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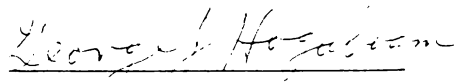
MODIFYING REPRODUCTIVE DEVELOPMENT
OF SUGARBEET (Beta vulgaris L.)
WITH GROWTH REGULATORS

presented by

Husen Djajasukanta

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OF SUGARBEET (BETA VULGARIS L.) WITH
GROWTH REGULATORS

By
Husen Djajasukanta

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ABSTRACT

MODIFYING REPRODUCTIVE DEVELOPMENT OF SUGARBEET (BETA VULGARIS L.) WITH GROWTH REGULATORS

By

Husen Djajasukanta

Potential use of growth regulators in hastening or delaying flowering of sugarbeet (Beta vulgaris L.) was studied in the field and in the greenhouse in 1975, 1976, and 1977 at East Lansing, Michigan. Five slowly bolting and two rapidly bolting lines were grown to compare the effects of eight different chemicals at different concentrations and frequencies of application applied as foliar sprays. For field experiments, overwintered roots from sugarbeet seed fields in Oregon were used. Rooted stem cuttings and seed plants, exposed to different periods of photothermal induction prior to growth regulator treatments, were used in the greenhouse experiments.

Five growth regulators appeared to be ineffective on the slowly bolting lines. The applications of gibberellin GA₄A₇ (2x50 ppm) shortened and ethephon (2,000 or 4,000 ppm) delayed the time of flowering of the rapidly bolting lines SP 6822-0 and UI 1861 x 2161, respectively. Heights of flower stalk (stem) were not affected.

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INTRODUCTION

Male and female component plants of sugarbeet (Beta vulgaris L.) for producing hybrids may fail to flower at the same time under natural conditions. Slowly bolting lines should be hastened to flower or rapidly bolting lines should be delayed from flowering to synchronize time of flowering of both slowly and rapidly bolting lines to allow hybridization.

A number of growth regulators have been used successfully to modify growth and development of numerous plants. Flowering by sugarbeet may be accelerated by gibberellin treatments. Other growth regulators have potential effects in modifying sugarbeet plants.

The objectives of this study were to test the hypotheses that (1) the application of gibberellin and other growth promoting substances of correct concentrations at a given stage of development could shorten the time to flower for slowly bolting sugarbeet plants, and (2) the application of growth retardants of correct concentrations at a given stage of development could lengthen the time to flower for rapidly bolting sugarbeet plants.

LITERATURE REVIEW

Research results showing modified growth and development of various plant species by the application of growth regulators have been reported. Many reviews have surveyed the literature on modification of plant growth by growth regulators (Cathey, 1975; Sachs and Hackett, 1969 and 1972; Wittwer, 1968 and 1971; Thomas, 1976; Wareing, 1976).

There is evidence of increasing use of gibberellic acid (gibberellin GA_3) for a variety of purposes. For example, gibberellic acid has been used to accelerate flower formation in lettuce. Promotion of flower initiation by gibberellic acid is well-known for many long day-requiring rosette plants. Gibberellin GA_4A_7 mixture is used in hybrid cucumber seed production and for enhancement of fruit setting in apples and pears.

Among the growth retardants reported effective in a large number of plant species are (2-chloroethyl)trimethyl ammonium chloride (CCC, chlormequat) and succinic acid 2,2-dimethyl hydrazide (SADH). Two other growth retardants, α -cyclopropyl- α -(p-methoxyphenyl)-5-pyrimidine methanol (ancymidol) and (2-chloroethyl) phosphonic acid (ethephon), have also been used on various plants. CCC, SADH, and ancymidol are used for reducing stem length in a range of ornamental pot plants, nursery crops and fruit trees. Leaf

and flower initiation may be inhibited. CCC is widely used on wheat in western Europe. SADH is extensively used for reducing vegetative growth and promoting flower initiation in tree fruits. The uses of ethephon include the induction and ripening of pineapples. Flower stalks of many vegetables can be reduced by ethephon.

Selected research results of experiments with gibberellin on some plants are cited in this review. According to Bukovac and Wittwer (1967) several biennials grown at temperatures slightly above the critical temperature for flower formation were induced to flower with gibberellin. The normal cold requirement for flowering may be partially or, in few instances, completely replaced by the application of one or several foliar sprays of 100 to 1,000 ppm of gibberellin.

Globerson (1972) stated that the combination of root soaking and foliar spraying carrot plants with 100 ppm gibberellin GA_3 (gibberellic acid, GA) caused a higher percentage of plants to flower than did spraying alone. According to Dickson and Peterson (1960), an aqueous solution of gibberellin at 100 and 1,000 ppm applied five to six times to carrots in greenhouse and in the field, commencing at the six to eight leaf stage, induced earlier and higher percentages of flowering plants.

GA sprayed at the rate of 3 to 10 ppm on young lettuce plants increased yield. Treated plants matured

about two weeks earlier and the plants had extremely uniform maturity (Harrington, 1960).

Flowering of cauliflower (Brassica oleracea var. botrytis) cv. 'Hilary Seale' was accelerated maximally by a combination of cold treatment and gibberellin GA₃ (50 ppm) (Leshem and Steiner, 1968). Salter and Ward (1972) concluded that gibberellin GA₄A₇ had little effect on crop maturity characteristics of cauliflower plants.

Flowering was induced in Zinia elegans under non-inductive 24-hour photoperiods by the application of gibberellic acid (100 mg/l), although flowering was later than under inductive 8-hour photoperiods (Sawhney and Sawhney, 1976).

May and Bula (1971) reported that 85 to 90% of red clover plants (Trifolium pratense L.) of the single-cut cv. 'Tammisto' maintained under an inductive photoperiod but noninductive thermoperiod treated with two foliar sprays of gibberellin GA₃ initiated floral stems within 4 weeks after treatment.

Garrod (1974), Gaskill (1957), and Snyder and Wittwer (1959) have reported effects of gibberellins on sugarbeet plants. Garrod studied the effects of GA on young (vegetative) sugarbeet plants. According to Gaskill, with at least one bolting-resistant sugarbeet cultivar, gibberellic acid can serve as a substitute for a substantial part of the photothermal induction treatment normally required for satisfactory reproductive development. Snyder and Wittwer

concluded that flowering in sugarbeet may be accelerated and even induced with gibberellin if treatments (repeated spray application of solutions of 1,000 ppm to growing tips) are accompanied by exposure of the plants to a long (18-hour) photoperiod.

Results of experiments with different kinds of growth retardants cited in this review further involved with a variety of mostly horticultural crop plants. According to Shanks (1969), ethrel, a mixture of (2-chloroethyl) phosphonic acid and related compounds, has shown activity in dwarfing of several flower crops. Shanks (1972) also reported that SADH was ineffective but CCC (chlormequat) and ancymidol retarded growth of several cultivars of chinese hibiscus (Hibiscus rosa-sinensis L.), inducing shorter nodes and more and earlier flowering during summer months. The length of terminal shoots was also reduced by ethephon. Ethephon reduced flowering and stimulated the growth of lower axillary shoots of unpruned plants.

Foliar spray of 50 ppm ancymidol was effective in reducing internode elongation of five tropical, foliage horticultural plant species as reported by Henley and Poole (1974). SADH (10,000 ppm) reduced internode elongation in two other species studied.

According to Dorrell (1973), SADH and CCC (1,000 and 10,000 ppm) reduced total plant height of cultivars of sunflower (Helianthus annuus L.). Flowering was also delayed.



Less stem elongation of various plants was reported by Cathey and Stuart (1961) when the potting soil was treated with CCC and other growth retardants.

According to Hackett and Sachs (1967), the growth retardant cycocel ((2-chloroethyl)trimethyl ammonium chloride) promoted flowering of rooted cuttings of Bougainvillea grown under short days. GA₃ greatly delayed flowering.

In comparing the effectiveness of some growth retardants, Cathey and Heggestad (1973) concluded that foliar sprays of ancymidol were at least 80 to 500 times more active than chlormequat in retarding stem elongation of cultivars of poinsettia (Euphorbia pulcherrima Willd.).

According to Marshall, Joiner, and Witte (1974) ancymidol reduced heights of midcentury hybrid lily 'Enchantment' but not the size of the inflorescences.

A single spray application of ancymidol (0.125 mg/10-cm pot) or two 0.5% sprays of SADH at 2-week intervals reduced height of five cultivars of garden type chrysanthemums grown as single plants in pots (Wilfret, 1974). According to Hebb, Witte, and Sheehan (1974) ancymidol (2, 4, and 8 ppm) applied as soil drench reduced height of two cultivars of standard chrysanthemums. SADH (1,250, 2,500, and 5,000 ppm) reduced heights of plants grown under 2-week photoperiod treatment. Ancymidol delayed flowering.

'Sovereign' F₁ cultivar of marigold (Tagetes erecta L.) plants grown in a complete nutrient solution and treated



with a weekly foliar spray of SADH were significantly shorter than the controls. Grown under short days, the flowering was delayed up to 8 days by SADH (McConnell and Struckmeyer, 1970).

Applied to short-day, Great Northern Nebraska No. 1 sel. 27 dry bean (Phaseolus vulgaris L.) line, 500 ppm CCC promoted early flowering when plants were grown under long photoperiod (Coyne, 1969).

Foliar sprays of ethephon retarded the height of onion (Allium cepa L.) and when applied to non-bolting plants partially prevented seed stalk emergence and reduced seed yield of early developing inflorescences. Two field applications of 480 ppm ethephon, starting when 75% of the plants had visible seed stalks, reduced seed stalk heights (Levy, Ventura, and Kedar, 1972).

Bolting of cos lettuce (Lactuca sativa L. var. romana) was delayed by treatments with CCC and SADH (Nothman, 1973).

Promising results of the use of gibberellin and other growth regulators in modifying plants were used as a basis of experiments reported herein to study the potential use of growth regulators to synchronize time of flowering of male and female component plants for producing hybrid sugarbeet. In addition to growth regulators mentioned in the selected references cited, 2,4-D and urea also have been studied. According to Howell and Wittwer (1954) foliar applications of 2,4-D to sweet potato resulted in flowering. Although

urea is generally used as fertilizer, in minute concentrations it has potential use as a growth regulator.



MATERIALS AND METHODS

Field Experiments with Growth Promoters

Four experiments in 1975 and two experiments each in 1976 and 1977 were conducted to test whether growth promoters would hasten sugarbeet plants to flower. Naturally cold-induced roots from sugarbeet seed fields in Oregon were planted in May at East Lansing, Michigan. The roots were stored in the cold room at 5°C for two months and then transferred to the field. Pests and diseases were controlled as needed.

The sugarbeet lines used, their bolting characteristic and the growth promoters applied in all field experiments with growth promoters are listed in Table 1. Field experiment numbers 5 and 6 repeated field experiment numbers 1 and 2, respectively.

A randomized block design was used in all experiments. Treatments were replicated four times in 1975 and 1976, and three times in 1977 experiments. The experimental unit was a single-row plot, consisting of 4 plants in 1975 and 10 plants in 1976 and 1977. The rows were 90 cm apart with 30 cm spacing between plants within each row.

The growth promoter treatments were different concentrations, either as single or equally-split applications. In the 1977 experiments all growth promoters were applied



Table 1. Field Experiments with Growth Promoters at East Lansing, Michigan.

Expt. No.	Year	Sugarbeet Line		Growth Promoter	Number of Treatments
		Name	Characteristic		
1	1975	F 73-17	slowly bolting	GA ₄ A ₇	6 ¹
2	1975	F 69-546-H4	slowly bolting	GA ₄ A ₇	6 ¹
3	1975	UI 1861 x 2161	rapidly bolting	GA ₄ A ₇	3 ¹
4	1975	SP 6822-0	rapidly bolting	GA ₄ A ₇	3 ¹
5	1976	F 73-17	slowly bolting	GA ₄ A ₇	6 ¹
6	1976	F 69-546-H4	slowly bolting	GA ₄ A ₇	6 ¹
7	1977	EL 31	slowly bolting	GA ₃	3
				GA ₄ A ₇	3
				2,4-D	3
				Urea	3
				Ethephon	3
8	1977	EL 36	slowly bolting	GA ₃	3
				GA ₄ A ₇	3
				2,4-D	3
				Urea	3
				Ethephon	3

¹Including check treatment.



in equally-split applications. Urea, 2,4-D, and ethphon were applied in low concentrations.

Each plant received a foliar spray of growth promoter in water with Tween 20 at 0.1% by volume added as surfactant. Approximately 3 ml of solution per plant were applied for the 1975 experiments and 10 ml for the 1976 and 1977 experiments. Plants sprayed with water were used as checks. The plants were sprayed 2 to 3 weeks after planting. In split applications, the plants were resprayed one week later.

Growth responses measured and analyzed were (1) time of flowering, calculated as days from planting to first flower appearance, and (2) heights of flower stalks (stems) in cm at weekly intervals for a couple of weeks starting from one week after treatment. Averaged data per plant were analyzed following statistical procedure of analyses of variance and the associated tests of significance and comparisons. Data were obtained from bolting plants per plot which survived during the experiments, 2 to 4 plants in 1975 and 3 to 9 plants in 1976 and 1977 experiments. In the 1977 experiments only time of flowering was recorded.

Field Experiments with Growth Retardants

Two experiments were conducted in 1977 to test whether growth retardants would delay the flowering of sugarbeet plants. The location, source of planting materials, and experimental design were the same as for the other experiments. Sugarbeet roots of two rapidly bolting lines

UI 1861 x 2161 and SP 6926-0 were planted in May, but most plants of SP 6926-0 line failed to survive so only one experiment could be conducted.

The effects of four different growth retardants were compared in a randomized block design with three replications. The growth retardants were CCC, SADH, ancymidol and ethephon, each at three different concentrations in equally-split applications.

Other methods and procedures employed for this experiment were the same as for the 1977 experiments with growth promoters. Time of flowering was measured and analyzed. There were 3 to 9 surviving and bolting plants in each plot.

Greenhouse Experiments with Gibberellin

Four greenhouse experiments in 1976/1977 were conducted to test whether gibberellin GA_4A_7 would hasten flowering of sugarbeet. In an effort to have more precise control and measurement of experimental plant variables, genetically identical clones, obtained from stem cuttings, were used in two experiments, and from split roots in a third experiment. The fourth experiment involved plants grown from seed. The experiments were conducted in the Michigan State University Plant Science greenhouses.

Stem cuttings were obtained from bolting plants. Cuttings were made from several plants to obtain a greater number of clonal groups. To obtain split roots, seeds were planted and grown until the plants were large enough to

split into two halves longitudinally through the growing tips. One half of the split root was used for gibberellin treatment and the other half was used as a control.

Prior to the application of gibberellin, the plants or clones were exposed to different degrees of photothermal induction in the cold room, 8 and/or 10 weeks for rapidly bolting, and 10 and/or 12 weeks for slowly bolting lines. The temperature of the cold room for induction was kept at about 5°C. The plants were illuminated continuously by incandescent lamps.

The plants were grown on vermiculite in 15-cm pots supplied daily with nutrient solution containing Ca, K, NH_4 , Mg, Fe, NO_3 , Cl, H_2PO_4 , SO_4 ions and trace elements. Pests and diseases were controlled as needed.

Gibberellin was applied as a 10-ml foliar spray per plant 2 to 3 weeks after photothermal induction, during the post-induction period in the greenhouse. When double spraying was done, the second spray was applied 1 week after the first. The post-induction temperature was increased gradually each week for the first 3 weeks from a maximum of 13 to 16 to 20°C. Supplemental light from fluorescent lamps was used to obtain a 14 to 16-hour daylength.

In greenhouse experiment I, stem cuttings of slowly bolting F 66-562-HO sugarbeet line were used. The plants were exposed to photothermal induction for 12 weeks. Two gibberellin treatments, and a check, were compared in a completely randomized design with five single-plant



replications. Solutions of GA_4A_7 as ProGibb 2% LC in water were Tween 20 added as surfactant were applied. Check plots were sprayed with water.

Green house experiment II was similar to the greenhouse experiment I. However, for this experiment length of photothermal induction was 10 weeks. Four gibberellin GA_4A_7 , as ProGibb, treatments, and a check, were compared in a completely randomized design with five replications. Grown for approximately 2 months the experimental plants remained vegetative. The plants were then reinduced photothermally for 10 weeks. The five treatments were applied again as before.

In greenhouse experiment III, split roots of both slowly bolting F 66-562-HO and rapidly bolting UI 1861 x 2161 lines were used. The half roots were photothermally induced for 10 weeks. A group of half roots was sprayed with four different GA_4A_7 treatments. Another group of half roots served as checks. Five replicated paired comparisons were made for each line and treatment. Similar to greenhouse experiment II, since the experimental plants remained vegetative for approximately 2 months after gibberellin treatments, photothermal reinduction and gibberellin retreatment were done as before.

Seed plants of the two sugarbeet lines used in greenhouse experiment III were also used in green house experiment IV. Photothermal inductions were 8 and/or 10 weeks for the rapidly bolting and 10 and/or 12 weeks for the slowly



bolting lines. Three GA_4A_7 treatments, and a check, were compared in a completely randomized design with five replications. Most plants (90%) of the slowly bolting F 66-562-HO did not bolt, hence only the experiment with UI 1861 x 2161 was continued to finish.

Growth responses measured and analyzed were the same as in field experiments. Time of flowering was calculated as number of days after photothermal induction to first flower appearance. The single-plant plot data were analyzed similar to the other experiments.

RESULTS AND DISCUSSION

Field Experiments

Time of Flowering. Results of field experiments in 1975 and 1976 (experiment numbers 1, 2, 5, and 6; see Table 1) suggested that treating with foliar sprays of different concentrations and frequencies of application of gibberellin GA_4A_7 did not significantly shorten the time of flowering of two slowly bolting sugarbeet lines, F 69-546-H4 and F 73-17 (Table 2). Similarly, the experiments in 1977 (experiment numbers 7 and 8; see Table 1) also indicated that foliar spraying different kinds of growth promoter (gibberellins GA_3 and GA_4A_7 , 2,4-D, urea, and ethephon) at different concentrations as equally-split applications to slowly bolting sugarbeet lines EL 36 and EL 31 grown in the field did not significantly shorten the time of flowering (Table 3).

On the other hand, results of the field experiments in 1975 (experiment numbers 3 and 4; see Table 1) showed that rapidly bolting sugarbeet line SP 6822-0 treated with double foliar spraying of gibberellin GA_4A_7 , each at 50 ppm, flowered in a significantly shorter time. However, gibberellin GA_4A_7 did not shorten significantly the time of flowering of rapidly bolting line UI 1861 x 2161 grown in the field (Table 4).

Table 2. Time of Flowering of Two Slowly Bolting Sugarbeet Lines Sprayed with Gibberellin at East Lansing in 1975 and 1976 Field Experiments.

GA ₄ A ₇ Treatments ppm	1975		1976	
	F 69-546-H4	F 73-17	F 69-546-H4	F 73-17
-----Days to First Flower Appearance-----				
Check	43.2 a	40.6 b	39.4 c	34.4 d
50	46.3 a	40.7 b	39.6 c	33.8 d
2x50	47.1 a	37.0 b	40.0 c	34.6 d
100	48.0 a	41.4 b	39.7 c	34.7 d
2x100	45.3 a	43.6 b	39.1 c	35.3 d
200	43.8 a	40.3 b	39.3 c	34.4 d

Data in each column followed by the same letter are not significantly different at 0.05 probability level.



Table 3. Time of Flowering of Two Slowly Bolting Sugarbeet Lines Sprayed (as a Split Application) with Different Kinds of Growth Promoter at East Lansing in 1977 Field Experiments.

Treatments ppm	Days to First Flower Appearance	
	EL 36	EL 31
Check	45.4 a	46.3 b
GA ₃ 100	45.1 a	46.0 b
GA ₃ 300	45.8 a	44.3 b
GA ₃ 500	45.6 a	45.5 b
GA ₄ A ₇ 50	44.4 a	42.8 b
GA ₄ A ₇ 100	44.8 a	47.9 b
GA ₄ A ₇ 200	46.3 a	44.5 b
2,4-D 10	48.5 a	44.7 b
2,4-D 100	46.4 a	45.8 b
2,4-D 1000	47.1 a	42.8 b
Urea 100	45.8 a	44.7 b
Urea 2000	45.6 a	49.7 b
Urea 4000	44.6 a	47.7 b
Ethephon 5	47.2 a	47.4 b
Ethephon 100	44.4 a	45.9 b
Ethephon 1000	45.9 a	50.2 b

Data in each column followed by the same letter are not significantly different at 0.05 probability level.

Table 4. Time of Flowering of Two Rapidly Bolting Sugar-beet Lines Sprayed with Gibberellin at East Lansing in 1975 Field Experiments.

GA ₄ A ₇ Treatments ppm	SP 6822-0	UI 1861 x 2161
Days to First Flower Appearance		
Check	34.2 a	38.0 c
50	34.0 a	37.5 c
2x50	30.7 b	37.5 c

Data in each column followed by the same letter are not significantly different at 0.05 probability level.

The genetic program for flowering of plants is not expressed until the right time. Some plants have devices that sense when the correct season for flowering has arrived. Plants have built-in mechanisms which respond to environmental stimuli such as daylength (photoperiodism) or cold treatment (vernalization). Some also respond to chemical stimuli and initiate flowering.

Gibberellic acid has strong effects on bolting and flowering in many plants. It has been found to replace both vernalization and photoperiodic induction in many long-day plants. Gibberellic acid causes flowering in many rosette plants. One possible explanation is that gibberellic acid is essential in the stimulation of growth leading to bolting, which is a prerequisite to flowering.

However, in these studies, gibberellins GA₃ (gibberellic acid) and GA₄A₇ were not effective in stimulating

flowering of the slowly bolting sugarbeet, a rosette plant, lines. The difference in response to gibberellin between different sugarbeet lines was presumably due to different genotype. The rapidly bolting line SP 6822-0 was responsive to gibberellin GA_4A_7 . It may have an insufficient amount of endogenous gibberellic acid, so that it was responsive to the applied gibberellin.

Other chemicals (2,4-D, urea, and ethephon at low concentrations) were ineffective as growth promoting substances on sugarbeet.

Foliar spraying of growth retardant ethephon at 2,000 and 4,000 ppm as equally-split applications to rapidly bolting line UI 1861 x 2161 grown in the field in 1977 significantly delayed the time of flowering. SADH, ancymidol and CCC did not delay the time of flowering significantly (Table 5).

Growth retardants appear to function as anti-gibberellins. The endogenous regulation of flower initiation, which is governed by gibberellin, could be affected by applied growth retardant. It was evident that rapidly bolting line UI 1861 x 2161 was responsive to ethephon. Perhaps, the insufficient content of endogenous gibberellic acid to stimulate flowering was augmented by the applied ethephon.

Heights of Flower Stalks. Results of both 1975 and 1976 field experiments indicated that gibberellin GA_4A_7 did not significantly increase the heights of flower stalk (stem) of slowly bolting sugarbeet lines F 69-546-H4 and

Table 5. Time of Flowering of Rapidly Bolting UI 1861 x 2161 Sugarbeet Line Sprayed (as a Split Application) with Different Kinds of Growth Retardants at East Lansing in 1977 Field Experiment.

Treatment ppm	Days to First Flower Appearance
Check	34.9 a
SADH 500	35.5 a
SADH 1000	35.3 a
SADH 2000	36.3 a
Ancymidol 2	37.4 a
Ancymidol 4	37.7 a
Ancymidol 8	36.8 a
CCC 100	35.7 a
CCC 2000	35.4 a
CCC 4000	37.0 a
Ethephon 100	34.7 a
Ethephon 2000	44.2 b
Ethephon 4000	41.2 b

Data followed by the same letter are not significantly different at 0.05 probability level.



F 73-17 at all times of measurements (Table 6). Similar results were also found from 1975 field experiment with two rapidly bolting lines SP 6822-0 and UI 1861 x 2161 sprayed with gibberellin GA_4A_7 (Table 7).

Stimulation of growth leading to bolting is a prerequisite to flowering. The growth regulators used in these studies did not significantly increase or decrease the heights of flower stalks. The growth regulators in these studies were ineffective in both modifying the height of flower stalk and time of flowering of all sugarbeet lines studied, except in two cases, where GA_4A_7 shortened time of flowering of sugarbeet line SP 6822-0, and ethephon delayed time of flowering of sugarbeet line UI 1861 x 2161.

Greenhouse Experiments

Time of Flowering. Stem-cutting plants of slowly bolting line F 66-562-HO, exposed to either 12 or 10 weeks of photothermal induction, and sprayed with different concentrations, either as single or split application, of gibberellin GA_4A_7 (experiments I and II) flowered at about the same time as unsprayed control plants (Table 8). Most of the plants did not bolt in the experiments using split roots of sugarbeet lines F 66-562-HO and UI 1861 x 2161 (experiment III).

Gibberellin GA_4A_7 did not shorten significantly the time of flowering of rapidly bolting line UI 1861 x 2161 grown in the greenhouse (experiment IV) with prior photothermal induction of either 10 or 8 weeks (Table 9).



Table 6. Flower Stalk Heights of Two Slowly Bolting Sugar-beet Lines After Spraying with Gibberellin at East Lansing in 1975 and 1976 Field Experiments.

GA ₄ A ₇ Treatments ppm	1975		1976	
	F 69-546-H4	F 73-17	F 69-546-H4	F 73-17
-----cm-----				
Week 1:				
Check	---	---	11.5 a	15.5 b
50	---	---	14.3 a	15.0 b
2x50	---	---	14.1 a	17.3 b
100	---	---	14.0 a	17.9 b
2x100	---	---	14.1 a	13.4 b
200	---	---	14.7 a	14.1 b
Week 2:				
Check	40.1 c	48.1 d	35.5 e	40.7 f
50	31.6 c	50.6 d	40.9 e	39.2 f
2x50	35.1 c	52.5 d	42.9 e	44.0 f
100	29.7 c	47.0 d	41.8 e	44.0 f
2x100	33.8 c	39.8 d	41.9 e	40.7 f
200	40.0 c	50.0 d	40.4 e	39.8 f
Week 3:				
Check	68.7 g	66.7 h	42.0 i	57.0 j
50	50.1 g	65.5 h	51.4 i	55.5 j
2x50	55.5 g	75.9 h	54.5 i	59.0 j
100	43.2 g	69.5 h	51.6 i	57.3 j
2x100	57.1 g	62.0 h	56.2 i	54.1 j
200	63.1 g	70.4 h	53.6 i	53.6 j
Week 4:				
Check	102.1 k	---	---	---
50	97.4 k	---	---	---
2x50	95.3 k	---	---	---
100	91.8 k	---	---	---
2x100	91.4 k	---	---	---
200	87.6 k	---	---	---

Groups of data in each column followed by the same letter are not significantly different at 0.05 probability level.

Table 7. Flower Stalk Heights of Two rapidly Bolting Sugarbeet Lines After Spraying with Gibberellin at East Lansing in 1975 Field Experiments.

GA ₄ A ₇ Treatments ppm	SP 6822-0	UI 1681 x 2161
-----cm-----		
Week 2:		
Check	63.3 a	72.5 b
50	62.3 a	83.6 b
2x50	68.5 a	76.3 b
Week 3:		
Check	---	85.0 c
50	---	98.1 c
2x50	---	91.2 c

Groups of data in each column followed by the same letter are not significantly different at 0.05 probability level.

Table 8. Time of Flowering of Stem-Cutting Plants of Slowly Bolting Sugarbeet line F 66-562-HO Exposed to Different Periods of Photothermal Induction and Sprayed with Gibberellin in the Greenhouse in 1976/1977.

GA ₄ A ₇ Treatment ppm	Period of Photothermal Induction	
	12 weeks	10 weeks
Days to First Flower Appearance		
Check	50.6 a	67.2 b
50	54.8 a	70.6 b
2x50	54.8 a	65.4 b
100	---	68.4 b
2x100	---	63.2 b

Data in each column followed by the same letter are not significantly different at 0.05 probability level.

Table 9. Time of Flowering of Seed Plants of Rapidly Bolting Sugarbeet Line UI 1861 x 2161 Exposed to different Periods of Photothermal Induction and Sprayed with Gibberellin in the Greenhouse in 1976/1977.

GA ₄ A ₇ Treatment ppm	Period of Photothermal Induction	
	10 weeks	8 weeks
Days to First Flower Appearance		
Check	26.8 a	34.0 b
50	26.8 a	35.8 b
2x50	26.4 a	33.8 b
100	26.8 a	41.0 b

Data in each column followed by the same letter are not significantly different at 0.05 probability level.

Results of the greenhouse experiments supported the results of field experiments. The application of gibberellin in greenhouse experiments might have been more effective when the length of photothermal induction had been much shorter than the critical thresholds for flower induction, so that gibberellin could have replaced partial requirement of photothermal induction.

Heights of Flower Stalks. Results of greenhouse experiments indicated that gibberellin GA₄A₇ did not significantly increase the heights of flower stalk of slowly bolting sugarbeet lines F 66-562-HO at all times of measurements (Table 10). As presented in Table 11 rapidly bolting line UI 1861 x 2161, exposed to either 10 or 8 weeks and sprayed or not sprayed with gibberellin GA₄A₇, had about the same heights of flower stalk.

Since gibberellin GA₄A₇ was found ineffective in modifying time of flowering it could be expected that it was also ineffective in modifying height of flower stalk.

Table 10. Flower Stalk Heights of Stem-Cutting Plants of Slowly Bolting Sugarbeet Line F 66-562-HO Exposed to Different Periods of Photothermal Induction, after Spraying with Gibberellin in the Greenhouse in 1976/1977.

GA ₄ A ₇ Treatment ppm	Period of Photothermal Induction	
	12 weeks	10 weeks
	-----cm-----	
Week 1:		
Check	21.6 a	---
50	21.0 a	---
2x50	29.4 a	---
Week 2:		
Check	43.8 b	---
50	43.2 b	---
2x50	55.8 b	---
Week 3:		
Check	61.2 c	---
50	61.6 c	---
2x50	73.2 c	---
Week 4:		
Check	72.2 d	32.4 e
50	73.2 d	17.2 e
2x50	80.4 d	30.0 e
100	---	23.0 e
2x100	---	36.0 e
Week 5:		
Check	82.4 f	66.3 g
50	84.2 f	53.3 g
2x50	86.8 f	77.0 g
100	---	61.8 g
2x100	---	83.8 g
Week 6:		
Check	---	89.8 h
50	---	75.5 h
2x50	---	108.0 h
100	---	85.0 h
2x100	---	111.8 h

Groups of data in each column followed the same letter are not significantly different at 0.05 probability level.

Table 11. Flower Stalk Heights of Seed Plants of Rapidly Bolting Sugarbeet Line UI 1861 x 2161 Exposed to Different Periods of Photothermal Induction, after Spraying with Gibberellin in the Greenhouse in 1976/1977.

GA ₄ A ₇ Treatment ppm	Period of Photothermal Induction	
	10 weeks	8 weeks
	-----cm-----	
Week 1:		
Check	35.2 a	---
50	38.6 a	---
2x50	39.8 a	---
100	34.6 a	---
Week 2:		
Check	85.2 b	28.0 c
50	89.4 b	32.0 c
2x50	93.6 b	39.6 c
100	86.2 b	15.2 c
Week 3:		
Check	108.0 d	73.8 e
50	110.8 d	74.6 e
2x50	113.6 d	73.0 e
100	106.6 d	40.8 e
Week 4:		
Check	---	106.0 f
50	---	109.2 f
2x50	---	90.0 f
100	---	77.2 f

Groups of data in each column followed by the same letter are not significantly different at 0.05 probability level.

SUMMARY AND CONCLUSIONS

The problem of eliminating differences in time of flowering of male and female component plants in making hybrids of sugarbeet under natural conditions needs to be solved in one way or another. Successful use of various growth regulators in other plants or crops led to an effort to try them on sugarbeet plants.

In this investigation an attempt was made to study the effects of eight different chemicals with both promoting and retarding effects on plants. Although the problem is under natural conditions, field and also greenhouse experiments were conducted to have greater control of environmental variables.

Five slowly bolting and two rapidly bolting lines were included in the study. Seed plants and clones were grown. The growth regulators were applied as a foliar spray, either as single or split applications, at different concentrations. The responses measured and recorded were times of flowering and heights of flower stalk (stem).

The two rapidly bolting lines appeared to be responsive to the application of two kinds of growth regulators. Gibberellin GA₄A₇ could shorten and ethephon could delay the time to flower of SP 6822-0 and UI 1861 x 2161 lines, respectively. The heights of flower stalk were not affected.

The difference in responses to different growth regulators between different sugarbeet lines was probably due to different genotype. Other factors, such as environmental conditions and uncontrolled technical aspects of the application of the chemicals, could also play an important role in the difference in responses.

The significant acceleration of flowering in a rapidly bolting line by gibberellin GA_4A_7 and the retardation of flowering in another test by ethephon indicate that the time of flowering of rapidly bolting lines may be controlled sufficiently to be of practical use in seed production with further intensive research. The slowly bolting lines, being less responsive, may require considerably higher concentrations and more applications of the growth regulators to alter time of flowering than was anticipated in the present study.

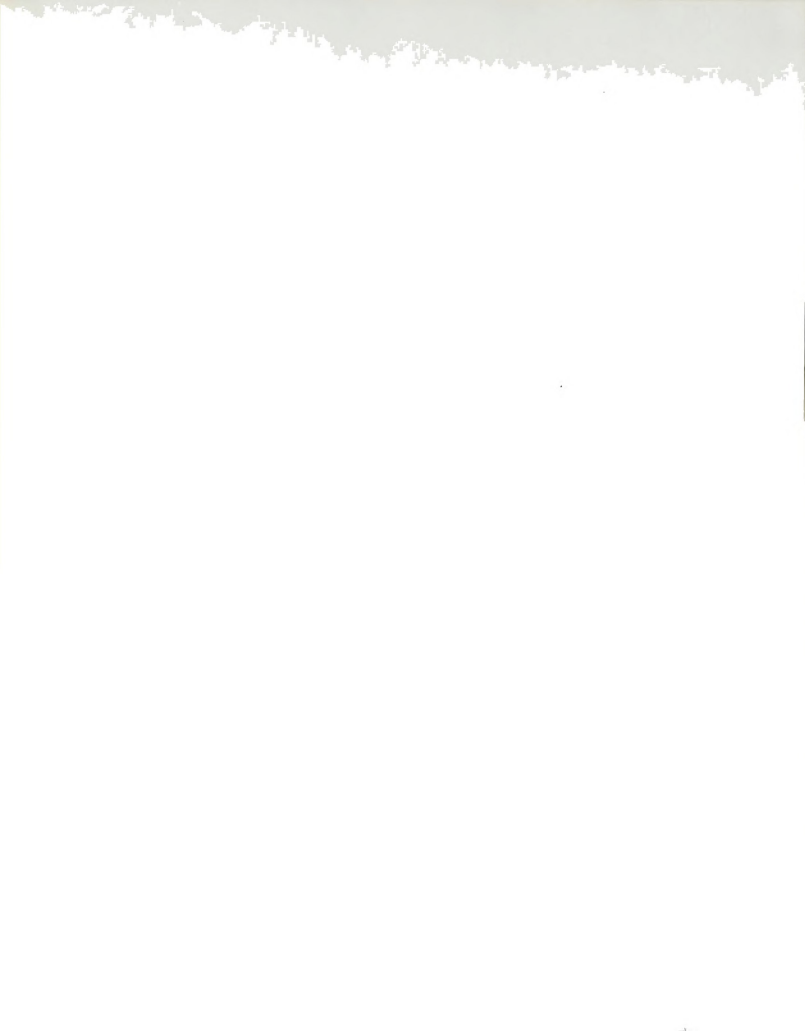
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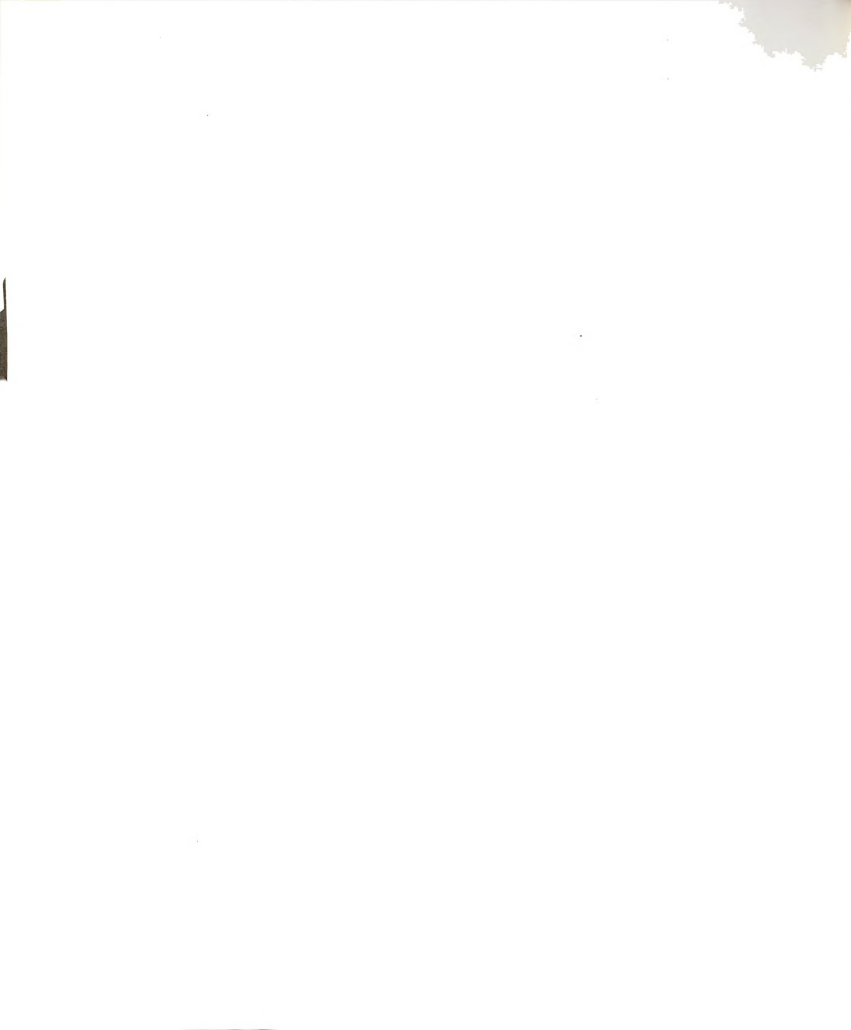
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