THE EFFECT OF DAYLENGTH, GIBBERELLIN, SEEDVERNALIZATION AND THEIR INTERACTION ON SPINACH[1])

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SUMMARY

In the two spinach varieties "Breedblad Scherpzaad Zomer" and "Koning van Denemarken" the effects of daylength, gibberellin and seedvernalization on the length-growth of the stem were studied. Also the combined effect of these factors was investigated. For the bolting in spinach the long day is of primary importance. The effect of each of the three factors separately is the strongest, combined with each other the effect of each is diminished.

A possibility for vegetative propagation on a small scale is mentioned.

INTRODUCTION

Vernalization has a weak effect on the bolting in spinach, but long day has a strong promoting effect. Gibberellin shows its most striking effect on the length-growth of stems, which can be increased enormously. It seems interesting to study the interaction between these three factors working directly or indirectly on the length-growth of the stem.

MATERIAL

Two spinach varieties, with striking differences have been used:

1 "Breedblad Scherpzaad Zomer" (BSZ), fast bolting in the long days during summer. Vegetative growth in short day is satisfactory, so this is a good variety for spring and autumn. The leaves are lighter green than those of "Koning van Denemarken".

2 "Koning van Denemarken" (KvD), slow bolting during summer and bad growing in short days, so a good variety in summer.

DESCRIPTION OF EXPERIMENTS

Experiment I

Seeds were put on wet paperfilter at room temperature till visible germination. Then they were kept during 0 days (–V) or 15 days (+V) at 2° C. Visible germination was used to be sure that the low temperature could act on the growing plant.

The germinated seeds were sown in pots on Februar 20 in a glasshouse, in the beginning with a mean temperature of 15° C, later increasing till 20° C.

Two compartments were used (fig. 1), both with strong light of 120 W/m^2 fluorescent lamps to get better growth during the dull weather of Februar

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and the beginning of March. These lamps were 50 cm above the plants and burned during the short day (—LD) period of 9 hours. The long day compartment (+LD) had accessory light for 10 hours with weak incandescent lamps. The temperature was about the same in both compartments.

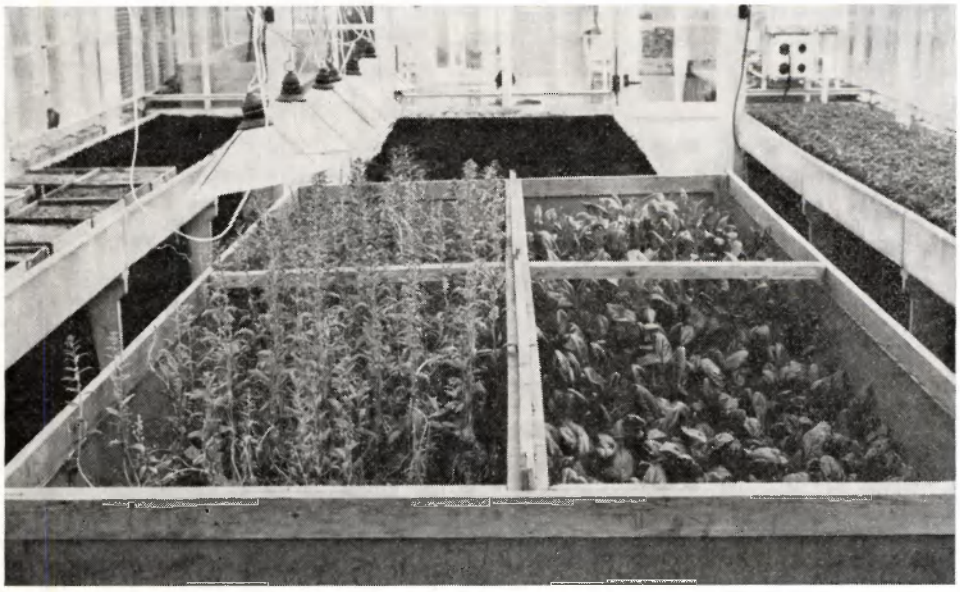

FIG. 1 VIEW OF EXPERIMENT I, +LD TO THE LEFT, —LD TO THE RIGHT IN WHICH —GA IN FRONT, +GA AT THE END.

On March 17, at the time that most of the plants had 3 true leaves and the first bolters were just visible in the long day group, the first spray with gibberellin 500 ppm took place (+GA). After two weeks a second spray followed. Water spray was used as a control (—GA).

In this way the 16 following objects were formed:

BSZ	—V	—GA	—LD	KvD	—V	—GA	—LD
BSZ	+V	—GA	—LD	KvD	+V	—GA	—LD
BSZ	—V	+GA	—LD	KvD	—V	+GA	—LD
BSZ	+V	+GA	—LD	KvD	+V	+GA	—LD
BSZ	—V	—GA	+LD	KvD	—V	—GA	+LD
BSZ	+V	—GA	+LD	KvD	+V	—GA	+LD
BSZ	—V	+GA	+LD	KvD	—V	+GA	+LD
BSZ	+V	+GA	+LD	KvD	+V	+GA	+LD

Mostly the objects contained 25—30 plants each. Eleven and 36 days after the first GA spray the plants were measured and the lengths studied (fig. 2, upper part). Three days after the first spray, lengths and widths of the leaves of all plants in the —LD treatments were measured, which gave an estimation of the vegetative crop, since a correlation of +0,949 was found between the weight of a plant and the surface of the leaves.

Experiment II

In this experiment during summer in a glasshouse only –LD treatments were present with 8 hours of light per day. A control and one week vernalized seeds were put into pots, 20 to 30 plants in each treatment. Figure 2 gives the results of the lengths measurements. In this experiment GA 50 ppm was given in drops in the heart of the plants every other day. In the 98 days of the experiment plants did not flower.

Experiment III

Most of the third experiment was done outside. Seeds as in experiment II were put in pots on two lorries from which one was outside in the daylight for 8 hours a day and in a dark shed for the remaining 16 hours (–LD). After having been outside for 8 hours, the other lorry was moved into a shed with supplementary 8 hours of weak light from incandescent lamps (+LD). Starting 18 days after sowing (July 22), GA was given as in experiment II. The –LD plants were much darker green than the +LD plants and had broader and sturdier leaves too. In the +LD treatments the first bolter was found three weeks after sowing.

The same 16 treatments occurred as in experiment I, but in this case there were 4 blocks and only 12–24 plants per object. The temperature becoming too cold outside, the plants were moved into the glasshouse on September 29, where the –LD treatments received the natural daylength of 11 hours, decreasing fast in this time of the year however.

Length-measurements are given in graph III of figure 2. On August 27, so 5 weeks after sowing, the –LD plants had to be thinned; at that time the weights of half of the plants were determined.

LENGTH-MEASUREMENTS

In experiment I only two readings were made, in the two other experiments measurements were regularly taken about once a week. Figure 2 gives the combined results.

On graphs I and III the enormous positive effect of the long day is clearly shown. The daylength is the most important factor in bolting of spinach. In III also the difference in bolting in the two varieties is to be been, BSZ bolting much faster than KvD. In the +LD treatment GA sometimes has a little positive, sometimes a small negative effect. The effect of GA in long day in which the plants are bolting relatively fast, is on a whole very small.

The effect of the seedvernalization in the long day is in three out of four cases positive and in III the difference between +V en –V is a rather large one, while the slow bolting variety KvD in long day is influenced by seedvernalization much more than the fast bolting variety BSZ.

Summarizing: in long day fast bolting occurs and the effects of +GA and +V are relatively small.

In the short day treatments the results are much more striking. The –LD has a retarding effect on the bolting and the effects of +GA and +V are more pronounced here than in the +LD treatment.

In all the experiments the +GA treatments have a larger effect than the corresponding –GA treatments. The +V treatments are higher than the cor-

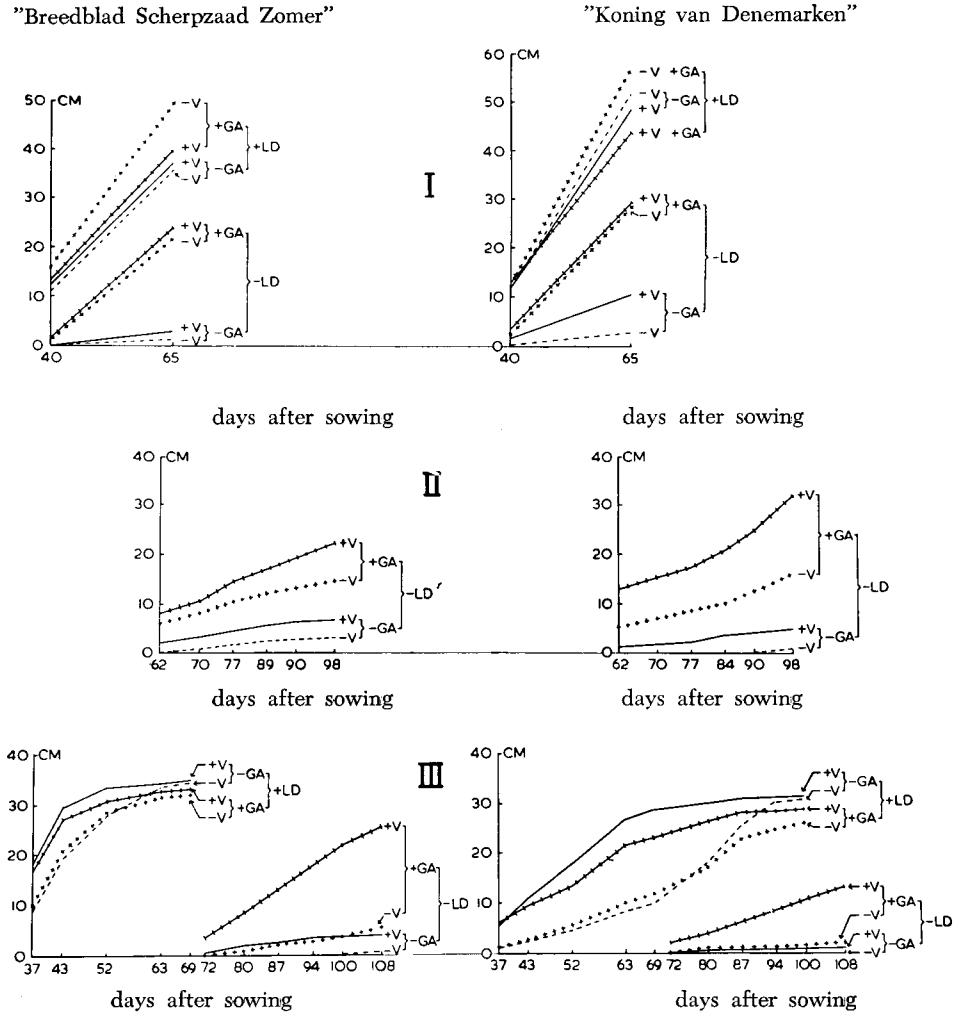

FIG. 2 LENGTHS OF PLANTS FROM THE DIFFERENT TREATMENTS IN EXPERIMENTS I, II AND III.

responding –V treatments and the differences increase with better growing conditions from experiment I to III, and the longer the plants stay vegetative. So the effect of the seedvernalization shows up after two months of vegetative growth in short days (III). The effect of +V is again greater in KvD than in BSZ. In strong plants (experiment III) under short day conditions it is necessary to combine +GA and +V to get an appreciatable bolting, while in weak plants (experiment I) +GA alone has a remarkable effect already. In general the effects of the different factors in III are more regular than in I, which will be the result of stronger plants and perhaps of the higher temperatures.

Table 1 shows the effect of a +treatment in relation to the corresponding –treatment. For instance, in experiment I 65 days after sowing the stemlengths of BSZ+L–GA–V together with KvD+L–GA–V divided by those of BSZ–L–GA–V together with KvD–L–GA–V results in 21.0. It shows that

Table 1 Relative effects of +LD, +GA and +V separately and in combinations in comparison to the control of each factor or combination.

Experiment	I	II	III+LD	III—LD
Days after sowing	65	77	52	108
Treatment				
+LD—GA—V/—LD—GA—V	21.0			
+LD—GA+V/—LD—GA+V	6.4			
+LD+GA—V/—LD+GA—V	2.1			
+LD+GA+V/—LD+GA+V	1.6			
+GA—LD—V/—GA—LD—V	12.2	11.7		14.2
+GA—LD+V/—GA—LD+V	3.9	4.6		8.6
+GA+LD—V/—GA+LD—V	1.2		1.0	
+GA+LD+V/—GA+LD+V	1.0		0.9	
+V—LD—GA/—V—LD—GA	3.1	4.3		9.0
+V—LD+GA/—V—LD+GA	1.0	1.7		5.5
+V+LD—GA/—V+LD—GA	1.0		1.6	
+V+LD+GA/—V+LD+GA	0.8		1.4	

as more factors are influencing the length-growth, the effect of each individual factor is relatively smaller.

Figure 3 illustrates some of these effects.

Yield of vegetative crop

Three days after the first GA spray or 30 days after sowing in experiment I the vegetative crop of the —LD treatments was estimated. The results were BSZ/KvD=16/14, +V/—V=13/17 and +GA/—GA=14/16. The last fact is rather strange since it is claimed that GA would stimulate vegetative growth.

In experiment III the vegetative crop in —LD treatments 38 days after sowing give the following results: BSZ/KvD=20/17, +GA/—GA=20/17. The effect of seedvernalization was not clear.

Discussion

In seedgrowing of spinach a rapid lengthgrowth of stems before flowering is needed. During summer the days are long enough (2, 4). Artificial vernalization is not necessary, nevertheless some natural vernalization after sowing in spring, when temperatures are much lower than in summer, may have its effect, especially in varieties like "Koning van Denemarken".

A strong effect of seedvernalization on bolting was found by Junges (1), who worked during winter with weak extra light in the night. With shorter days the effect of artificial or natural vernalization is more pronounced; with longer vernalization the critical daylength for bolting decreases (3, 5).

Gibberellin promotes stemgrowth the stronger, the less favourable the other factors for bolting are, so in short day and without vernalization (6, 7, 8, 9). Zeevaart (8) says that GA promotes flowering mostly in those cases in which bolting and flowering are closely connected and in which cold or at least long days are necessary for bolting. While in long day the effect of GA was almost absent, in short day the GA was essential for bolting (7).

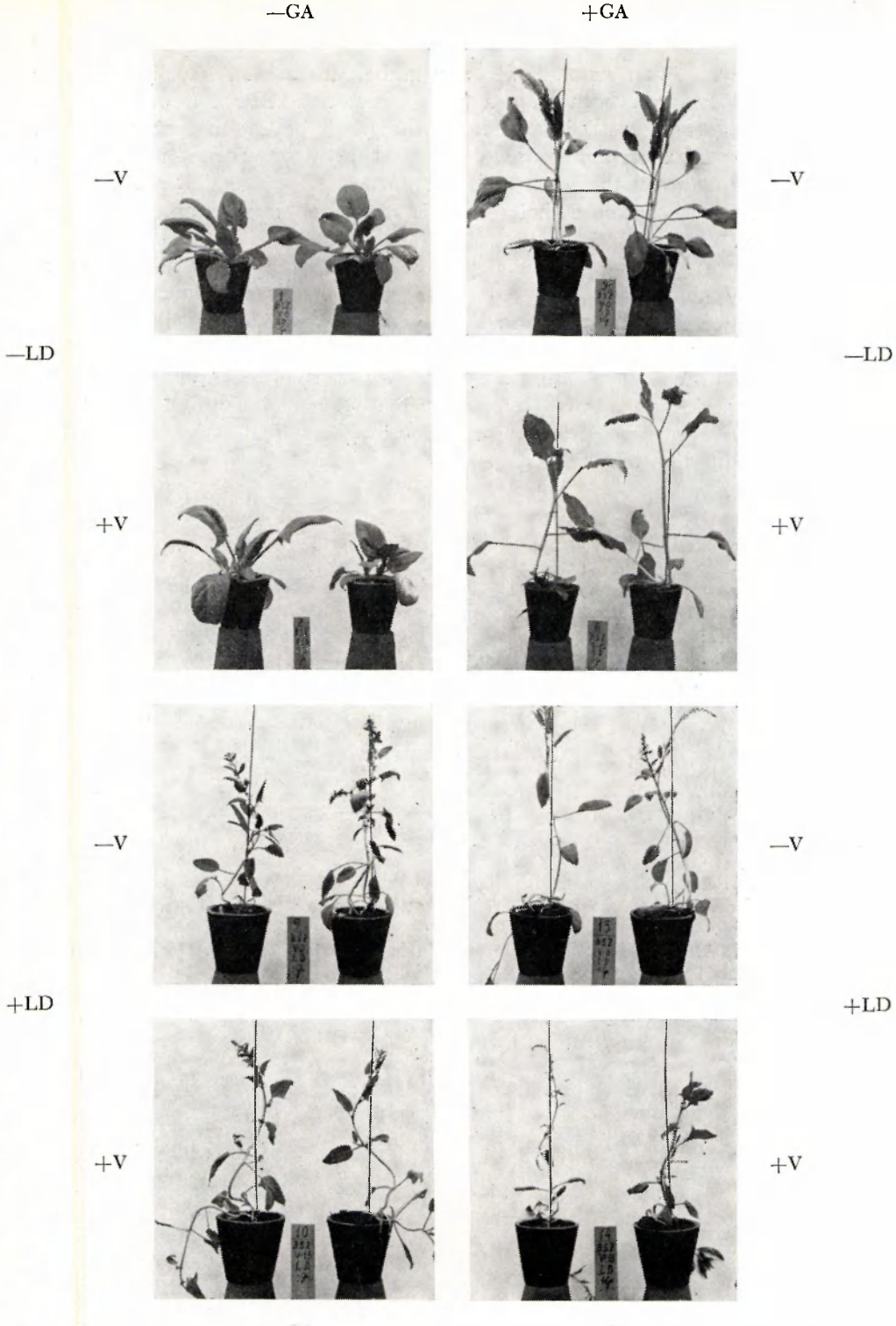

FIG. 3 EFFECTS OF DAY LENGTH, GIBBERELLIN AND VERNALIZATION ON THE VARIETY "BREEDBLAD SCHERPZAAD ZOMER" IN EXPERIMENT I. PHOTO —LD TAKEN ON APRIL 15, +LD ON APRIL 3.

In long days neither vernalization nor gibberellin has an important effect; in short days however both have a good effect and their combination even has the strongest effect. The effects of the three bolting inducing factors: long day, vernalization and gibberellin, are hardly to separate in this case. All three factors show the greatest effect if they are present alone. The less effective they are, the more their effect is stimulated by one or more of the other factors.

Gibberellin is said to promote vegetative growth in spring and autumn at relatively low temperatures. In our experiments however temperatures were rather high and the effect of gibberellin was not clear.

After a strong vegetative growth in short days gibberellin can stimulate the formation of a slowly bolting heavy stem. This stem looks suited for vegetative reproduction on a small scale. Cuttings were made during winter and some of them even rooted, but they did not stay alive. It seems worth while to continue this line of work.

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