Influence of Age and Supplemental Light On Flowering of Photothermally Induced Sugar Beet Seedlings[1]

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Photothermal induction of young seedlings by prolonged exposure to low temperature and artificial light (1,2,3)[3] is widely used in the United States to expedite sugar beet breeding work. However, the usefulness of this technique has been limited to some extent by a tendency toward reversal of induction where artificial light is not provided, as a supplement to sunlight, during the post-induction period. A striking illustration of this tendency was reported for seedlings removed from the induction chamber on August 2, 1951 (2). Similar results were obtained in a study involving seedlings of the variety GW359 transferred from the induction room into the open on July 21, 1959[4].

In the 1951 and 1959 comparisons, the induction treatment ended when days were relatively long but decreasing in length. In a 1960 study seedlings of two varieties were transferred from the induction chamber into the open on June 2, nearly 3 weeks before the longest day of the year[4]. Duration of the induction treatments were 8 and 14 weeks for GW359 and US 75, respectively. Final counts of flowering plants were made 12 weeks after the end of the induction treatment. In the GW359 population receiving continuous illumination during the post-induction period, 96% of the plants flowered. In the corresponding population receiving no supplemental light, only 53% flowered. For the bolting-resistant variety, US 75, comparable flowering percentages were 83 and 27, respectively. Each of these 4 percentages was based on a minimum population of 47 plants.

The 1959 and 1960 results left no doubt as to the need for supplemental light during the post-induction period under the conditions of the experiments. These results reinforced the tentative conclusion, reported for the 1951 investigations (2), that supplemental light tends to counteract the induction-reversing action of high temperature under such conditions.

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[3] Numbers in parentheses refer to literature cited.

[4] Unpublished results.

In connection with the breeding program at the Fort Collins station, induced seedlings have been used in several instances for production of seed in isolated locations where supplemental light was not available. In this undertaking an attempt was made to avoid the reversing effects of high temperature by earlier transfer of seedlings from the induction chamber to the field plots. The results were conflicting with respect to reversal and suggested the possibility that a relationship exists between the length of the pre-induction growth period in the greenhouse and the ability of a plant to flower when supplemental light is withheld throughout the post-induction period. In the experiments discussed in the preceding paragraphs the seedlings were quite young at the beginning of the induction treatment. Elapsed time from date of planting to the beginning of induction ranged from 9 to 14 days, and it was postulated that the need for supplemental light following the induction period was due in part to small plant size. The remainder of this report pertains to an experiment initiated in December 1960, primarily for the purpose of studying the relationship between the length of the pre-induction growth period and reversal.

Material and Methods

A bolting-resistant variety (US 75) and a variety having so-called "ordinary" bolting tendencies (GW359) were used in this study. Seed was planted in soil in 3-inch pots in the greenhouse, and the seedlings were thinned to 1 plant per pot soon after emergence. In the greenhouse, continuous illumination was provided, incandescent-filament lamps being used at night, and temperatures were maintained approximately as follows: 9:00 AM to 4:30 PM, 77°F.; 7:00 PM to 8:00 AM, 60°. For the photothermal induction treatment, the plants were held continuously at a temperature of about 45° (± 3°) with light supplied entirely by means of incandescent-filament lamps.

The basic experimental plan involved induction treatments of 13 weeks for US 75 and 9 weeks for GW359, exposures considered adequate for the respective varieties. These induction treatments were to end on May 4, 1961, the date set for transfer of the plants into the open. Planting of seed was timed to provide pre-induction growth periods in the greenhouse of 2, 4 and 7 weeks for each variety. In the induction room, treatments and varieties were randomized and precautions were taken to avoid detrimental plant competition. Comparable sets of control plants were produced by planting seed in the greenhouse 2, 4 and 7 weeks prior to May 4.

On May 4, representative plants of each treatment within each variety were transferred to 6-inch pots (2 plants per pot) and placed in location 1. This location (outdoors) was covered with 1/4-inch mesh wire screen for hail protection and was divided into 2 comparable sub-locations as follows: (a) supplemental light provided throughout each night by means of two 150-watt, incandescent-filament lamps approximately 3 feet above the pots; and (b) no supplemental light provided at any time. Treatments and varieties were randomized within each sub-location, and precautions again were taken to avoid detrimental plant competition between age groups. The pots in each sub-location occupied an area approximately 6 feet wide and 14 feet long.

Location 2 consisted of field plots on an outlying farm where no supplemental light was provided. A randomized-block experimental design was employed with liberal plant spacing. Seedlings were transferred to this location on May 9. Consequently, induction treatments, with respect to location 2, were 5 days longer

Figure 1.—Representative photothermally induced seedlings of the sugar beet variety US 75, 81 days after the end of induction treatment, showing the influence of age on reproductive development in a natural, long-day, post-induction environment without supplemental light. Each pot (size, 6-inch) contains 2 plants. The lengths of the pre-induction growth periods for plants in the 3 groups of 3 pots each, left to right, were 2, 4 and 7 weeks, respectively.

than indicated above. Likewise each set of control plants going into this location was 5 days older than originally planned.

Results

The appearance of foliage and seedstalks of US 75 in location 1-b, near the end of the study, is illustrated in Figure 1. Flowering percentages for all locations, together with information as to treatments and the number of plants in each population, are summarized in Tables 1 and 2.

As expected, none of the control plants of US 75 flowered. Control plants of GW359 flowered to some extent in locations 1-a, 1-b and 2, with a tendency toward higher flowering percentages among the older plants in each location, especially where supplemental light was not supplied. In this connection it is of interest that about one third of all GW359 plants of treatments 3 and 03 produced seedstalks that could be detected readily at the end of 7 weeks' growth under continuous illumination in the greenhouse.

The response of induced, potted seedlings to post-induction supplemental light may be summarized as follows: 1) In each variety, final flowering percentages for the respective age classes were consistently higher where supplemental light was supplied (location 1-a) than in the comparable location receiving no supplemental light (1-b), and the need for such illumination as a condition for flowering obviously was greater in US 75; 2) A tendency toward greater need for supplemental light by younger plants is indicated, especially in US 75 where final flowering percentages, in the absence of supplemental light (location 1-b), were 33, 50 and 67 for treatments 1, 2, and 3, respectively.

The relationship between age and the ability of induced plants to flower in the absence of post-induction supplemental light may be appraised further by inspection of the results obtained from location 2. Final flowering percentages for induced plants of GW359 in that location were confined to the range, 97 to 100, indicating negligible age effects. For comparable plants of US 75, on the other hand, the final flowering percentages for treatments 1, 2 and 3 were 66, 75 and 94, respectively. This strong trend in US 75, toward higher flowering percentages for older plants, is in agreement with the corresponding results obtained for that variety in location 1-b. Analysis of variance, combining these 2 sets of results, showed that the trend was highly significant. Flowering percentages for this material, 11 weeks after the end of induction, were about the same as at the conclusion of the experiment.

Table 1.—Effects of age and supplemental light on flowering of photothermally induced and non-induced seedlings of the sugar beet variety GW359, Fort Collins, Colo., 1961.

Location and conditions after transplanting			Induc.[a] time (days)	Trans-plant. date	Plant[b] age (days)	No. of plants	Treat-ment no.	Elapsed time after transplant. and cumulative % of plants flowering			
Loc. no.	Soil	Suppl. light						5 wks.	7 wks.	11 wks.	17 wks.
1-a	In pots	Nightlong	63	5/4	14	24	1	4	83	100	100
					28	24	2	21	75	100	100
					49	24	3	33	58	100	100
			0	5/4	14	12	01	0	0	33	33
					28	12	02	0	8	17	25
					49	12	03	33	33	33	42
1-b	In pots	None	63	5/4	14	24	1	4	50	88	88
					28	24	2	21	54	79	83
					49	24	3	21	38	92	96
			0	5/4	14	12	01	0	0	0	0
					28	12	02	0	8	8	8
					49	12	03	42	42	42	42
2	In field	None	68	5/9	14	31	1	3	74	90	97
					28	32	2	9	72	100	100
					49	32	3	22	91	100	100
			0	5/9	19	18	01	0	0	0	0
					33	18	02	22	28	28	28
					54	18	03	28	28	28	28

[a] Photothermal induction treatment ended on date of transplanting.

[b] Age at beginning of induction treatment for induced plants and age at time of transplanting for non-induced plants.

Table 2.—Effects of age and supplemental light on flowering of photothermally induced and non-induced seedlings of the bolting-resistant sugar beet variety US 75, Fort Collins, Colo., 1961.

Location and conditions after transplanting			Induc.[a]	Trans-	Plant[b]	No.	Treat-	Elapsed time after transplant. and cumulative % of plants flowering			
Loc. no.	Soil	Suppl. light	time (days)	plant. date	age (days)	of plants	ment no.	5 wks.	7 wks.	11 wks.	17 wks.
1-a	In pots	Nightlong	91	5/4	14	24	1	0	63	83	83
					28	24	2	0	58	88	88
					49	24	3	13	46	92	96
			0	5/4	14	12	01	0	0	0	0
					28	12	02	0	0	0	0
					49	12	03	0	0	0	0
1-b	In pots	None	91	5/4	14	24	1	0	21	33	33
					28	24	2	0	33	50	50
					49	24	3	4	29	67	67
			0	5/4	14	10	01	0	0	0	0
					28	12	02	0	0	0	0
					49	12	03	0	0	0	0
2	In field	None	96	5/9	14	32	1	9	47	66	66
					28	32	2	16	53	72	75
					49	32	3	6	63	94	94
			0	5/9	19	17	01	0	0	0	0
					33	18	02	0	0	0	0
					54	17	03	0	0	0	0

[a] Photothermal induction treatment ended on date of transplanting.
[b] Age at beginning of induction treatment for induced plants and age at time of transplanting for non-induced plants.

Discussion

It seems probable that the consistently higher final flowering percentages for the induced plants of each variety in location 2, as contrasted with those for the corresponding material in location 1-b, were due in part to the fact that the plants in location 2 had received slightly longer induction treatments. However, the magnitude of the differences in the case of US 75 suggests that other factors also were involved. In this connection it should be pointed out that the seedlings in location 2 were in field plots whereas those in 1-b were in 6-inch pots. The pots were placed on a hard surface without soil or other packing material between them and were spaced so as to avoid unfair competition between treatments. With the resultant exposure of the pots to sunlight, it is assumed that the daytime temperature of the soil in the vicinity of the crown and upper part of the taproot tended to be higher in the pots than in the corresponding places in the field. Such a temperature difference may have contributed somewhat to the observed contrast between locations 1-b and 2 in degree of flowering.

The results presented in this report indicated rather conclusively that, under conditions such as those prevailing in this experiment, the length of the pre-induction growth period is positively correlated with the ability of induced seedlings of some sugar beet varieties to flower in a natural, long-day, post-induction environment without supplemental light. The nature of this relationship is not clear, and further investigation seems desirable before an explanation is proposed. However, the knowledge that such a relationship exists should be of assistance to those using the seedling photothermal induction technique as a sugar beet breeding tool.

Summary

Seedlings of each of 2 sugar beet varieties were given starting periods in the greenhouse of 2, 4 and 7 weeks followed by photothermal induction treatments (continuous exposure to low temperature and artificial light) considered adequate for the respective varieties. Timing was such that by May 4, 1961, the plants of GW359 and US 75 had received 9 weeks' and 13 weeks' induction exposure, respectively. On that date, representative seedlings were transplanted in pots in the open. Five days later the remaining plants were transplanted directly in field plots. Half the potted plants of each variety and age class were provided with continuous illumination during the post-induction period. None of the other plants received supplemental light during that

time. Comparable sets of non-induced plants were maintained as controls.

Results were evaluated on the basis of percentage of plants flowering in each population within 17 weeks after the end of the induction treatment. Two conclusions with respect to conditions similar to those prevailing in this study are of special interest: 1) The tendency of young, photothermally induced, sugar beet seedlings to revert to the vegetative phase in a natural, long-day, post-induction environment without supplemental light, apparently varies with variety; and 2) this reversal tendency can be reduced substantially in some bolting resistant material by an increase of several weeks in the length of the pre-induction growth period.

Literature Cited

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