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Rhythmic growth phenomena in brussels sprout plants [1]

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Summary

Bud cuttings were taken at regular intervals from brussels sprout plants grown under different environmental conditions. The cuttings were rooted in peat moss, transplanted and grown under controlled conditions (16 hours fluorescent light and 17 °C in an air conditioned room). At an age of 12 weeks after striking lengths of plants were measured. A marked periodicity in growth was observed with maxima (normal growth) and minima (retarded growth) 8 to 16 weeks apart. Differences in plant lenghts varied between 1 and 9 cm. The cause of these phenomena was considered to be endogenic. The observed rhythmic phenomena do not occur during normal cultivation.

Introduction

The growth habit of brussels sprout plants can be divided into two phases. Seeds are normally sown in March to May and the young plants are planted on the field in June or July. In the first part of the season tall, erect stems with big leaves develop in a rather short time. In the second part, however, growth of both the stem and of the axillary buds (sprouts) is retarded leading to a compressed sprout head (formerly used as a kind of kale) and to more or less compact sprouts (nowadays a popular and well paid vegetable). This change in growth pattern has been analysed earlier (Kronenberg, 1971). It was found that growth retardation started in July with a maximum in the middle of August. In the last part of the growing season less favourable conditions limited growth. These results led to further research in the years 1970-1973.

Two different lines of throught were followed:
1. Do leaves or gibberellic acid have any influence?
2. What are the influences of environmental conditions?

It was shown (Kronenberg, 1973) that defoliation strongly decreased the growth retardation for which some activity of the leaves was assumed to be the cause. Effects of defoliation were most pronounced in the beginning of August exactly at the moment of the strongest retardation. Application of gibberellic acid did not change the growth retardation so it was concluded that GA_3 did not interfere with this growth retardation phenomenon. Following the second line of throught a series of three experiments was carried out, the results of which are reported below.

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First experiment (1970)

In the first experiment the effect of three different environmental conditions was studied. A selected brussels sprout plant of the cultivar 'Sandra' propagated vegetatively for a long period (Kronenberg, 1967) was used as a stock plant for cuttings. Bud cuttings were taken on 2 February 1970, planted in peat moss and rooted at 21 °C. The young plants were potted on 2 March. On 31 March they were divided into three groups and brought into:
1. an unheated greenhouse until 11 May, afterwards in the open with diffenrences in temperatures, daylengths and received global radiation.
2. an air-conditioned greenhouse at 17 °C in natural light (NL), without differences in temperatures, but with differences in daylengths and global radiation.
3. an air-conditioned room at 17 °C and 16 hours of fluorescent light (FL), without differences in temperatures, daylengths or global radiation.
The air-conditioned greenhouse and room form a part of the phytotron of the Department of Horticulture and have been described by Doorenbos (1964). From these plants bud cuttings with leaves of about 80 cm² surface were taken at regular intervals which were rooted in peat moss during 4 weeks at 21 °C and 16 hours FL, subsequently potted in 11-cm plastic pots and grown for 8 weeks at 17 °C and 16 hours FL. Twelve weeks after the cuttings had been struck plant length was measured. There were always 3 groups of 10 cutting plants taken on 15 dates (15 series).

Series were taken in the first part of the season every fortnight, in the expected interesting period of July and August every week, later on again fortnightly.

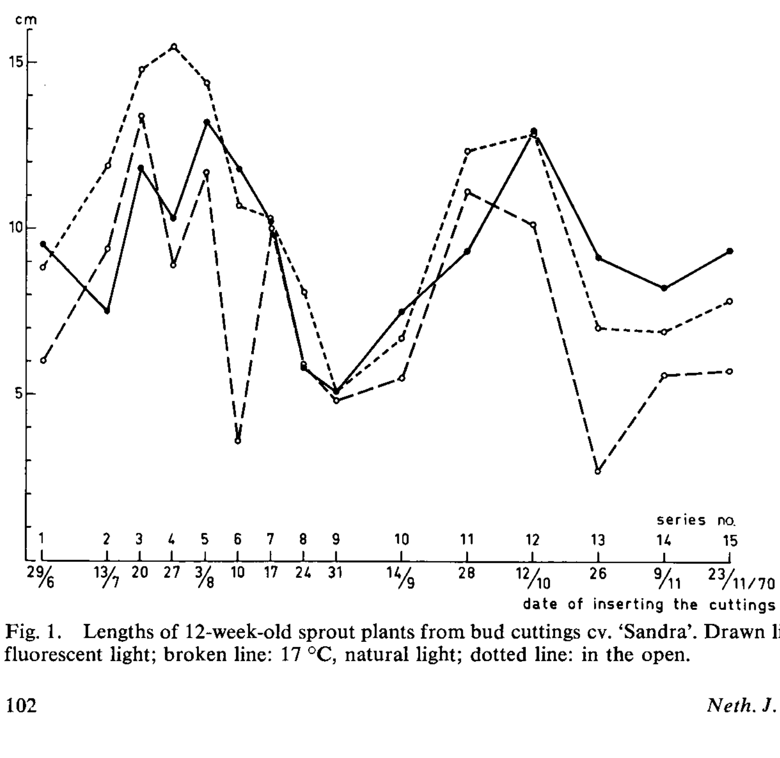

Fig. 1. Lengths of 12-week-old sprout plants from bud cuttings cv. 'Sandra'. Drawn line: 17 °C, 16 hours fluorescent light; broken line: 17 °C, natural light; dotted line: in the open.

The results of this experiment are given in Fig. 1, from which it is clear that there are no great differences in growth of the cutting plants between the three treatments. Though reactions were not always identical, there were two distinct periods of normal growth (series 3, 4, 5 and 11, 12) and two periods of growth retardation (series 8, 9, 10 and 13). These results are in fair agreement with earlier experiments (Kronenberg, 1971): since the present experiment runs over a longer period it shows also a second elongation maximum and a second minimum not found previously. From these results a rhythmic phenomenon was postulated, which seemed to be uneffected by environmental conditions under which the stock plants were grown. This experiment was therefore repeated in 1971 in an extended form.

Second experiment (1971)

In the second experiment stock plants were grown in nine different environments. They were produced in the same way as described in the first experiment, only the dates were slightly different: the cuttings were taken 1 March, potted 29 March and on 27 May divided into 9 groups and brought into:

1. the open;
2. the open, light intensity reduced to about 30 % with saran cloth;
3. the open, under saran cloth until 19 July;
4. the open, under saran cloth after 19 July;
5. short day: 8 hours of daylight;
6. long day: 8 hours of daylight + 8 hours low-intensity incandescent light;
7. air-conditioned room 17 °C, continuous FL;
8. air-conditioned room 17 °C, 16 hours FL;
9. air-conditioned room 17 °C, 8 hours FL.

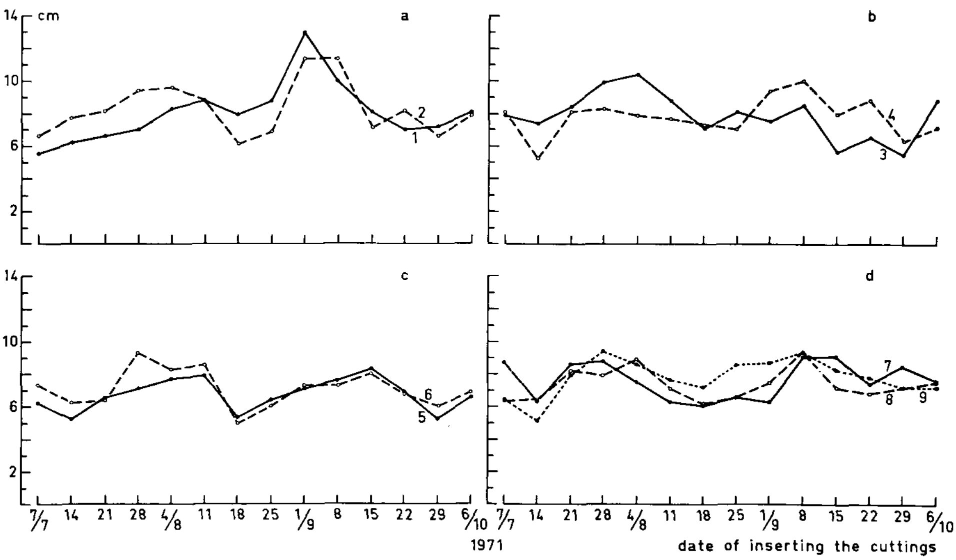

Fig. 2. Lengths of 12-week-old sprout plants from bud cuttings cv. 'Sandra'. Numbers 1 to 9 refer to treatments of stock plants mentioned above.

Series of 10 cuttings were made beginning 7 July and after that every two weeks till 6 October 1971. They were grown in the same way as described for the first experiment.

The results are shown in Fig. 2. The same periodicity shown in Fig. 1 is also found in Fig. 2.

Growth of cuttings is alternately normal and retarded, the difference of maxima and minima being 3 to 7 cm and their distance in time about 11 to 12 weeks. Again no influences of environmental conditions on the rhythmic phenomena were observed.

As Experiments 1 and 2 both lasted only half a year and only two maxima and two minima were found a longer experiment was planned in 1972-1973 to confirm the theory of an internally regulated rhythm.

Third experiment (1972-1973)

In the previous experiments the growth curve showed two peaks and two troughs over a period of 26 weeks. A third experiment was carried out for an extended period (52 weeks) to follow the continuation of this rhythm. For such a long period it was necessary to grow the stock plants in air-conditioned rooms, thus preventing a decline in growth which normally occurs under outdoor conditions. Moreover in a controlled environment a superior proof of a rhythmic phenomenon can be given. Experiment 3 was a repetition in extended from of series 3 in Experiment 1 and series 8 in Experiment 2.

Stock plants were raised from cuttings struck on 6 March 1972, potted on 3 April and brought into an air-conditioned room (17 °C, 16 hours FL) on 15 May. Fortnightly bud cuttings were taken, beginning 29 May 1972, ending 14 May 1973. There

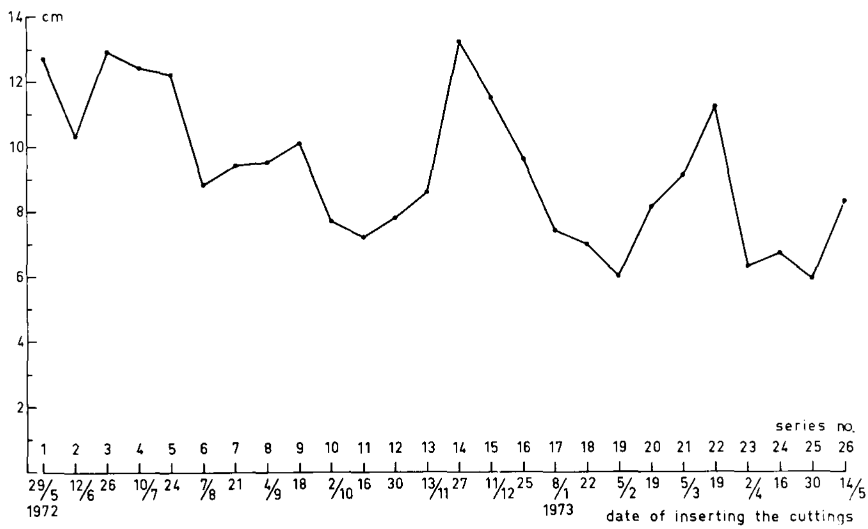

Fig. 3. Lengths of 12-week-old sprout plants from bud cuttings cv. 'Sandra' grown at 17 °C and 16 hours fluorescent light.

were 26 series of 20 cuttings. In this experiment cuttings were rooted during 2 weeks at 21 °C, potted, brought into a 17 °C air-conditioned room and grown under 16 hours FL. Plant lengths were measured after 12 weeks.

Fig. 3 gives the results. The maxima and minima of growth are rather irregular. Maxima appeared in series 3, 4, 5, in 9, in 14, in 22 and in 26, minima in series 2, in 6, in 11 and in 19. The distances between the peaks and the troughs were 8 to 16 weeks. The differences in plant lengths were 1 to 9 cm.

Discussion

In all three experiments maxima and minima in growth were observed. Since external factors (Experiments 1 and 2) did not effect the rhythmic phenomena, it seems logical to postulate an endogenous cause. Rhythms as described above, with rather long periods, appear to have been poorly studied up till now (Sweeny, 1969).

Experiments under controlled conditions nowadays are more feasible giving evidence of the existence of such long-term rhythms. As an exemple Lavarenne-Allary (1966) found that several species of oak seedlings in controlled environment (continuous light and 27 °C) alternately grew and became dormant as they do in nature, showing 4-8 such periods in the course of 7 months. To obtain some first-hand knowledge of *Quercus* seedlings two species were grown during 32 weeks in continuous FL and at 25 °C (acorns planted in 20 cm (deep) × 70 × 70 cm containers). The results of this preliminary experiment are shown below:

Species	Number of seedlings	Total number of rest periods	Number of rest periods per plant in 32 weeks	Lengths of rest periods in weeks	Average length of rest periods in weeks
Quercus rubra	5	25	2 - 7	1 to 27	4.28
Quercus sessiliflora	9	55	4 - 8	1 to 17	2.73

If we compare the results of *Quercus* with those of brussels sprouts it appears that both rhythms are irregular. However the amplitudes and wave lengths in brussels sprouts were more uniform. In comparing these results one has to realize that the *Quercus* plants were seedlings but the brussels sprout plants were clonal.

Wilkins (1969) stated five conditions to determine if a rhythmic phenomenon can be called endogenic.

1. *The rhythm should continue in an environment in which as many environmental parameters as possible are held constant.* The brussels sprout plants meet this requirement.
2. *The phase of the rhythm should be able to be shifted and the new phase retained under uniform environmental conditions.* In the 1972-1973 experiment it was tried to shift the phase, but bud cuttings of 4 weeks younger stock plants almost immediately took over the rhythm of the cuttings of the older stock plants.
3. *The rhythm should be initiated by a single stimulus.* After three years of experiment it seems that in brussels sprouts this rhythm is initiated by age of the plants. From the

beginning of the experiments it took some time – about 10 weeks – to reach the first maximum.
4. *The phase of the rhythm should be delayed under hypoxia.* The effect of inhibitors of this type was not studied. It was felt that changing such a long interval (10 weeks) required too long a treatment period.
5. *There must be a way to get the rhythm started.* Such an external stimulus has not been observed. In this case 3 and 5 are identical.

From the five conditions mentioned above number 4 is irrelevant to the case under consideration, while number 2 was not confirmed. Although not all the requirements mentioned were met, an endogeneous rhythm is assumed. In practice brussels sprout plants are kept only eight months on the field of which the last two or three under unfavourable growing conditions. The rhythmic phenomena described above, therefore, are not found in the field. Only the first downward part of the curve is evident: side shoots of sprout plants grow into sprouts.

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