ANNUAL SEED GROWING OF BEETS [1]

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Summary

1. The promotive effect that low temperature and long day are known to have on the flowering of beets was studied in order to develop a practical method of seed production in one year.

2. The natural cold affecting plants sown in the second or third week of January in frames (kept slightly above 0° C) had a stronger flower-promoting effect than artificial seed vernalization at 1° C for six weeks.

3. Supplementary light extending the photoperiod to 24 hours markedly increased the number of good seed plants. A night interruption of two hours produced similar effects but was less pronounced.

4. Early sowing and application of supplementary light until transplanting increased the percentage of good seed plants in two varieties of garden beets to 96–100 %. In a sugar beet and a fodder beet the percentage of good seed plants was lower.

5. In the latter two varieties the number of good seed plants could be increased to 92–98 % when before early sowing and continuous illumination the germinating seed was vernalized at 1° C in the refrigerator for six weeks.

6. When very strong doses of cold and light were given the number of good seed plants increased to a maximum, but the average yield of seed per plant was much lower than in groups less strongly vernalized.

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Introduction

The beet belongs to a group of plants in which flowering can be strongly influenced by environmental conditions. By close control of the latter flowering may be promoted to the extent that the cultivated varieties, all of which are biennials under normal conditions, pass through the whole of their development within one year. If this could be applied in practice it would have the following advantages for breeding and seed growing:

a breeding programs could be speeded up considerably, while stock seed could be augmented rapidly;

b for one crop of seed the land would be used for only one growing season, instead of two;

c the roots would not have to be pitted during winter (with ensuing loss by freezing or rotting in cold or mild winters, respectively);

d the seed plants would no longer be in their second year a source of contamination of "beet yellows".

On the other hand, this method has the following disadvantages:

a selection for root characters is not possible (this disadvantage may, to an extent, be met by growing a biennial crop simultaneously or alternately);

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b there would be no possibility to recognize and discard the unwanted annual forms that occasionally arise in the cultivated varieties;

c costs of chilling treatments, illumination and extra labour have to be subtracted from the financial gains of the advantages.

Among the environmental conditions governing flowering, temperature and light are by far the most important. In order to flower the beet requires a period of low temperature (5 to 7° C being about optimal) acting upon the growing tip, and a long photoperiod perceived by the leaves. High temperature and short day are not only unfavourable for flowering but to a certain extent will undo the flower-promoting effect of previous cold and long day (CHROBOCZEK, 1934, VOSS, 1936, 1940, OWEN, CARSNER & STOUT, 1940, BELL, 1946, STOUT, 1946).

In previous papers (WELLENSIEK & VERKERK, 1950, WELLENSIEK, 1952) we discussed the possibilities of practical application of these facts. In an experiment conducted in 1948 plants were vernalized by a cold treatment of the germinating seed, which was subsequently sown either in the field or in open frames. In the latter case half of the plants were given additional light extending the daily photoperiod to 16 hours. After two months the plants from the frames were transplanted to the field; from then on all received natural daylight only. Some of the results were: (a) supplementary light strongly promotes bolting but this effect decreases as the duration of the cold treatment is increased; (b) transplanting reduces and delays bolting, but this unfavourable effect disappears when supplementary light is given. In the 1949 experiment, also discussed in our previous paper (WELLENSIEK & VERKERK, 1950), a cold spell in March when the plants were in open frames overruled the effects of artificial seed vernalization, leaving only the effect of supplementary light.

These results led us to the experiments to be discussed here in which we studied (a) the effect of the natural winter temperature as compared to six weeks artificial cold, (b) the effect of six weeks artificial cold prior to early sowing, and (c) the effect of supplementary light interrupting the night or extending the photoperiod to 24 hours, as compared to natural day.

When judging the experimental results one should bear in mind that only those treatments have practical possibilities that yield close to 100 % good seed plants. In practice varieties are needed that are slow to bolt and one should take care lest a method of one year seed growing should become a selection of plants that bolt easily. That occasionally a plant occurs that does not bolt is not of great importance; such plants (called in Dutch "trotsers", meaning "defiers") are also found when the ordinary method of seed growing is followed.

MATERIAL AND METHODS

Four varieties of beets were used in the present experiments: "Egyptische Platronde" and "Noord-Hollandse Bleekblad", both red garden beets, "Kuhn P", a sugar beet, and "Groenkraag C.B.", a fodder beet. As the beet is a cross-pollinator these varieties are not homozygous, so their composition may vary somewhat from year to year.

The 1951 experiment, the results of which are summarized in Table 1, used

PHOTO 1. RED GARDEN BEET "EGYPTISCHE PLATRONDE", SOWN OUTSIDE JAN. 12TH 1951, PHOTOGRAPHED IN JULY. Above : natural daylight ; middle : interrupted night until transplanting ; below : continuous light until transplanting on May 9th.

all four varieties. Treatments started on January 12th and January 29th 1951; they were identical for each date. The seed was washed and soaked in water at 12° C for 24 hours. Half of it was sown in frames, the other half was kept in the refrigerator at 1–2° C and high humidity for six weeks, after which it was sown in the same frames. One set of plants received natural daylight only. Another was irradiated during the night for two hours, from 11 P.M. to 1 A.M., with a light intensity of 150–500 Lux. The third set was irradiated from sunset to sunrise with the same intensity, thus receiving a photoperiod of 24 hours. As the 1949 experiments had shown that the more the seedlings have been vernalized the more sensitive they are to frost, the frames were electrically heated when necessary to keep them slightly above 0° C. On May 9th, 100 plants of each of the 48 groups (see Table 1) were transplanted to the field where all plants received natural day.

In the 1953 experiment, the results of which may be found in Table 2, only "Kuhn P" and "Groenkraag C.B." were used. There were three sets of treatments, started on December 10th and 22nd 1952, and January 7th 1953, respectively, but otherwise identical. The seed was washed and soaked in water at 30° C for two hours, dried in air of the same temperature, moistened again and kept at 30° C for 24 hours. Subsequently it was put into the refrigerator where it was kept at 1° C for six weeks. After that period, that is, on January 21st, February 2nd and February 18th 1953, respectively, this seed was sown in frames together with seed that had not been vernalized but had only been induced to germinate at 30° C as described above. Again one group of plants received natural day only, while the other was illuminated by incandescent lamps of 50 Watts from sunset to sunrise. The frames were kept slightly above 0° C. On April 28th, 100 plants of each of the 24 groups (see Table 2) were transplanted to the field under natural conditions (compare photo 2).

PHOTO 2. GENERAL VIEW OF 1953 EXPERIMENT ON MAY 29TH, 31 DAYS AFTER THE PLANTS HAD BEEN TRANSPLANTED TO THE FIELD.

RESULTS

In the 1951 experiments the number of plants that showed signs of bolting was noted every week from May 16th to September 26th. The number of bolters increased during the whole of this period, especially in the groups insufficiently vernalized. However, plants that flower late in the season are worthless as seed producers. Therefore, in Table 1 not the number of bolters is given, but the percentage of good seed plants. In general, these are plants that bolted before July.

Table 1. Percentage of good seed plants in 1951 in 4 varieties, vernalized either in frames or in the refrigerator and receiving natural day (n.d.) or supplementary light interrupting the night for two hours (i.n. = interrupted night) or extending the photoperiod to 24 hours (c.l. = continuous light).

1	2	3	4	5	6	7	8	9	10	11	12	13
Variety	Started on Jan. 12th						Started on Jan. 29th					
	natural vernal.			6 weeks at 1°			natural vernal.			6 weeks at 1°		
	n.d.	i.n.	c.l.	n.d.	i.n.	c.l.	n.d.	i.n.	c.l.	n.d.	i.n.	c.l.
"Eg. Platronde" .	88	97	100	85	90	100	86	98	96	63	64	91
"N.H. Bleekbl." .	86	95	96	69	81	92	72	98	98	41	64	67
"Kuhn P"	67	85	82	32	46	78	58	61	84	23	22	45
"Groenkraag" . . .	68	88	95	33	53	57	51	72	91	9	11	31

The results may be summarized as follows. It is obvious that the effect of natural low temperature surpasses that of 6 weeks artificial cold. As could be expected, plants sown on January 12th (columns 2–4) have been more strongly vernalized than those sown 17 days later (columns 8–10), but even in the latter case the effect has clearly been stronger than that of artificial vernalization (columns 11–13). A comparison of columns 5–7 with 11–13 shows that plants artificially vernalized from January 12th to February 23d have been markedly influenced by the natural cold after sowing.

Continuous light (columns 4, 7, 10, 13) has a stronger flower-promoting effect than interrupted night (columns 3, 6, 9 12) although the latter also markedly promotes flowering as compared to natural day (columns 2, 5, 8, 11). The relative effect of additional illumination is strongest when the vernalization by cold has been inadequate (columns 11, 12 and 13, and the figures for "Kuhn P" and "Groenkraag C.B." in general).

The figures given here show that the percentage of good seed plants after early sowing is satisfactory in garden beets (96–100 %), but in the fodder beet "Groenkraag C.B." it is less favourable (95 %, but in one treatment only), and in the sugar beet "Kuhn P" it is unsatisfactory (82 %).

In view of this in 1953 a second experiment was conducted with these two varieties in which three groups sown at different dates were compared with three groups which had been exposed to 1° C for six weeks *before* being sown at the same dates. The effect of continuous light again was studied. (Further technical data have been given on (p. 101)). The results have been summarized in Table 2.

A comparison of the columns 2, 6, 10 and 3, 7, 11 with the corresponding columns 4, 8, 12 and 5, 9, 13 shows that a period of artificial seed vernalization before early sowing increases the number of seed plants to a level that is satisfactory in "Kuhn P" and promising in "Groenkraag C.B.", at least in continuous light. Some results of earlier experiments have been confirmed, viz. (a) the earlier the seed is sown, the better, (b) continuous light has a strong promotive effect on bolting and (c) the relative effect of light is most pronounced when the cold treatment has been insufficient (photos 2 and 3).

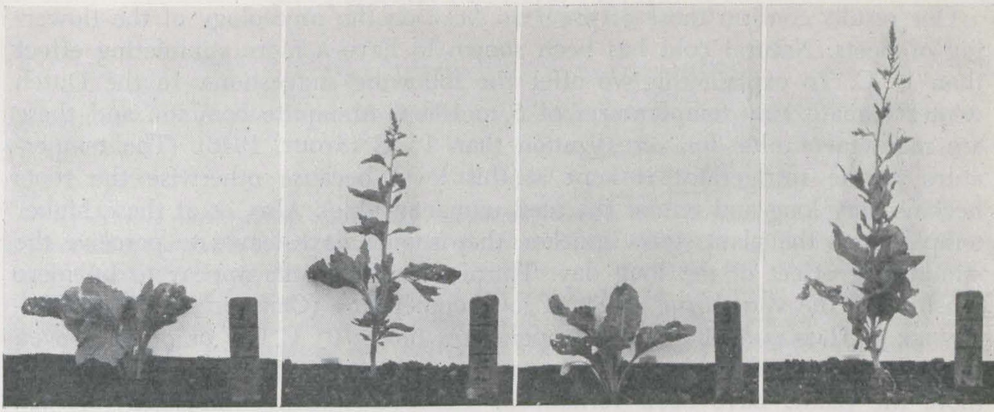

PHOTO 3. FIRST PLANT OF EACH OF THE FIRST FOUR ROWS ON PHOTO 2. From left to right (1) control, (2) continuous light until transplanting, (3) 6 weeks artificial seed vernalization prior to sowing, (4) both artificial seed vernalization and continuous light.

Table 2. Percentage of good seed plants and average yield of these in grams in 1953 in 2 varieties, sown either directly in frames (nat.) or treated at 1° C for 6 weeks previously (art. + nat.) and subsequently treated with natural day (n.d.) or continuous light (c.l.).

1	2	3	4	5	6	7	8	9	10	11	12	13
	Sown on Jan. 21st				Sown on Feb. 2nd				Sown on Feb. 18th			
	nat.		art. + nat.		nat.		art. + nat.		nat.		art. + nat.	
	n.d.	c.l.	n.d.	c.l.	n.d.	c.l.	n.d.	c.l.	n.d.	c.l.	n.d.	c.l.
% good seed pl.												
"Kuhn P"	78	98	91	98	51	88	72	96	17	64	75	91
"Groenkraag C.B."	40	87	62	92	28	56	60	88	7	26	48	90
yield p. pl. in g.												
"Kuhn P"	125	106	124	51	108	118	138	86	73	99	142	149
"Groenkraag C.B."	125	80	94	62	74	117	79	80	51	88	133	90

A noteworthy effect is that very strong doses of cold and supplementary light tend to reduce the average yield of seed. This is especially striking in column 5 where continuous light and very early sowing have raised the number of good seed plants to a maximum but simultaneously reduced the yield per plant to a minimum.

DISCUSSION

In our series of experiments (1948, 1949, 1951 and 1953) the general tendency has been to treat the plants with a longer period of cold and a longer photoperiod by which an increasing percentage of good seed plants has been obtained. In red garden beets the % of good seed plants in 1948 (9 weeks 1° C, sown March 9th, 16 hours of light until transplanting) was about 18 %, in 1949 (sown Feb. 15th, natural cold, continuous light until transplanting) 48 and 25 % and in 1951 (sown Jan. 12th, natural cold (but no frost), continuous light until transplanting) 96 and 100 % in "Egyptische Platronde" and "Noord-Hollandse Bleekblad", respectively. For the sugar beet "Kuhn P" and the fodder beet "Groenkraag C.B." it was 17 and 14 % in 1949, 82 and 95 % in 1951, and 98 and 92 %, respectively, in 1953 (6 weeks 1° C prior to sowing on Jan. 21st, natural cold (but no frost), continuous light until transplanting).

Our results confirm those of previous work on the physiology of the flowering of beets. Natural cold has been shown to have a more stimulating effect than 1° C. To explain this we offer the following suggestions. In the Dutch winter climate, day temperatures of 5 to 10° C are quite common and these are more favourable for vernalization than 1° C (STOUT, 1946). (The temperature in the refrigerator is kept at this level because otherwise the roots become very long and render the seed unmanageable). Also, as at these higher temperatures the plants grow quicker, they sooner have leaves to perceive the stimulating effect of the long day. Thirdly, bigger plants appear to be more sensitive to the vernalizing effect of low temperature (CHROBOCZEK, 1934, WELLENSIEK & HAKKAART, 1954). At temperatures below 0° C less or perhaps even no vernalization takes place. Moreover, as our 1949 experiment has shown, the more the plants have been vernalized, the more sensitive they are to frost. This disadvantage of the natural climate has been removed in the 1951 and 1953 experiments by keeping the frames slightly above 0° C.

Continuous light appeared to have a stronger flower-promoting effect than a photoperiod of 16 hours or interrupted night. In the latter case, the 2 hours of artificial illumination probably could have been applied directly after night fall with just as much effect.

A few more experimental results may be stressed that are of special importance when practical application of the methods described here is considered. In the first place plants should not be "over-vernalized". If the doses of cold and light have been too strong, plants form their inflorescences before a sufficient number of leaves has been laid down to furnish the assimilatory surface necessary for a normal amount of seed (photo 1). However, especially in the case where the method is used to speed up breeding programs, this need not be a serious disadvantage because a small number of seeds is usually sufficient. From a given area the same amount of seed may be harvested when the plants are put closer together in the field.

Secondly, the effect of continuous illumination increases as the duration of the cold treatment is decreased. Therefore, the later the seed is sown, the greater the necessity to supply a 24 hour photoperiod.

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