Studies on the Use of Gibberellic Acid to Induce Flowering in Sugar Beets

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Received for publication March 24, 1958

Gibberellic acid is a product refined from the fungus, *Gibberella fujikori,* (1)[2] which is the causal organism of the rice disease that causes excessive stem elongation and subsequent lodging that makes harvesting of the rice crop difficult. Within the past few years, plant physiologists have become interested in the acid because of its growth regulating properties (1, 2). Among the plants upon which it had some effect, were sugar beets. It appeared to speed the development of a seed stalk, offering a chance of shortening the time between generations which would speed some phases of sugar beet breeding work.

Studies reported here were conducted to determine the effectiveness of various gibberellic acid treatments in hastening the reproductive cycle of sugar beets, including earlier flowering and maturing of viable seed as well as hastening seed stalk development. Also of importance was to observe the reaction of several inbred and open pollinated strains of sugar beets with differing bolting characteristics to gibberellic acid.

Unless otherwise stated, aqueous solutions of gibberellic acid[3] prepared with the aid of ethyl alcohol and liquid detergents, as suggested by Marth, Audia, and Mitchell (2) were used in concentrations of 100 p.p.m., 500 p.p.m. ad 1,000 p.p.m. A few beets were treated with a .1% gibberellic and lanolin base paste. The spray material was applied as a foliar spray, sufficiently to moisten the upper surface of the sugar beet leaves, but directed mainly onto the central new leaf growth. Hand application of the lanolin base paste material was made as near the growing point as possible.

Seed Field Studies

Small areas of commercial beet seed fields were sprayed by personnel of West Coast Beet Seed Company near Salem, Oregon. A foliar spray of 1,000 p.p.m. gibberellic acid was applied November 2, 1956, to sugar beets two to three months old. A total of 700 feet of beet row was treated including several fields and varieties while they were still growing quite rapidly. No severe freezing had occurred before the beets were treated.

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[2] Numbers in parentheses refer to literature cited.

[3] The gibberellic acid used in these studies was furnished, as experimental samples, by Merk and Company, Rahway, New Jersey, and by Eli Lilly and Company, Indianapolis, Indiana.

Observations on January 30, 1957, showed larger, more erect leaf foliage on the November 2, 1956, gibberellic acid treated areas in relation to non-treated areas in all varieties compared. At this time it appeared possible that gibberellic acid applications in the fall could help over-wintering sugar beets by producing a heavier foliage for cover during severe freezing. However, by March 22, 1957, observations on the areas treated November 2, showed from 75 to 95 percent of the beets to be dead, apparently from freezing injury. The older beets appeared to be damaged less than the younger beets. One of the dead beets showed the remains of a three-inch seed stalk. Evidently, the 1,000 p.p.m. concentration foliar spray of gibberellic acid in November had prevented the beets from hardening off and the beets winterkilled severely.

On January 29, 1957, over 30 inbred and commercial varieties of beets were treated with a 1,000 p.p.m. concentration of gibberellic acid as a foliar spray near Salem, Oregon, by Spreckels Sugar Company personnel. Twenty feet of row of each variety were treated. At this time, minimum night temperatures were about 8° F. to 10° F. above zero and daytime temperatures slightly above freezing. This weather lasted approximately one week, after which the ground and beets thawed, and the beets remained essentially dormant for a few weeks. With the spring rains and warmer temperature the beets resumed their normal development for seed production.

On March 22, 1957, another 1,000 p.p.m. foliar spray of gibberellic acid was applied to 20 feet of beet row. Application areas this time included 10 feet of row treated in January plus an additional area not previously treated. This arrangement gave three areas where the beets were treated differently with gibberellic acid plus an adjacent untreated area. These treatments were: 1. a 1,000 p.p.m. concentration of gibberellic acid applied January 29, 1957, 2. a 1,000 p.p.m. concentration of gibberellic acid applied January 29, and March 22, 1957, 3. a 1,000 p.p.m. concentration of gibberellic acid applied March 22, 1957, and 4. the untreated area.

A 500 p.p.m. concentration was compared with the 1,000 p.p.m. treatment on one very non-bolting variety on each treatment date using the same application design.

By March 22, 1957, definite petiole elongation and lighter color of top growth was noticeable in the areas treated in January. Also, short seed stalks were observed on 50 percent of the beets treated in January. No seed stalks were observed on any beets in the untreated areas.

Treatments of 1,000 p.p.m. gibberellic acid applied on January 29, and the double treated area of January 29 and March 22, induced a more uniform early seed stalk development than the untreated and the March 22 treated areas in one non-bolting variety. However, this difference became less apparent as the beet seed stalks developed.

In May 1957, two months after the last treatment of gibberellic acid was applied, no winterkilling was noticeable in areas treated in January or March or both nor in the untreated areas.

Seed stalks on every variety of beets indicated the photothermal induction period was sufficient for induction even in untreated areas. By May, no obvious differences between the treated and untreated areas were apparent. At no time was there a difference observed between the area treated with 500 p.p.m. and that treated with the 1,000 p.p.m. There were no more seed stalks produced and the seed stalks were no taller nor sturdier on any treatment than the untreated check at flowering.

From these studies, it seemed apparent that if fall planted sugar beets had sufficient thermal induction to develop seed stalks and produce seed the following spring, there was no advantage in the use of gibberellic acid to speed the flowering process. Some differences in seed stalk development between treated and untreated areas were apparent in March but these differences did not persist until harvest time.

Field Studies on Spring Planted Beets

Another test was designed to determine the effect of gibberellic acid on beets planted in early spring. If gibberellic acid would induce flowering without a thermal induction period it might be possible to obtain beet seed in a single crop year.

With this in mind, four varieties of beets representing a range in bolting characteristics were planted in Oregon in the spring (April 19, 1957). The following gibberellic acid treatments were applied to the foliage of each variety: 1. 100 p.p.m., 2. 500 p.p.m., 3. 1,000 p.p.m., all single treatments applied May 20, 1957, 4. 1,000 p.p.m. concentration on May 20, 1957, and again on June 10, 1957, 5. 1,000 p.p.m. concentration on June 10, 1957, and 6. the untreated check area.

On June 25, 1957, approximately two weeks after the last application of gibberellic acid, there were no seed stalks visible on any variety, whether treated or untreated, and the top growth expressed no visible vigor or color differences. Later the beets were removed but no seed stalks were ever visible on this planting.

Another experiment with gibberellic acid was conducted at Spreckels, California, in 1957, on beets of a slow bolting variety planted in December of 1956. Four concentrations of material (50 p.p.m., 100 p.p.m., 500 p.p.m., and 1,000 p.p.m.) applied as a foliar spray on two dates were compared with one untreated area. Each area consisted of two rows of beets ten feet long on forty-inch beds. This was replicated four times. Treatment dates were May 7 and May 22, 1957.

On July 16, 1957, observations showed no seed stalks on any beets in the untreated plots. The 1,000 p.p.m. treated area had two bolters in one replication and none in the other three replications. Treatments of 500 p.p.m., 100 p.p.m., and 50 p.p.m. showed one bolter each in one replication but no bolters in three other replications.

In the general field, there were a few scattered bolters indicating some of the seed stalks in the treated area could have been there also by chance and not induced by a gibberellic acid treatment. In any event, no evidence was discovered that would encourage further studies of attempting to produce seed on spring planted beets with gibberellic acid.

Gibberellic Acid Studies on Stecklings

In another test, three applications of a 500 p.p.m. concentration of gibberellic acid were made to the foliage of inbred stecklings[4] at Spreckels, California, in the spring of 1957. The stecklings were overwintered (1956-57) in a field plot in the same general area. The winter of 1956-57 was inadequate for inducing very slow bolting material to develop seed stalks. This inbred is relatively slow bolting.

Usually, in the Spreckels area the photothermal period is sufficient to induce seed stalk production in all beets of varieties considered intermediate and relatively easy bolting. However, extremely slowbolting varieties overwintered in this area are often not sufficiently induced to produce seed stalks on all plants. At the time this transplanting was made it was not known whether or not the photothermal period had been sufficient to induce seed stalk production on all beets.

Shortly after the stecklings had been transplanted, the nearly complete absence of seed stalks was apparent. The gibberellic acid material was applied first on April 30, 1957, followed by other treatments on May 7 and May 22, 1957, to every fourth beet in the plot. Beets were 12 inches apart in the row. As a

[4] As used in this paper, stecklings refer to relatively small beets transplanted from nursery or other overwintering plots into seed plots and mother beets refer to large beets selected individually for breeding use.

result of these treatments. 80 percent of the plants receiving gibberellic acid flowered and set seed while only 34 percent of the untreated plants set seed.

This would seem to indicate that in breeding material where the amount of natural thermal induction may not quite be sufficient to develop seed stalks, gibberellic acid may be of value in offering sufficient additional stimulus to make the beets bolt.

Greenhouse Studies

Greenhouse studies have included 500 p.p.m. and 1,000 p.p.m. concentrations of gibberellic acid in aqueous solutions and a .1% gibberellic acid lanolin base paste.

The .1% gibberellic acid lanolin base paste was used in the greenhouse on a paired plant experiment. It started in August 1956. Twenty beets from three varieties which had been growing in six-inch pots in the greenhouse for approximately four months were paired, by variety, for this experiment. Two varieties were much easier bolting than one relatively slow bolting variety. These plants had received two weeks of thermal induction at 40° F. The paired plants were kept in the greenhouse with controlled night temperatures of 65° F. Maximum day temperatures ranged from 60° F. to 75° F. Additional light was applied at night so the plants had nearly continuous light. Small globules of the .1% gibberellic acid in lanolin paste, about the size of a grain of wheat, were applied to the young growing points of one beet from each pair. The first treatment was applied on August 13, 1956, followed by a second application one week later.

Table 1 shows the plant pair numbers, variety, and length of seed stalk in inches, when present, for the gibberellic acid treated and untreated beets at four observation dates.

From Table 1, it can be observed that in pair number 6 the untreated beet produced a seed stalk before the treated one. Apparently, the small amount of thermal induction received was sufficient for this easy bolting strain. Table 1 also indicates seed stalk elongation had stopped after having started in some cases on the treated beets (No. 7 and No. 9). Also, all except two of the A5218 plants failed to flower and reverted to a vegetative condition finally. A distinctive rosette-type growth at the tops of the partially elongated seed stalk was produced. Successive treatment of the plants that reverted to a vegetative condition resulted in further elongation of the seed stalk. These plants would apparently deplete the stimulus for seed stalk development and revert to a vegetative condition until treated again

Table 1.—Paired Plant Comparisons Between Gibberellic Acid Treated (.1% in Lanolin Base Paste) and Untreated Plants in the Development of Seed Stalks.

Observation dates:		9/7/56 Length in Inches of Seed Stalk		9/20/57 Length in Inches of Seed Stalk		10/1/56 Length in Inches of Seed Stalk		10/31/56 Length in Inches of Seed Stalk	
Pair Number	Variety	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated
1	A5503**	8	1	16	8	20+	20+	flowering	flowering
2	A5218*	1	0	4	0	8	0	10	0
3	A5503**	1	0	6	0	14	0	18	0
4	A5218*	4	0	8	0	14	0	flowering	0
5	A5218*	3	0	6	0	14	0	flowering	10
6	A5526***	12	24	24	flowering	flowering	flowering	flowering	flowering
7	A5218*	1	0	3	0	8	0	8	0
8	A5218*	3	0	14	0	18	0	30+	0
9	A5218*	0	0	1	0	1	0	1	0
10	A5218*	1	0	4	0	8	0	12	0

* A very slow bolting variety.
** Intermediate bolting variety.
*** Easy bolting variety.

with gibberellic acid and in this manner the stems appeared to elongate by steps (see Figure 1). Some plants finally produced seed and others did not. In most cases in this experiment, the beets treated with gibberellic acid (.1% lanolin base paste) which developed seed stalks and produced flowers had distorted, twisted terminal growth, similar in appearance to burned tips or blasted buds from chemical or fertilizer burn, which greatly reduced the number of flowers produced and seed set. The seed set on these plants, however, appeared to germinate satisfactorily.

No noticeable distortions were observed on any of the untreated plants that produced stalks and set seed.

Figure 1.—Elongation characteristics of gibberellic acid treatment on very slow bolting beets. Beet on left ceased elongation after first treatment and second treatment made it resume its elongation. Beet on right received only one treatment.

Gibberellic Acid Studies on Mother Beets

During August of 1956, several mother beets that had overwintered and failed to develop a seed stalk were removed from the field breeding plots and transplanted into pots or beds in the greenhouse. It can be assumed that the thermal induction period was not sufficient to induce seed stalk production the following spring and summer on these beets and they should be considered very slow bolting. In 1956, the plan was to treat these plants with an artificial photothermal period to induce seed stalks in the greenhouse and use them in our breeding program. After the potted mother beets had been in the cold chamber for two weeks, they were placed in the greenhouse and kept as cool as outside temperatures would permit in a well ventilated greenhouse. Part of these beets were treated with a .1% gibberellic acid lanolin base paste and the others were treated with a 1,000 p.p.m. aqueous solution as a foliar spray. Two additional treatments consisting of 1,000 p.p.m. concentrations applied as foliar sprays were made at ten-day intervals. The number of plants developing seed stalks greatly exceeded the expected. This made possible the use of this material in all desired crosses well before the summer field breeding plot work began. In August of 1957, mother beets that had not produced seed stalks in an overwintered breeding plot were again selected and treated with gibberellic acid in an attempt to induce rapid flowering as in 1956. The desirable results of 1956 were essentially duplicated and the gibberellic acid treatment with some slight modifications is now considered to be standard procedure to increase the speed of flowering of breeding material of a very slow bolting nature in the greenhouse. The ability to more closely control the conditions in the greenhouse apparently contributes to the more satisfactory use of gibberellic acid in the greenhouse than the writers were able to demonstrate in the field.

Summary and Conclusions

Gibberellic acid was applied to sugar beets in field plantings and in the greenhouse. Field plantings of seedlings and stecklings were treated and the greenhouse studies included seedlings, stecklings and mother beets. The gibberellic acid was applied as a 0.1% lanolin base paste and as a 100 p.p.m., 500 p.p.m., and 1,000 p.p.m. aqueous solution. The lanolin paste was applied in quantities about the size of a grain of wheat smeared on the young growing points of the plant. The aqueous solutions were applied as sprays by wetting the young growing parts to dripping. General conclusions from these studies were:

1. If sugar beets overwintered for seed have had sufficient thermal induction to stimulate the beets to develop a seed stalk, no advantage was demonstrated by the use of gibberellic acid.

2. Where the thermal induction of beets appeared to be borderline or barely insufficient to induce the beets to develop seed stalks. it appears that gibberellic acid may be of some use in providing the additional stimulus for seed production.

3. Biennial beets could not be made into annuals by use of gibberellic acid under the conditions described in this paper.

4. In greenhouse studies where conditions can be more closely controlled, gibberellic acid appeared to be of advantage in speeding the flowering process on breeding material and, in this manner, aided in spreading the work load more evenly over a larger portion of the year.

5. The use of gibberellic acid in the form of a spray was more convenient to use and more rapidly applied than a lanolin base paste.

Literature Cited

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