A Preliminary Report on the Use of Gibberellic Acid to Hasten Reproductive Development in Sugar Beet Seedlings[1]

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In genetic studies and breeding work with sugar beets, *Beta vulgaris* L., the length of the life cycle frequently is an important factor limiting the rate of progress. A method announced by the author in 1952 (1, 2)[3], involving prolonged photothermal treatment of young seedlings, now is being used by a number of sugar beet research workers in the United States as a means of hastening reproductive development. With strains or varieties of sugar beets having ordinary or average bolting tendencies, the complete life cycle, from seed to mature seed, can be produced satisfactorily in six months—two such cycles, successively, within a year—by means of this method. However, techniques for reducing still further the time required for the life cycle would be highly desirable, particularly for bolting-resistant types.

Recent studies by numerous investigators have shown that reproductive development of certain types of plants is hastened considerably by the application of gibberellic acid and related substances. No attempt will be made to review the reports of those studies, but certain observations are of special interest. Marth, Audia, and Mitchell (6) summarized their findings regarding floral response in a wide variety of plants as follows: "There was no evidence that gibberellic acid could induce plants to initiate flower primordia. Accelerated stem elongation was, however, sometimes accompanied by relatively rapid flower development compared with that of untreated plants. Treated pepper plants, on the other hand, remained vegetative longer and flowered 30 days later than did controls. Elongation of seed stalks of beet plants was stimulated, but it is not known at this time whether seed production was accelerated." Wittwer and Bukovac (7) found that flowering of various types of plants, including some biennials, was hastened considerably by application of gibberellins. Remarkable stem elongation was observed on gibberellin-treated sugar beets, not exposed to cold, but apparently flower buds had not appeared on those plants by the time their report was prepared. Lang (4), working with the biennial, *Hyoscyamus niger*, concluded that gibberellin appeared to replace primarily the cold requirement of that plant for floral development, but not the long-day requirement.

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[3] Numbers in parentheses pertain to list of references.

A preliminary experiment started at Fort Collins, Colorado, in September, 1956, indicated rather strongly that gibberellic acid[4] could serve to materially hasten reproductive development in young sugar beet seedlings if used in conjunction with photothermal-induction treatment. Results regarding timing of gibberellic acid applications were not conclusive, but pointed toward the advisability of making those applications after the period of photothermal treatment rather than before or during that period.

Methods

The results presented in this report were obtained entirely from the bolting-resistant inbred, NB1[5]. The photothermal-induction treatment employed, involving continuous incandescent illumination, without sunlight, and continuous low temperature (approximately 45-46° F.), was similar to that described in an earlier report (2). Except for such periods of induction, all plants were kept in a greenhouse throughout the duration of this study. The seedlings were started in 3-inch pots, thinned to 6 per pot, and transferred to 6-inch pots (as 6-plant clusters) before crowding became noticeable. Planting of seed and induction treatments were so timed that the groups of seedlings representing the different induction exposures were nearly the same size on January 8, 1957, the date when all induction treatments were concluded and the first applications of gibberellic acid were made. Gibberellic acid was prepared for use as an aqueous solution (1,000 p.p.m.), with the aid of ethyl alcohol and liquid detergent, as suggested by Marth, Audia, and Mitchell (5). It was applied as a foliar spray, almost to the point of run-off.

Up to January 8, incandescent light was provided in the greenhouse for 4 hours in the middle of each night. All-night light was provided, from that date forward, as previously described for the post-induction period (2)[6]. Except as otherwise indicated, moderately warm greenhouse conditions were maintained, temperatures averaging approximately as follows: 9:00 a.m. to 4:00 p.m., 77° F.; 7:00 p.m. to 8:00 a.m., 57°; over-all, 65°.

Two experiments of an exploratory nature were conducted. Different lengths of induction treatment were included in each experiment. In addition, two post-induction temperature levels were compared in Experiment 1, and different numbers of applications of gibberellic acid were compared in Experiment 2. In the former, half the plants were held from January 8 to February 25 in a greenhouse room in which day and night temperatures were approximately 19° and 10°, respectively, lower than those described in the preceding paragraph. Additional details regarding methods are given in Tables 1 and 2.

[4] The gibberellic acid used in the Fort Collins studies reported in this article was furnished, as experimental samples, by Merck and Company, Rahway, New Jersey.

[5] Developed by J. S. McFarlane, Geneticist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Salinas, Calif., for use in areas where a high degree of resistance to bolting is a necessity for satisfactory commercial sugar beet production.

[6] For convenience, the term, "post-induction period," is used in this report to designate the entire period from the conclusion of the exposure to continuous cold and continuous artificial light until the end of the study. It is recognized that induction probably occurred to some extent during that time, especially in the cool greenhouse room.

Table 1.—Effects of Gibberellic Acid on Bolting and Flowering of Sugar Beet Seedlings, at Two Temperatures, Following Varying Photothermal-Induction Treatments; Experiment No. 1.

Date seed planted (1956)	Photothermal induction		Gib. acid appl.[a]	Warm[b]				Cool[b]			
					Plants with stalks 5/10/57[c]				Plants with stalks 5/10/57[c]		
	Days	Dates (1956-57)		Total Plants	Total with Stalks	Reproductive type	Flowering[d]	Total Plants	Total with Stalks	Reproductive type	Flowering[d]
	No.		No.	No.	No.	No.	No.	No.	No.	No.	No.
12/18	0	—	0	12	0	0	0	12	0	0	0
do	0	—	4	12	12	0	0	12	12	0	0
12/6	21	12/18-1/8	0	12	0	0	0	12	0	0	0
do	21	do	4	12	12	4	4	11	11	8	7
11/15	43	11/26-1/8	0	12	4	4	4	12	6	4	2
do	43	do	4	12	12	11	11	12	12	12	12

[a] Dates of application: 1/8, 1/22, 2/5, and 2/22/57

[b] "Warm" and "cool" pertain to greenhouse temperatures during the 7-week period beginning 1/8/57. Over-all average temperatures for the two rooms during that period, based on thermograph charts, were approximately 65°F and 51°F., respectively. Thereafter, all plants were held in the warm room.

[c] Stalks less than 1 inch high disregarded.

[d] Reproductive-type plants on which opening of flowers had begun by 5/10/57.

Table 2.—Effects of Photothermal Induction and Gibberellic Acid on Bolting and Flowering of Sugar Beet Seedlings; Experiment No. 2.

Date seed planted (1956)	Photothermal induction		Gib. acid applications				Total Plants	Plants with stalks 5/9/57[a]		
	Days	Dates (1956-57)	Number	Dates (1957) 1/8	1/22	2/5		Total with Stalks	Reproductive type	Flowering[b]
	No.						No.	No.	No.	No.
12/18	0	—	0				12	0	0	0
do	0	—	3	x	x	x	11	11	0	0
12/6	21	12/18—1/8	0				12	0	0	0
do	21	do	1	x			12	0	0	0
do	21	do	2	x	x		12	12	1	0
do	21	do	3	x	x	x	11	11	2	2
11/15	43	11/26—1/8	0				12	3	2	0
do	43	do	1	x			11	8	3	1
do	43	do	2	x	x		12	12	10	9
do	43	do	3	x	x	x	12	12	9	9

[a] Stalks less than 1 inch high disregarded.

[b] Reproductive-type plants on which opening of flowers had begun by 5/9/57.

Results

A progress report on Experiment 1 was given at the twenty-eighth annual meeting of the Colorado-Wyoming Academy of Science, Fort Collins, Colorado, April 13, 1957, based on plant classifications made on March 28 (3).

Representative pots of certain treatments in the warm-room set of material belonging to Experiment 1 are shown in Figure 1. Striking effects of gibberellic acid, in promoting reproductive development, are shown in pot D, contrasted with pot C. Both had been given 43 days' photothermal induction. Pot D subsequently had received four applications of gibberellic acid; pot C, none. At the time the photograph was taken (March 16), 11 of a total of 12 plants, represented by D, had reproductive-type seed stalks and four were flowering. On the other hand, no stalks were apparent on the 12 comparable plants represented by C.

Figure 1.—Response of seedlings of a bolting-resistant sugar beet strain (NB1) to photothermal induction and gibberellic acid; 6 plants per pot in 6-inch pots. Induction time, in days, and numbers of gibberellic acid applications, respectively, were as follows: A- 0, 0; B- 0, 4; C- 43, 0; D- 43, 4. Arrow points toward tip of a vegetative stalk. Photograph was taken March 16, 1957 (Experiment No. 1).

Early effects of gibberellic acid, without the aid of photothermal induction, are illustrated in pot B, Figure 1. At that time, short stalks were evident on all 12 such plants, and all those stalks tentatively were classed as vegetative in type. Pot A had received neither photothermal induction nor gibberellic acid. As expected, the 12 plants in the experiment, represented by A, were without stalks. The vegetative type stalks resulting from gibberellic acid treatment, without photothermal induction, are shown more clearly in pot B, Figure 2, August 1, 1957.

Final plant classification data for Experiment 1 are summarized in Table 1. Three points are of particular interest: (a) Gibberellic acid obviously stimulated the development of reproductive type stalks, where preceded by photothermal induction, but failed to show such effects without the aid of induction. (b) Forty-three days' induction, where followed by gibberellic acid, appeared to be essentially adequate for satisfactory reproductive development, but inadequate where gibberellic acid was not used. (c) The fact that cool greenhouse conditions did not appear to be necessary for satisfactory reproductive development, where 43 days' induction plus gibberellic acid were provided, is of special importance to the sugar beet breeder because of practical considerations.

On May 10, 1957, approximately 25 weeks after date of planting, all seed was harvested from each of the 11 plants classed as reproductive in

Figure 2.—Response of sugar beet seedlings to gibberellic acid without photothermal induction; same plants as A and B in Figure 1; photographed August 1, 1957. Note the vegetative-type stalks on the plants receiving gibberellic acid (B).

type in Table 1, warm room, with 43 days' induction plus gibberellic acid. Fully matured seed balls occurred on each plant, and some were near the shattering stage. Germination tests made in steamed soil showed satisfactory viability for the seed obtained from each of the 11 plants. Seed lots obtained by enforced selfing, in paper bags, were about equal to the open-pollinated lots in viability. Average germination for all lots was approximately 88 percent.

It is known that the bolting-resistant strain used in this study (NB1) normally requires considerably more than 43 days' photothermal induction for subsequent satisfactory reproductive development, and well over 6 months' total time for production of the complete life cycle. Consequently, the outcome of Experiment 1, in showing satisfactory results for only 43 days' induction, where gibberellic acid was used, with the mature seed crop harvested in less than 6 months from date of planting of the original seed, represents a significant advance in the development of sugar beet breeding techniques.

The results for Experiment 2 are presented in Table 2. Because of crowded conditions and relatively severe shading which arose in this experiment within a few weeks after gibberellic acid treatments were begun, the numbers of reproductive-type individuals shown in the table are thought to be somewhat lower than normally could be expected, and variability in response is considered greater than usual for such inbred material. Consequently, these results should be viewed with caution. It is of interest to note that the general pattern of gibberellic acid stimulation of reproductive development, shown in this table for two or more applications, parallels rather closely that presented for the warm room in Table 1. As to numbers of applications, the results in Table 2 indicate merely that more than one was needed under the condiions and timing of this experiment.

Summary

Two exploratory-type experiments were conducted at Fort Collins, Colorado, during the period, November 1956 to May 1957, to study the possibility of hastening reproduction in a bolting-resistant sugar beet strain by means of gibberellic acid. Although relatively small numbers of plants were used, the results were so striking as to warrant the conclusion that, with at least one type of bolting-resistant sugar beet, gibberellic acid can serve as a substitute for a substantial part of the photothermal-induction treatment normally required for satisfactory reproductive development. In this way, the amount of time required to produce the complete life cycle can be reduced materially.

The NB1 sugar beet strain, used in this study, normally requires considerably more than 43 days' photothermal induction for satisfactory reproductive development of young seedlings, and well over six months' total time for the complete life cycle. In this study, 43 days' induction appeared to be adequate, where followed by four foliar applications of gibberellic acid (aqueous solution, 1,000 p.p.m.), and 11 of a set of 12 plants, so treated, produced mature seed of good viability within approximately 25 weeks from the date when the original seed was planted.

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