Plant Physiol. (1968) 43, 1696–1698

The Association of Carbohydrate Changes in the Shoot Tip of Cauliflower With Flowering[1]

Sidki Sadik and J. L. Ozbun

Department of Vegetable Crops, Cornell University, Ithaca, New York 14850

Received June 10, 1968.

Abstract. Changes in levels of sugars and starch in the shoot tip of cauliflower, *Brassica oleracea* L. var. *botrytis* D. C. cv. Main Crop were studied during periods of growth which were inductive or non-inductive to flowering. Flowering was induced by growing plants for 2 weeks under 16 hr of light at 5°. During this period of floral induction there was a significant increase in sugar and starch content compared to that in vegetative plants grown at 20 to 26°. Sugar and starch content did not increase and flowering was prevented when light and CO_2 were excluded during growth at 5°. A 3-day dark period at 20° or a high temperature treatment at 33° with light following growth at 5° reduced the carbohydrate level and prevented flowering.

The importance of carbohydrate level in cold-requiring plants has been indirectly implied by many workers dealing with the physiology of flowering (1, 2, 3, 6, 7); however, a direct correlation between carbohydrate content and flowering has not been demonstrated.

In a study (8) dealing with histochemical changes occurring in the shoot tip of cauliflower, it was observed that starch accumulates during floral induction, whereas little starch is present in shoot tips of vegetative plants. This finding was the impetus for the present study which is concerned with carbohydrate changes in the shoot tip of cauliflower during periods of growth which are inductive or non-inductive to flowering.

Materials and Methods

Cauliflower, *Brassica oleracea* L. var. *botrytis* D. C., cv. Main Crop was used in this study. Plants of this cultivar remain vegetative when grown at 20 to 26°, whereas flowering occurs in 1-month old plants following 2 weeks of growth at 5°. Plants were started and grown in a growth chamber at temperatures of 20° night and 26° day (20–26°) and at a light intensity of 2000 ft-c for 16 hr daily, supplied by cool white fluorescent tubes and four 25 w incandescent bulbs. Flowering was induced by growing plants at 5°. During their growth at 5°, the plants were supplied with 16 hr of light daily with an intensity of 2000 ft-c. Following cold treatment, plants were transferred to the 20 to 26° growth chamber and grown with control plants until floral primordia were visible under a dissecting microscope.

To determine the carbohydrate changes in the shoot tip and flowering response of cauliflower plants as affected by growth at 5°, 4-week old plants were transferred from the 20 to 26° growth chamber to the 5° growth chamber. The plants were grown at that temperature for periods ranging from 1 to 14 days. At the end of each cold treatment, half of the plants from each treatment were harvested for carbohydrate analysis and the rest of the plants was transferred to the 20 to 26° growth chamber until flowering. The percent of plants flowering and the length of time required until flowering were recorded. Experiments were terminated after 16 weeks of growth at 20 to 26°.

After harvesting plants for carbohydrate analysis all leaves were dissected out and shoot tips were cut off 1 cm below the growing point. Shoot tips were chopped and dried in a forced air oven at 70° and then ground to pass a 60-mesh screen. Samples weighing 200 mg were put in 10 × 50 mm cellulose thimbles and extracted in a Soxhlet with 80 % ethanol for 8 hr. The ethanolic solution was made up to 100 ml with 80 % ethanol and filtered. Aliquots of the ethanolic extracts were evaporated to dryness and the sugars were taken up in water. Pigments were extracted from the aqueous phase with methylene chloride. The sugar-free tissue which remained in the thimble following extraction with ethanol was weighed and transferred to 50-ml centrifuge tubes. Starch was solubilized twice with 52 % perchloric acid. Alcohol soluble sugars and solubilized starch were analyzed with anthrone (3). Glucose was used as a standard.

In order to study the effect of CO_2 on carbohydrate changes and flowering during growth at 5°, plants were enclosed in glass chambers through which CO_2-free air was passed at a rate of 3.3 liters/min. The air was freed of CO_2 by passing it through a 45 × 15 cm tower of indicating soda lime. In experiments where plants were grown in

[1] Paper 573, Department of Vegetable Crops, Cornell University, Ithaca, New York 14850.

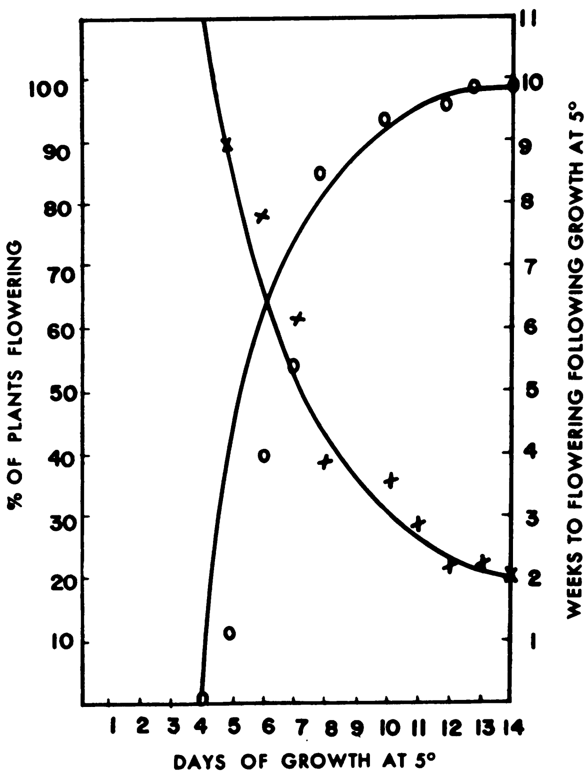

FIG. 1. Influence of growth duration at 5° on percent of plants flowering and on the length of time required until flowering at 20 to 26° following growth periods at 5°.

the dark, the plants were enclosed in a well ventilated light-proof box set in a greenhouse at 20°.

Results and Discussion

The flowering response of 4-week old plants of cauliflower grown at 20 to 26° following periods of growth at 5° is shown in figure 1. The results indicate a direct relationship between the duration of growth at 5° and the percentage of plants flowering and an inverse relationship between the duration of growth at 5° and time until flowering. Flowering was induced in all plants after 2 weeks at 20 to 26° following growth for 2 weeks at 5°. As the duration of growth at 5° is decreased the percentage of flowering plants decreases and the length of time until flowering is increased.

The changes in carbohydrate content that occur in the shoot tip over a period of 2 weeks are shown in figure 2. The starch and soluble sugar content rose significantly during the first week of growth at 5° and decreased slightly thereafter. The starch and soluble sugar content decreased in the first 11 days of growth at 20 to 26° and then rose to a level significantly less than that in plants grown at 5°. This increase in carbohydrates after 11 days at 20 to 26° (plants were almost 6 weeks old) coincided with curd formation and inhibition of new leaf initiation (*7*). Due to this morphological change

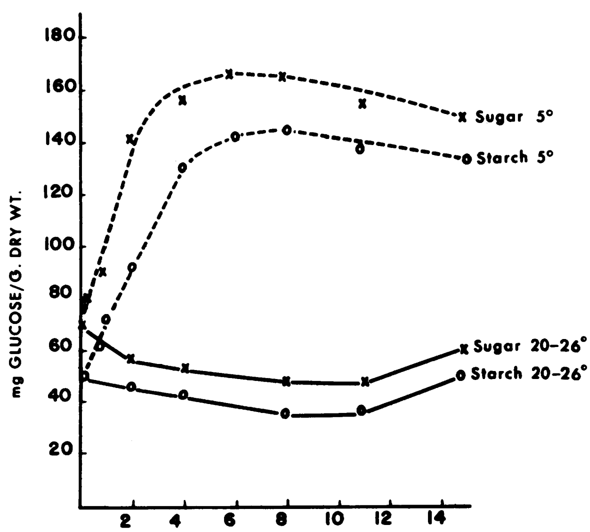

FIG. 2. Changes in sugar and starch content of the shoot tip of cauliflower as a function of growth at 5° or 20 to 26°.

Table I. *Effect of Temperature, CO_2, and Light on Starch and Sugar Content of 4-Week Old Cauliflower Plant Apices and on Their Flowering Response*

Treatment no.	Treatment	Sugar	Starch	Plants flowering
		mg glucose/g d wt		%
1	1 wk at 5°, + light, + CO_2	166.60	142.17	55
2	1 wk at 5°, + light, — CO_2	69.13	51.64	0
3	1 wk at 5°, — light, + CO_2	56.60	54.65	0
4	1 wk at 20–26°, + light	69.30	52.09	0
5	1 wk at 5°, + light, + CO_2, + 3 days dark at 5°	130.35	105.61	25
6	1 wk at 5°, + light, + CO_2, + 3 days without CO_2 at 5°, + light	128.65	104.05	20
7	1 wk at 5°, + light, + CO_2 followed by 3 days dark at 20°	55.16	45.25	0
8	1 wk at 5°, + light, + CO_2 followed by 3 days at 33°, + light	78.91	65.29	0

in the shoot tip which can occur independently from flowering (7), a comparison between carbohydrate levels of plants at this stage and before would not be valid.

The increase in carbohydrate level during growth at 5° led to an investigation of the possible role of carbohydrates in flowering. Treatments for this investigation were designed to either prevent carbohydrate synthesis during growth at 5° or to deplete carbohydrates immediately following the cold treatment and to study the effect of these treatments on flowering. Carbohydrate synthesis during growth at 5° was prevented by either growing plants in the dark or without CO_2 but with light. A decrease in carbohydrates level after 1 week of growth at 5° was accomplished by growing plants for 3 days in the dark at 20° or with light at 33°.

The results of these experiments are shown in table I. Starch and sugar content increased following 1 week of cold in the presence of light and CO_2. This treatment resulted in 55 % of the plants flowering. However, with the exclusion of light or CO_2 during 1 week of growth at 5°, sugar and starch content did not increase and was about equal to that in control plants at 20 to 26°. Plants grown under these conditions did not flower. The sugar and starch content was reduced significantly from their previous level following 1 week of growth at 5° with light and CO_2 when followed by 3 days of darkness at 5° or 3 days with light at 5° but without CO_2. Under these conditions flowering was reduced significantly. On the other hand, the 3-day dark treatment at 20° and high temperature treatment at 33° with light, generally referred to as devernalization, reduce carbohydrate levels and prevent flowering.

The results of these experiments indicate that flowering of cauliflower plants can be prevented if carbohydrate synthesis is blocked during cold treatment or if carbohydrates are depleted following cold treatment. Decreasing the level of carbohydrates attained following 1 week of growth at 5° by growing the plants in the dark or without CO_2 for 3 days at 5° decreases the number of plants flowering (compare treatments 5 and 6 with 1, table I). It is premature to draw a direct correlation between carbohydrate level and flowering since other metabolic processes can be affected by CO_2 and light exclusion. The fact remains, however, that high carbohydrate levels in the plant seem to accompany or precede flowering.

The involvement of carbohydrates in flowering may seem questionable since the highest levels of carbohydrates were attained after 1 week of cold while 2 weeks of growth at 5° were required for maximum flowering. In this regard it is possible to think of the carbohydrate build-up during the first week of cold as a preparatory step that leads to the synthesis of a substance responsible for flowering. Assuming that there is a "floral substance" produced during growth at 5°, its presence and/or effectiveness may not be realized as long as the plant is depleted of carbohydrates. Results of treatments 5, 6, 7, and 8 (table I) where carbohydrate levels are depleted support this speculation.

Literature Cited

1. GRAINGER, J. 1964. A possible mechanism for the action of floral stimuli in plants. Hort. Res. 4: 104–25.
2. KRUZHILIN, A. S. AND Z. M. SHVEDSKAYA. 1960. The role of leaves in the vernalization of winter cereals and biennials. Fiziol. Rast. 7: 287–95.
3. MCCREADY, R. M., J. GUGGOLZ, V. SILVIERA, AND H. S. OWENS. 1950. Determination of starch and amylase in vegetables. Anal. Chem. 22: 1156–58.
4. MILLER, J. C. 1929. A study of some factors affecting seedstalk development in cabbage. Cornell Univ. Agr. Expt. Sta. Bull. 488.
5. PLATENIUS, H. 1932. Carbohydrate and nitrogen metabolism in the celery plant as related to premature seeding. Cornell Univ. Agr. Expt. Sta. Memoir 140.
6. PURVIS, O. N. 1961. The physiological analysis of vernalization. Encycl. Plant Physiol. 16: 76–122.
7. SADIK, S 1962. Morphology of the curd of cauliflower. Am. J. Botany 49: 290–97.
8. SADIK, S. AND J. L. OZBUN. 1967. Histochemical changes in the shoot tip of cauliflower during floral induction. Can. J. Botany 45: 955–59.
9. THOMPSON, H. C. 1929. Premature seeding of celery. Cornell Univ. Agr. Expt. Sta. Bull. 480.
10. TRIONE, E. J. 1966. Metabolic changes associated with vernalization of wheat. I. Carbohydrate and nitrogen pattern. Plant Physiol. 41: 277–81.