Some Effects of Gibberellin on Stem Elongation and Flowering in Sugar Beets[1,2]

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Control of both vegetative and reproductive responses in many crops is often approached with two opposite objectives. In production for fresh market or processing, a vegetative plant is often desired; while for a seed crop, bolting and flowering must be induced. Varieties of many biennial crops, including sugar beets, are being developed that are increasingly resistant to bolting. However, the more non-bolting the variety, the more difficult is seed production; and for the plant breeder the time required for the completion of a life cycle is increased.

Gibberellin may greatly modify the flowering responses of biennials and under some environmental conditions may promote earlier flowering and seed production. The cold requirement for stem elongation and flowering in *Hyoscyamus niger* (2)[4] and certain varieties of carrot, stock, and foxglove (3) may be completely replaced. Many cold-requiring biennials are also obligate long-day plants; and, while gibberellin may partially, or even completely replace the temperature requirement for flowering, it is unable to substitute for the photoperiodic requirement (2, 3). Gaskill (1) reported that a non-bolting variety (NB1) of sugar beet failed to bolt when gibberellin was applied in the absence of cold. However, when the sugar beets received partial "photothermal induction" (continuous illumination and temperatures of 45-46° F. for 43 days) followed by four foliar sprays at two-week intervals of 1000 p.p.m. of gibberellin, bolting as well as flowering and seed production occurred. Under conditions of partial photothermal induction alone, very few plants flowered (1). Thus, the critical thresholds of temperature and photoperiod for flower induction in sugar beets may be altered to facilitate earlier seed maturity in variety improvement programs and in commercial seed production. Gibberellin should prove particularly useful under field conditions where rigorous control of environment is not feasible.

Experiments were designed to determine the effect of gibberellin on the temperature and photoperiodic requirements for flowering in sugar beets.

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[2] The gibberellin used in these studies was the potassium salt of gibberellic acid (gibberellin A_3) supplied by Merck and Co., Rahway, N. J.

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[4] Numbers in parentheses refer to literature cited.

Experimental

Preliminary Studies

Response of Non-Induced Plants Grown at High Temperatures and Short Days—Roots of clone 55 CLF-17[2] were harvested in mid-October 1956, stored at 50 to 60° F. for two weeks in a root cellar, and then planted in pots and placed in a greenhouse for three weeks prior to treatment. Six plants each were sprayed to run-off with solutions containing 0.1 percent Tween 20 and gibberellin concentrations of 500, 1,000, 2,500 or 5,000 p.p.m. Half (three) of the plants were resprayed with the same concentrations 15 days later. Greenhouse temperatures approximating 65° F. were maintained at night, and plants were exposed to the prevailing mid-winter photoperiod of 9 to 11 hours.

Ninety days after treatment, the heights of the plants receiving the higher concentrations (2,500 and 5,000 p.p.m.) of gibberellin ranged from 4 to 6 feet with less stem elongation at 500 or 1,000 p.p.m. All, however, remained vegetative, the stalks finally terminating in aerial rosettes of varying heights. The second application induced very little additional stem elongation as compared with plants sprayed only once. The higher concentrations also caused the petioles of lower leaves to broaden and split longitudinally near the base and bend downward in a type of epinasty. The terminal leaves likewise appeared abnormal for several weeks following treatment. Lateral or side branches were markedly suppressed by the higher dosages. In plants producing more than one sprout, none of which possessed apical dominance, the shoots elongated more slowly and were shorter than on plants having a single shoot manifesting apical dominance.

Responses of Varieties and Clones Within Varieties—Individual plants within a sugar beet variety often exhibit marked differences in bolting. Accordingly, it was desirable to know if uniform bolting would result following treatment with gibberellin. Known quantities of gibberellin were applied in water solution to the crowns of non-induced plants of the clones listed in Table 1. Variability in stem elongation was as great between clones within a single variety as between clones of different varieties. This suggests that uniformity in bolting and seed production may not be easily realized with gibberellin and that optimal amounts for accelerating flowering may vary greatly among varieties, and even among clones within a variety.

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[2] Clone derived from a plant with lineage of American Crystal No. 2-601 x H 149, supplied by Professor H. L. Kohls, Department of Farm Crops, Michigan State University.

Table 1.—Comparative Stem Elongation of Sugar Beet Varieties, and Clones of Plants Within a Variety, Following Treatment With Gibberellin.

Variety	Clone	Gibberellin Applied	Plants Treated	Elongation After 4 Months
		(Micrograms)	(Number)	(Centimeters)
54B4	50593	100	2	3 and 12
54B4	50599	100	2	41 and 57
54B4	50599	1,000	2	75 and 83
US 400	50624	1,000	2	1 and 1
US 400	50614	1,000	1	6

Transport of Gibberellin Bolting Stimulus in Plants with Double Shoots Vegetative cuttings of sugar beet often develop more than one shoot. Such cuttings are admirably suited to study translocation of the gibberellin stimulus from the tip of one shoot to that of another. An initial study with clones F429-11m and E429-21m of the variety 54B4-17, indicated that gibberellin applied to one shoot had no effect on the bolting of non-treated shoots on the same plant.

In a more extensive experiment, 13 well established plants of clone 55 CLE-17, with shoots clearly separated, were selected. One hundred micrograms of gibberellin were placed on the primary or tip shoot of some plants and on the secondary or side shoot of others on October 24 and at approximately two-week intervals thereafter until January 9. The plants were watered without wetting the treated shoots and grown at the prevailing (9- to 11-hour) photoperiod, and at a night temperature approximating 65° F. By January 9, the treated shoots had elongated 18 to 27 inches. Differences were even more pronounced by March 4 (Figure 1). In contrast, the non-treated shoots, irrespective of position on the plant, failed to elongate. These results suggest a very localized effect of gibberellin on sugar beets.

Photoperiod and Temperature Studies

Effects of Gibberellin on Annual and Bienial Sugar Beets Grown Under 9- and 18-Hour Photoperiods- Seeds of annual (SL 9460) and biennial (US 400) sugar beets were sown September 9, 1957. Eight wooden flats (4″ x 16″ x 24″) containing vermiculite as the growing medium were used for each of the sugar beet types, and each flat contained 10 seedlings. Complete nutrient solution was applied to the vermiculite as needed. A photoperiod of 9 hours was maintained until October 14. On this date 4 to 5 leaves had developed, and four flats of 10 plants each of both the annual and biennial sugar beets were placed under a 9-hour and under an 18-hour photoperiod. Within each environment, the plants in two of the four flats containing annual sugar beets, and two of those containing the biennial type were sprayed for the first time (October 14) with a solution containing 1,000 p.p.m. of gibberellin and 0.1 percent Tween 20 as a wetting agent. The spray treatments were repeated on November 7 and December 24. Equal numbers of flats containing non-sprayed plants in the two environments constituted the controls. A minimum night temperature approximating 55° F. was maintained throughout the experiment.

Figure 1.—A biennial sugar beet plant with two shoots that developed from a vegetative cutting. Shoot on left treated with 100 micrograms of gibberellin at approximately two-week intervals. Treatments initiated October 24 and continued until January 9. Photographed March 4, 1958. Plant grown under prevailing photoperiod and a night temperature of 65° F. Note the localized effect of gibberellin in the bolting of the treated shoot (left) in contrast to the absence of stem elongation in the non-treated shoot (right).

The effects of both photoperiod and gibberellin on stem elongation and flowering of the annual and biennial sugar beets are presented in Table 2 and Figure 2. Absence of flowering

Table 2.—Effects of Gibberellin on Flowering and Stem Elongation of Annual and Biennial Sugar Beets Grown Under Short (9-Hour) and Long (18-Hour) Photoperiods, and at a Minimum Night Temperature of 55° F.

Photoperiod	Gibberellin[1]	Time to Flowering[2]	Plants That Produced Normal Flowers	Plant Heights Range	Plant Heights Mean
(Hours)		(Days)	(Percent)	(Centimeters)	
		Annual Sugar Beet (SL 9460)			
9	—	No Flowering	0	No Stem Elongation	
	+	No Flowering	0	46 to 62	54
18	—	80 to 105	100	100 to 143	119
	+	77 to 92	100	103 to 154	124
		Biennial Sugar Beet (US 400)			
9	—	—	0	1 to 146	62
	+	—	5[3]	52 to 211	140
18	—	151 to 206	90	62 to 180	130
	+	78 to 175	100	130 to 227	188

[1] Spray applications (1,000 p.p.m.) on October 14, November 7, and December 24.
[2] Number of days after initial (October 14) application of gibberellin.
[3] Inflorescence small and appeared after 199 days.

in the annual-type sugar beet under short days suggests an obligate long-day requirement for flowering, which was not satisfied by repeated treatment with gibberellin, even though marked stem elongation occurred (Table 2). Flowering of the annual sugar beets under a long photoperiod was accelerated by about 12 days with gibberellin, and seedstalks were slightly taller than those not treated with gibberellin.

As with annual sugar beets, most of the biennial plants flowered readily under the long photoperiod, but only one of 20 gibberellin-treated plants flowered under the short photoperiod. Flowering was generally accelerated under long days when the plants were treated with gibberellin (Figure 2), although some gibberellin-treated plants actually flowered at a date later than the first plants which flowered in the absence of gibberellin (Table 2). The data suggest that both annual and biennial sugar beets are obligate long-day plants. Gibberellin generally promoted flowering only when the plants were subjected to long days, although extensive stem elongation, without flowering, occurred subsequent to treatment of plants subjected to short days.

Effects of Gibberellin on Biennial Sugar Beets Grown at Various Photoperiods and Temperatures—Seeds of US 400 were sown January 2, 1958, and the seedlings grown in flats of vermiculite as in the previously described experiment. All plants were maintained under a 9-hour photoperiod and at a temperature above 65° F. until February 27 when the gibberellin, photoperiod, and temperature treatments were initiated (Table 3). The initial (February 27) and subsequent (March 13 and 27, and April 10) gibberellin treatments consisted of sprays of 1,000 p.p.m. (plus 0.1 percent Tween 20) directed onto the growing tips. As in the previous experiment, two flats of 10 plants each were employed for each treatment.

Figure 2.—Effects of gibberellin and photoperiod on stem elongation and flowering in US 400 biennial (top) and SL 9460 annual (bottom) sugar beets. Left to right: 9-hour photoperiod; 9-hour photoperiod + gibberellin; 18-hour photoperiod; and 18-hour photoperiod + gibberellin.

Table 3.—Effects of Gibberellin, Photoperiod, and Temperature on Flowering and Stem Elongation of US 400 Sugar Beets.

Night Temperature	Photoperiod	Gibberellin[1]	Time to Flowering[2]	Plants That Produced Normal Flowers	Plant Heights Range	Plant Heights Mean
(°F.)	(Hours)		(Days)	(Percent)	(Centimeters)	
55	9	—	No Flowering	0	No Stem Elongation	
		+	No Flowering	0	21 to 77	54
	12	—	No Flowering	0	No Stem Elongation	
		+	No Flowering	0	33 to 115	67
	18	—	96 to 115	65	0 to 105	60
		+	90 to 125	80	28 to 155	95
65	9	—	No Flowering	0	No Stem Elongation	
		+	No Flowering	0	12 to 84	36
	18	—	No Flowering	0	No Stem Elongation	
		+	62 to 117	40	41 to 194	106

[1] Spray applications (1,000 p.p.m.) on February 27, March 13 and 27, and April 10.
[2] Number of days after initial (February 27) application of gibberellin.

The data in Table 3 confirm the results of the earlier experiments. Flowering occurred only on plants exposed to an 18-hour photoperiod. At 55° F. and an 18-hour photoperiod, flowering was slightly accelerated by gibberellin, and there was an increase in the percent of plants which flowered. When the long-day requirement was satisfied, gibberellin induced 40 percent of the plants to flower, even at the "non-inductive" night temperature of 65° F. Of the plants which flowered, earliest flowering occurred on those sprayed with gibberellin and grown at a minimum night temperature of 65° F. and an 18-hour photoperiod (Table 3). Normal seedballs were subsequently produced by plants in which flowering was accelerated with gibberellin. Stem elongation was induced in all plants treated with gibberellin, irrespective of temperature or photoperiod (Figure 3).

Summary and Conclusions

Flowering in sugar beets may be accelerated and even induced with gibberellin, if treatments (repeated spray applications of solutions of 1,000 p.p.m. to the growing tips) are accompanied by exposure of the plants to a long (18-hour) photoperiod. At an 18-hour photoperiod and a night temperature of 55° F., gibberellin promoted earlier flowering of both annual (SL 9460 and biennial (US 400) sugar beets. No normal flowering occurred at a 9-hour photoperiod. Appreciable flowering was induced with gibberellin (40 percent of treated plants) in US 400, a biennial variety of intermediate bolting tendency, when grown at a non-inductive temperature (65° F.) and simultaneously exposed to a long (18-hour) photoperiod. Considerable stem elongation in sugar beets resulted from all gibberellin treatments, irrespective of photoperiod and temperature. In plants produced from vegetative cuttings that had two or more terminals, the gibberellin stimulus for stem elongation was not transmitted from the treated shoot to one that was not treated.

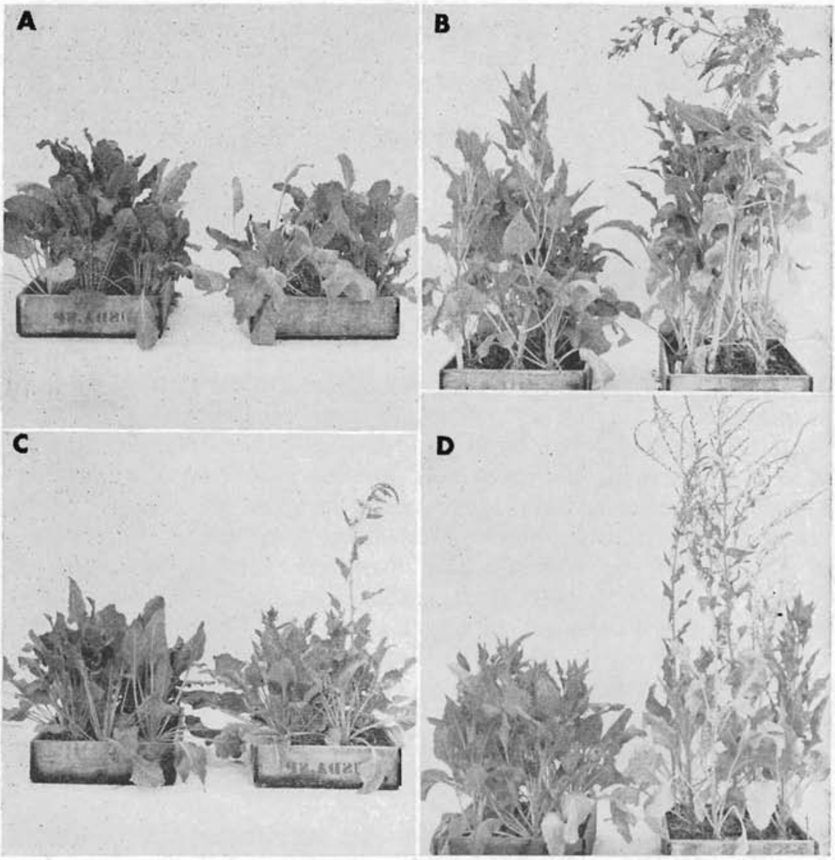

Figure 3.—Effects of gibberellin, night temperature, and photoperiod on stem elongation and flowering in US 400 biennial sugar beets. A—65° F. minus gibberellin; B—65° F. plus gibberellin; C—55° F. minus gibberellin; D—55° F. plus gibberellin. Within each group (A, B, C, D), the plants on the left were exposed to a 9-hour photoperiod those on the right to an 18-hour photoperiod.

Marked variations occurred in the flowering behavior of types and varieties of sugar beets and in plants within the same variety exposed to the same environment. While flowering was generally accelerated and at times induced by spray applications of gibberellin, the variable flowering responses were not eliminated. Nevertheless, the results of these findings should prove useful for promoting earlier flowering and seed production as a means of accelerating variety improvement programs. Further testing under field conditions is needed before the value of gibberellin can be assessed in commercial sugar beet seed production.

Literature Cited

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