in an interruption of basipetal auxin transport, producing morphological aberrations in treated plants. Reported responses have included loss of apical dominance, an increase in floral bud number, temporary vegetative growth cessation, leaf wrinkling, and darkening of leaf color (2,8,9,10,22). These responses have had positive affects on crop production as yield increases also have been reported, especially in legume crops.

Application of TIBA is generally by foliar spray (6). Labelled TIBA studies have shown that, once it is absorbed into the plant, the molecule moves to later-developing organs.

D.1 CROP PLANT RESPONSES TO TIBA.

Application of TIBA to various crop plants has increased seed or pod yield, though not consistently (4,5,9,12,16,26,31). Treatment of alfalfa (Medicago sativa L.) at early bloom resulted in increased seed yield at the 0.10 level of significance (12). Treatment at full bloom resulted in decreased yield when the rate was 17.5 g/ha, while all other rates (lower and higher) increased the yield over the control. Alfalfa yield increases were due to an increased number of seed-bearing stems per plant.

Greer and Anderson (9) reported increased seed yield in soybean (Glycine max L. Merr.) accompanied by smaller, darker green leaves, a vertical orientation of upper leaflets and a triangular canopy shape. Increased branching and decreased height also occurred. Yield increases in TIBA-treated soybeans were due to more numerous but smaller seeds (2,4,15,27,38).

Greer and Anderson (9) proposed that the triangular canopy shape produced by TIBA application created a more photosynthetically efficient plant since leaves were shaded less. This greater photosynthetic efficiency was postulated to produce the observed yield increases. In order to increase yields per acre, narrower rows were advocated with the

smaller TIBA-treated plants, which yielded as well as, if not better than, untreated plants (4,9).

Earlier work (7) reported increased floral bud number if TIBA was applied to photoinduced plants. Increased floral bud number also could account for the increased yield. On one-month-old plants, young leaf epinasty, apical internode shortening, apical dominance loss, apical bud darkening and abscission were side effects of TIBA application (8). Dry weight and height of treated plants additionally were significantly lower than for the control. No adverse effect of TIBA treatment was found on soybean root nodulation (4).

Environmental factors greatly affect soybean response to TIBA. Height of treated plants was greatly reduced when exposed to a pre-treatment dry/post-treatment wet regime (27). Adequate soil moisture given throughout the plants' life, and treatments of either pre-dry/post-dry or pre-wet/post-dry all gave larger plants. Pod number and top dry weight were decreased in treated plants if given a post-wet treatment, regardless of previous soil moisture status. A post-dry treatment, whether pre-wet or pre-dry, produced no TIBA effect on pod number and dry weight.

TIBA response increased with increasing temperature. A pre-wet/post-dry moisture treatment under either low

(16-21°C) or warm (21-27°C) temperatures increased pod number. The greatest pod number increase, however, was under a post-wet water treatment in high (32-34°C) temperatures. With TIBA treatment at floral initiation under pre- and post-wet conditions, pod numbers increased from 10 on the control to 59 on treated plants. Pre-dry and post-wet soil moisture treatments increased pod number from 14 to 53. Under the high (32-34°C) temperature treatment, TIBA decreased floral and pod abortion incidence.

In general, plant height and top dry weight were decreased with TIBA. Pod dry weight, however, was double that of the control, and pods were generally more mature on treated plants. Field studies (17) indicated soybean yields to be higher when temperatures were normal or above normal and precipitation was above normal.

Different cultural techniques in combination with TIBA treatment produced varied results. Soybeans treated with TIBA and grown at a 50.8 cm row spacing yielded 6.5% higher than either wider or narrower row spacings (38). Treated plants were slightly shorter with narrower row spacings, and lodging was significantly reduced with decreasing row width. The application of fertilizer to a highly productive soil had no effect on morphological changes brought about by TIBA

treatment, although nitrogen content was 6% lower in TIBA-treated plants (15).

Bengal gram (Cicer arietinum L.) responded to TIBA treatment with yield increases of 108% and 66%, according to cultivar (31). Yield increases were due to increased seed number rather than increased weight. Poor-yielding cultivars responded more to TIBA treatment than did higher-yielding cultivars.

TIBA applied at first flower to horsebean (Vicia faba L.) had little effect on flower number, seeds per pod, or seed size (26). However, total yield was affected with the greatest yield increase in the first five flowering nodes. The upper nodes contributed less to overall yield with the last few flowering nodes decreasing overall yield. Yield increases were due to increases in pod set and seed production; neither seed size nor number per pod was affected. Characteristic morphological anomalies of TIBA treatment were observed on the horsebean, including vertical orientation of upper leaves, shorter internodes, and earlier pod set and maturity.

Southern pea, Vigna unguiculata (L.) Walp. treated with TIBA grew more compactly, had runner number suppressed and had racemes with fruiting pods protruding above the canopy

(30). Yields were increased at the lower (10 ppm) TIBA application rate, and maturity was uniform.

In another study (16) a tendency toward increased yield was noted at low treatment rates on 'Blackeye', but yields were reduced with higher rates. 'Purple Hull' responded with decreased yields at all TIBA rates, indicating a significant cultivar interaction in southern pea.

Yield data for peanut (Arachis hypogaea L.) treated with TIBA have been highly variable over different years and cultivars (13). Fancy pod percentage and seed size were increased by TIBA treatment, but only at certain spray timings and rates. In addition, internode length and branch length were affected by TIBA application, but only under those treatment conditions affecting yield differences. A vertical orientation of upper leaflets and leaflet rolling or puckering were also observed following TIBA application.

In other work (8) a cultivar difference was observed in internode and branch length response to TIBA treatment. Yields were not significantly affected in this study. One suggested use for TIBA on peanut (39) notes that high rates of the chemical will reduce plant size, such that it could be effective as a vine growth control agent.

Initial experiments with TIBA and snap beans (Phaseolus vulgaris L.) described the characteristic morphological responses associated with TIBA application (10). These include internodal growth inhibition, loss of apical dominance, abscission of buds and leaves at high rates, and a darkening and wrinkling of new leaflets. An increase in flowers was reported, and further experimentation indicated the increase was not directly correlated to the reduction in leaf area and fresh weight, either negatively or positively.

Field-grown snap beans had yields variably increased with TIBA treatment (5). Yield differences occurred in pod set rather than pod size. Shorter plants with wrinkled and darker leaves were noted in response to TIBA treatment. An interaction between cultivar and seasonal variations was noted and proposed for further research.

D.2 CULTURAL PRACTICES AND WATER RELATIONS IN SNAP BEAN PRODUCTION.

Snap beans are inexpensive crops to produce, due mainly to mechanization of production and harvest (37). A warm climate is preferred, although excess heat can cause pod and blossom abortion. Very heavy soils are avoided in bean production because of seedling emergence difficulties, with a sandy or muck soil preferred. Most snap beans produced in

the United States are of processing types (23). These are generally bush cultivars, possessing concentrated pod set and erect growth, in addition to a round pod shape, dark green color and low fiber content (37).

Beans are not very responsive to fertilizer application, although fertile soils produce well. Fertilizers high in nitrogen are avoided, since vegetative growth is increased at the expense of fruiting, and harvesting problems can be created (36).

Plant density is an important factor in snap bean production. An optimum density varies from cultivar to cultivar (34). Square spacings have been shown to increase yield, and lower plant densities (using 'Oregon 1604', 'Oregon 58', 'Gallatin 50', 'L-81', and 'Keystone 4672') tend to produce a higher percentage of smaller pods (34), while wide spacings encourage lodging, since plants cannot protect each other from the wind (29). Mack and Hatch (23) observed, for 'OSU 949' and especially 'Tendercrop', that as population density increased a greater percentage of size 4 and smaller pods were produced. When growing these cultivars in a square spacing, highest yields occurred at a population density of about 6 plants per square foot. Smaller-leaved and more compact cultivars have been shown to respond well to high plant densities (34).

Nitrogen fertilization boosts yields even higher with high density planting (32). Increased irrigation works with increased nitrogen fertilization to produce higher yields and can produce yields 82% over snap beans grown under low nitrogen fertilization and inadequate moisture. In sandy soils under moderate to high rainfall, several nitrogen applications may be necessary.

Adequate soil moisture is primary in snap bean yield. Flowering and pod-forming periods are critical times for soil moisture, but the preflowering period is also important (7). Plants subjected to water stress at preflower and flower stages yielded significantly less than those plants under stress at the post-flower stage. Total yields for this same experiment showed a 35% yield reduction in plants stressed in the preflower stage and a 71% yield reduction in plants stressed in the flower stage. Harvest was often delayed with plants stressed during the pre-flower and flower stages.

High stress from excessively low water application at the preflower stage resulted in a lowered pod set at the first harvest (7). Plants under high stress at flowering were quite susceptible to later inhibition of flower initiation. Plants remained small and stunted if stressed in either the flower or preflower stage.

Drought injury and water consumption increases with snap bean age (19). Younger plants water stressed in the pre-flower stage recovered from the stress faster, if irrigated at bloom, even though their growth was stunted. Kattan and Fleming (19) maintain that irrigation prior to bloom is not needed, provided soil water was adequate throughout the growing season and soil moisture levels were high at seeding. High soil moisture stress during pod development is seen as most yield-limiting and quality-reducing, even if optimum conditions preceded the stressful conditions. Quality was reduced by a high percentage of malformed pods, greater seed development, and poorer color.

Other studies (23,33) showed that snap beans were equally susceptible to water stress (0.75 bar) at all stages of growth. Pod yield was greatest when snap beans were irrigated continuously.

If moisture tensions reached 0.50 and 0.75 bars before irrigation, pod yields dropped 41 and 47%, respectively. Yield reductions were proportional to the amount of soil water stress experienced by the plant prior to harvest.

Either low moisture levels throughout growth or low pre-bloom/high postbloom moisture produced greater percentages of oversized pods, perhaps due to an earlier maturity (23).

In contrast, both high moisture levels throughout growth and high prebloom/low postbloom moisture produced lower yields of oversized beans. Consistent high moisture levels increased vine weight, and either consistent low or high prebloom moisture with low postbloom levels also increased dry matter content.

D.3 GROWTH ANALYSIS.

In order to study plant growth and resultant yield through growth functions, British plant physiologists developed growth analysis techniques (36). Among the numerous functions employed in plant growth analysis, the following are common in various TIBA and bean studies:

1. Crop growth rate (CGR), the increase of plant material per unit of time (24,28,38).
2. Relative growth rate (RGR), the increase of plant material per unit of material present per unit of time (28).
3. Net assimilation rate (NAR), the increase of plant material per unit of assimilatory material per unit of time (24,28).
4. Leaf area ratio (LAR), the ratio of assimilatory material to the plant material present (28,35).

The last three are interrelated, with RGR being the product of NAR and LAR (29).

Yield differences between bean cultivars are correlated with growth analysis calculations. In a comparison between pea, marrow, and yelloweye bean types, a higher LAR was correlated with higher yields in both marrow and yelloweye (36). Pea bean was found to have a higher LAR than either marrow or yelloweye beans, but it eventually accumulated excess leaf area with a resultant NAR reduction.

In comparing a normal bush bean with a mutant strain having smaller, glossy leaves, Motto et al. (26) found definite differences in growth analysis calculations. TIBA produces smaller leaves on treated plants, thus parallels may be drawn between the mutant plant mentioned above and TIBA-treated plants. The mutant plants had a reduced dry matter accumulation involving all plant parts and all sampling dates. CGR was not significantly different between normal and mutant plants, but the mutant's NAR was 62% greater.

Plants treated with growth regulators to increase yields often alter their morphological shape as well. Tanner and Ahmed (35) found TIBA-treated soybeans to not differ from control plants in total dry matter production or in CGR, but the reproductive part CGR was significantly higher. It was

suggested that TIBA acts to redistribute photosynthates between source and sink by slowing vegetative growth and increasing reproductive growth. A significant correlation existed between leaf area index (LAI) and total dry weight for both control and TIBA-treated plants. No correlation occurred between maximum LAI and seed yield in the control plants, but these factors were correlated in the TIBA treated plants. This trend indicated that the control plants had achieved excess foliage, according to the negative correlation between LAI and NAR, whereby yield reduction occurs after an optimum LAI has been developed (34).

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CULTIVAR, ROW SPACING, AND SOIL MOISTURE EFFECTS ON SNAP
BEAN YIELD AND MORPHOLOGICAL RESPONSE TO TIBA APPLICATIONS
AT EARLY BLOOM

by

Julie A. Haigler

(Abstract)

Application of 2,3,5-triiodobenzoic acid (TIBA) at 1, 2, 4, 5 and 12 g/ha to field-grown snap beans (Phaseolus vulgaris L.) at early bloom caused a reduction in plant height and width but not dry weight. Yield differences occurred with the cultural variables of cultivar ('Sprite' and 'Dark-Seeded Provider') and row spacing (single and double rows) but not with the chemical treatment. Low soil moisture at the time of TIBA application was suspected of interfering with absorption and action of the chemical.

In the winter and spring of 1981 greenhouse studies were conducted with 2 g/ha TIBA treatment of double-row snap beans grown under 3 pre-flower moisture regimes. Early yield was increased with the TIBA treatment, but the total yield did not differ due to a reduced second harvest, such that TIBA functioned as a yield catalyst under these study conditions. Environment was a more important determinant of the snap bean productivity as yield increased with more

avail- able soil moisture in both trials and decreased with warmer temperatures during the second crop trial. The importance of environmental influences on TIBA effect is discussed.