Comparison of the Metabolism of Nitrogen and Carbohydrate Compounds during Vernalization of Kohlrabi and Radish

球莖甘藍與蘿蔔之春化作用對氮素和碳水化物代謝比較

by

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Summary

Effective seed vernalization in seed vernalizing plants of radish was accompanied by an increase in sugar content during low temperature treatments. Green-plant vernalizing plants of kohlrabi showed no such sugar increase in seed vernalization treatment. Green-plant vernalizing plants of kohlrabi showed the same changes in sugar pattern as seed vernalizing types radish, but only after the plant had grown to a certain stage at which it was responsive to low temperature treatments.

Seed vernalizing plants may contain high levels of mobilizing sugars in the seed while green-plant vernalizing types might contain obligate sugar only. A low temperature response from these crops was due to a gradual increase in mobilizing sugars during the growing process. Mature plants of seed vernalizing and green-plant vernalizing types contain higher levels of mobilizing sugars, making them more responsive to low temperature conditions.

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Introduction

There are many studies of sugar content and metabolic changes during vernalization[5,6,7,12,16,19]. All of these reports indicated that an increasein sugar content was involved in flower development or in the case of explants grown in vitro without sugar, the absence of sugar resulted in failure of flower initiation. There is little information, however, on the comparison of the metabolic changes occurring between green plant vernalization types and seed vernalization types. Peking Late kohlrabi as greenplant vernalization type and Ta-Mei-Fua Late radish as seed vernalization type were used in this experiment to study their relationship to the metabolism of carbohydrates and nitrogen compounds during vernalization.

Materals and Methods

A. Seeds of radish and kohlrabi were pregerminated at 20℃ for 24 hours, and then placed in a cool room at 4±1℃ for 1,2,3, and 4 weeks. Untreated seeds were used as checks. After each treatment, half of the seeds from each group were planted in 4-inch pots at 20℃ for observation of flower behaviour. The remaining seeds were used for analysis of nitrogen and carbohydrate contents (Fig. 1).

B. Seeds of kohlrabi and radish were sown on September 1, 1977 and October 17, 1980, respectively. Mature kohlrabi and radish plants were taken from the field on December 3, 1977 and November 25, 1980 and placed in high-humidity growth chambers at 8±1℃ and 9±1℃, respectively. The plants were vernalized for one to several weeks, after which they were transplanted to the field. Non-vernalized plants were used as check. Flowering percentages were measured and samples were taken for analysis when removed from growth chamber and after they were planted in the field (Fig. 2. and 3).

Nitrogen was determined by Kjeldahl method, soluble sugar by the anthrone method and reducing sugar by the Somogyi method.

Results and Discussion

The flowering behaviour of radish after seed vernalzation is shown in Figure 4. All of the plots exposed to low temperature began to flower 28 days after sowing, and flowering rates on November 3 were 50%, 70%, 96% and 100% for the 1, 2, 3 and 4 week treatments, respectively. The check did not flower. The fastest flowering rate was from the plot exposed to low temperatures for 3 weeks. Kohlrabi (cv. Peking) seeds did not flower regardless of treatments, indicating that kohlrabi is a green plant vernalizing type.

Mature kohlrabi plants with longer vernalization period began to flower on February 15, 1980. However, there were no flowered plants in those treatments which received only short period of vernalization or check (nonvernalized). On March 15, flowering rates were 16.3%, 0%, 61.1%, 88.9% and 94.6% for 3, 4, 5, 6 and 7 week vernalization treatments, respectively (Fig. 5). The low flowering rate of the plants vernalized for 4 weeks compared with the rate of plants vernalized for 3 weeks might be due to the fact that Peking Late Maturing kohlrabi is a fixed variety which is not uniform in genetic background. In general, however, plants with a longer vernalization duration flowered more quickly with complete bolting and flowering whereas plants with shorter vernalization periods either did not flower or flowered incompleteiy.

Mature radish plants after vernalization showed different flowering rates from different durations of low tempenature treatment.On February 18, the rates were 46.2%, 50%, 100% and 100% for 1, 2, 3 and 4 week low temperature treatments, while the non-treated check did not flower (Fig. 6). The plants exposed to low temperature for 3 weeks were the first to flower on February 8, and demonstrated the fastest flowering rate.

The changes in carbohydrate and nitrogen contents of the seeds treated with low temperatures are shown in Figure 7 and Figure 8, respectively. On radish, reducing sugar, total sugar and total carbohydrate contents were highest after the first week of treatment and then gradually decreased. Starch content tended to be stable even with lengthening low temperature conditions while non-reducing sugar decreased noticeably. Although total nitrogen did not change under low temperatures, soluble nitrogen tended to increase with longer durations of low temperatures. On kohlrabi, total nitrogen contents did not change during any low temperature treatments. There also were no differences in the behavior of the sugar and starch contents of the check plot and the low temperature treated plots.

Suzuki[19] indicated that the highest level of total carbohydrate, total sugar and reducing sugar contents was attained 20 days after low temperature treatment in seed vernalizing turnip. The highest levels were attained after the first week of low temperature treatments in radish indicatinig differences between crops in their response to low temperature duration. The results might show that the longer the duration of low temperatures required to promote flowering, the more slowly these compounds reached a plateau. The behavior of non-reducing sugar, starch and nitrogen in turnip seed was similar to the observed in radish. Miklailova[8] indicated that sugar contents did not increase in the greentplant vernalizing type of cabbage seeds after 80 days of low temperature treatments, agreeing with the results obtained in this experiment with kohlrabi seed.

The experiment showed that flower induction of seed vernalizing type plants was the result of an increase in sugar content during low temperature treatments. The lack of a similar increase in the green plant vernalizing type plants resulted in no flower induction. The total sugar content of radish seeds was more than twice that of kohlrabi before vernalization. Reducing sugar content rapidly increased and non-reducing sugar content gradually decreased during low temperature treatments in radish. Howver, no changes of these compound were found in kohlrabi. The results suggest that the hydrolysis of nonreducing sugar to reducing sugar in radish seeds under low temperature conditions might be a key point for its flower induction.

Mature plants of both radish and kohlrabi flowered after low temperature treatments. Radish plants flowered after one week of low temperatures and flowered completely when exposed for 3 weeks. Kohlrabi did not flower after 3 weeks of low temperatures, but flowered completely after 6-7 weeks of low temperatures.

Non-reducing sugar content showed the greatest difference in the contents of radish and kohlrabi. The non-reducing sugar content of radish was 8-9 times that of kohlrabi before the low temperature treatments. Both radish and kohlabi increased total carbohydrate, total sugar and non-reducing sugar contents at the beginning of the low temperature treatments and declined contents thereafter. Starch content decreased slightly in both radish and kohlrabi during low temperature treatments. Although changes in total nitrogen content were slight, soluble nitrogen increased slightly during vernalization. The rise in soluble nitrogen content was earier in radish than in kohlrabi. This indicates that mature plants of both green plant vernalizing and seed vernalizing types contained sufficient amounts of mobile sugar even before low temperature treatments. Sugar content also decreased during bolting. Changes in nitrogen and carbyhydrate metabolism for mature plant vernalization were also similar for both

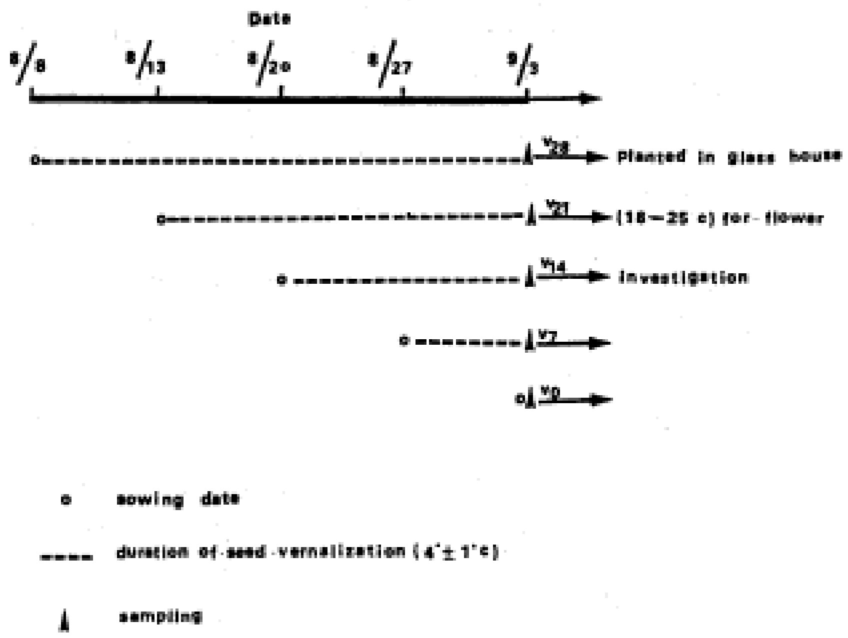

Fig. 1 Experimental plan on seed vernalization of Ta-Mei-Fua radish and Peking kohlrabil

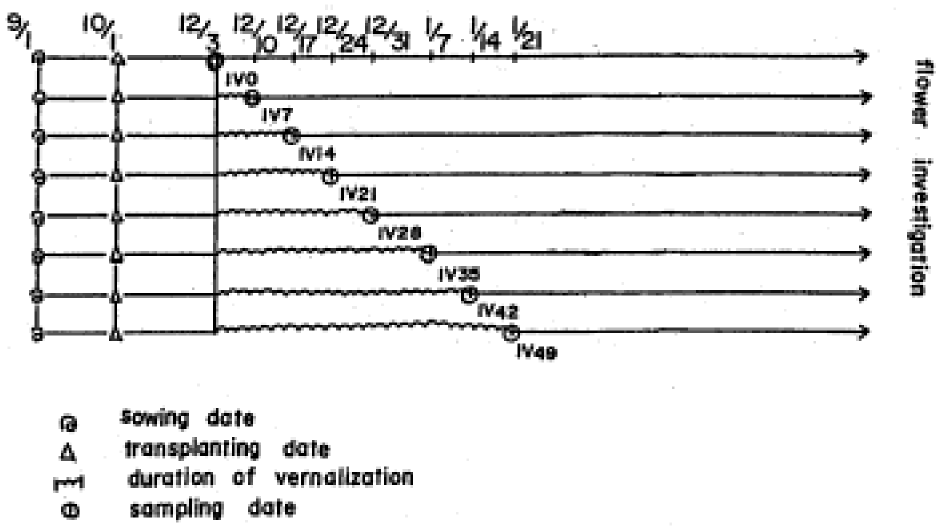

Fig. 2. Experimental plan for mature plants vernalization of kohlrabi

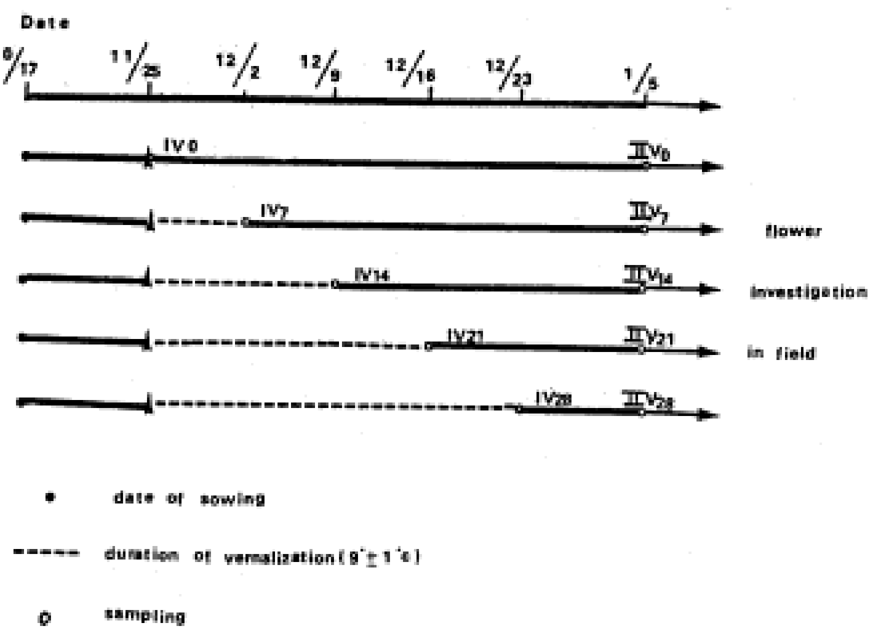

Fig. 3. Experimental plan for vernalization of Ta-Mei-Fua radish.

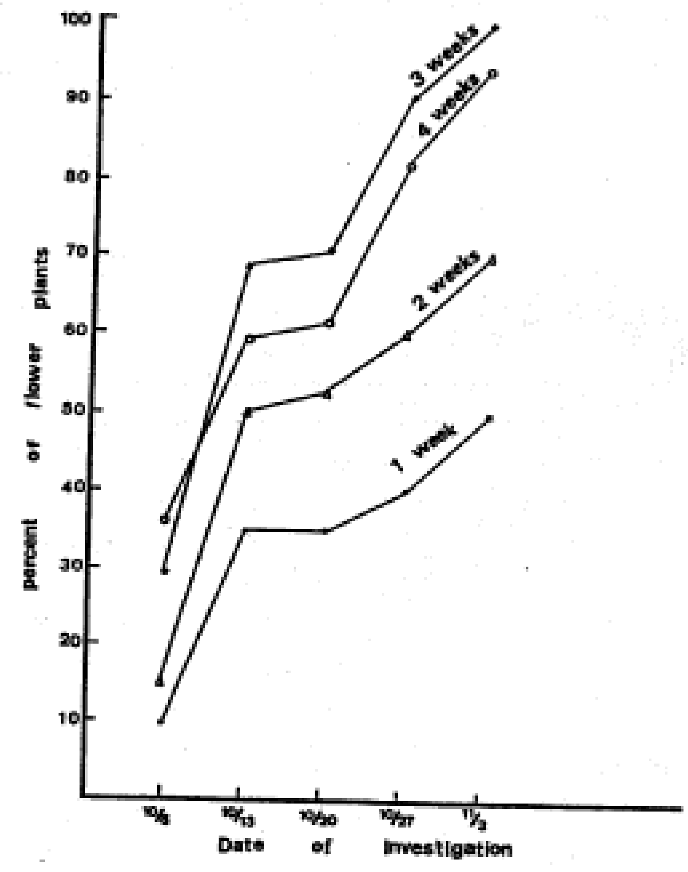

Fig. 4. Effect of different duration of seed vernalization (4±1℃) on the flower

behavior of Ta-Mei-Fua radish.

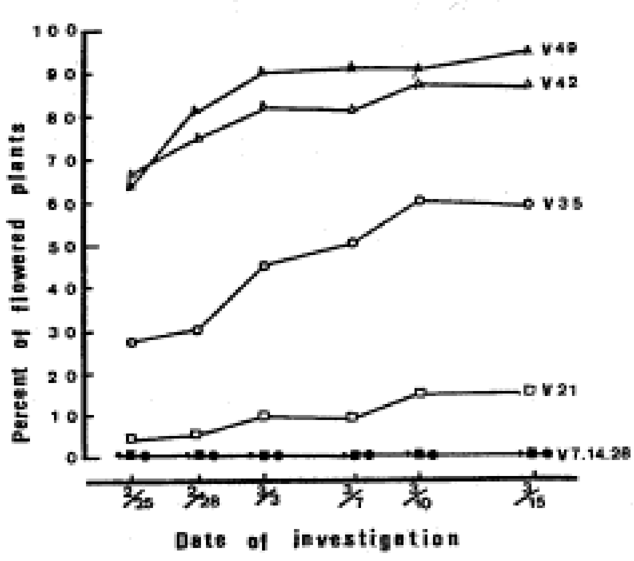

Fig. 5. Effect of different durations of low temperature treatment (8℃) on the flowering of kohlrabi

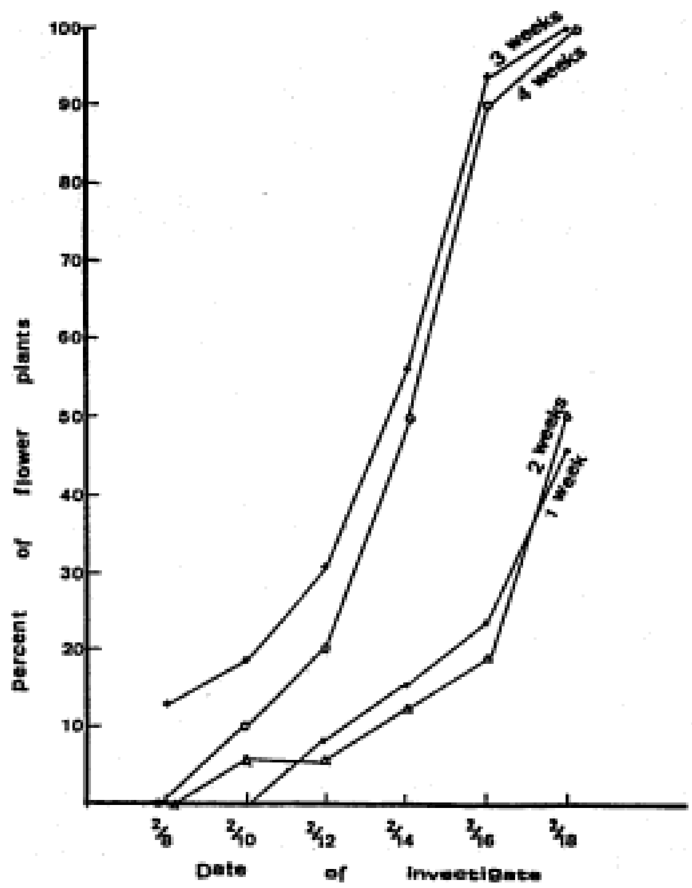

Fig. 6. Effect of different duration of low temperature treatment (9°±1℃) on the flower behevior of Ta-Mei-Fua radish.

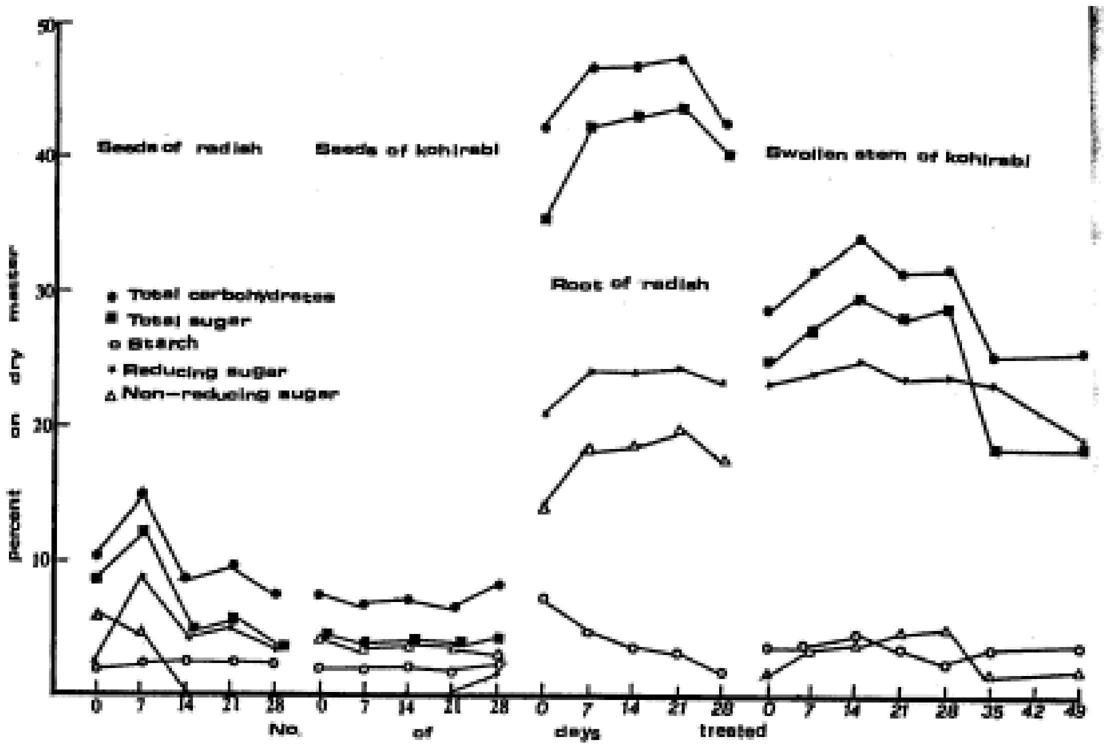

Fig. 7. Comparative changes of carbohydrates contents in kohlrabi and radish treated under low temperature with different durations.

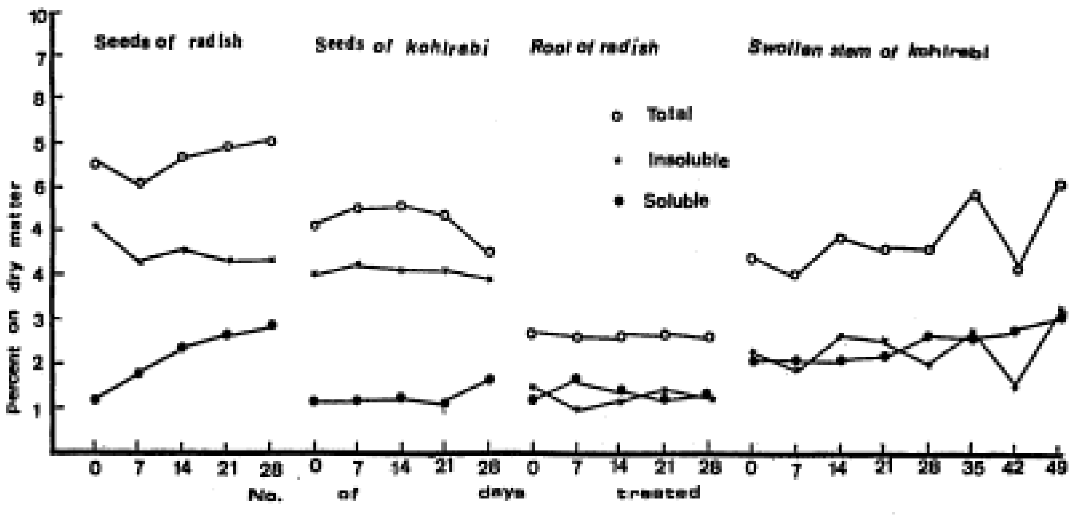

Fig. 8. Comprative changes of nitrogen contents in kohlrabi and radish treated under low temperature with different durations.

vernalizing types. Miller[9] and Boswell[11] showed that sugar and carbohydrate contents tended to increase in cabbage which had over-wintered. Similar results were found with wheat[2,4]. Suzuki[19] showed that non-reducing sugar and total carbohydrate contents of the stem and leaves of cabbage seedlings were highest after 30 days of low temperature treatments. The present experiment found that total sugar and non-reducing sugar contents were highest after 28 days of low temperature treatments for kohlrabi (cv. Peking) and radish (cv. Ta-Mei-Fua),respectively. The sensitivity for the green plant of Chinese cabbage was determined by the genetic background and it thermostage[21]. Green plant vernalization types would have patterns of flower formation and development identical to those of seed vernalizing types if they reach a certain stage of maturity.

Comparing nitrogen and carbohydrate contents of kohlrabi seeds and mature plants, total sugar content of the seeds was found to be only about 1/5 that found in mature plants, and almost no reducing sugar was found in seeds before low temperature treatments. Reducing sugar, non-reducing sugar, total sugar and soluble nitrogen contents of the mature plants tended to increase under low temperature treatments. On the other hand, no changes were noted for seeds undergoing low temperature treatments. These results suggest that the low sugar content in seeds of green plant vernalizing types may contain obligate sugar and that plants of this vernalizing type must grow to a certain stage in which mobile sugars accumulate and can be affected by low temperature conditions.

Comparative changes in seeds and mature plants of radish, mature radish plants had higher nitrogen and carbohydrate contents before low temperature treatments than those in seeds. Although the sugar content in seeds was lower, a certain level was still present, suggesting that this sugar content may be a basic condition for low temperature sensitivity. Reducing sugar, total sugar, total carbohydrate and soluble nitrogen contents all tended to increase in both seeds and mature plants during low temperature treatments. Total nitrogen, however, did not change significantly in either. Non-reducing sugar content increased and starch content decreased in mature plants exposed to low temperatures. In seeds, however, the opposite was the case, with nonreducing sugars tending to decrease and starch tending to be stable during low temperature treatments. The changes noted in radish seeds were the same as identified by Suzuki[19] in turnip seeds. A decrease in non-reducing sugar and an increase in reducing sugar of seed. or a decrease in starch and an increase in sugar of mature plant during low temperature treatments might be the cause of flower formation in seed vernalizing type plants.

The results suggest that effective or non-effective seed vernalization is determined by changes in sugar contents, especially the changes in reducing sugar and total sugar contents under low temperature conditions. Reducing sugar could possible originate from the non-reducing sugars of the seed, but what kinds of reducing or non-reducing sugars are contained in the seed is still unknown. In general, the sugars are reversible through sucrose synthesis or degradation according to the reaction:

$$\text{Glucose-1-phosphate+fructose} \underset{}{\overset{\text{sucrose phosphroylase}}{\rightleftarrows}} \text{sucrose+phosphoric acid}$$

Sucrose phosphorylase catalyzes both reactions, and non-reducing sugars can be synthesized in seed vernalizing type plants depending on low temperature conditions. On the contrary, obligate sugars cannot be degraded in green plant vernalizing types by seed vernalization. The sugar content of mature plants was high, and total sugar, reducing sugar content of mature plants was high, and total sugar, reducing sugar and non-reducing sugar contents increased during low temperature treatments. Starch content noticeably decreased in radish at the same time. Starch is made up of two components, amylose and amylopectin. Amylose in more soluble in water and is possibly synthesized or degraded according to the reaction:

$$\text{Glucose-1-phosphate} \overset{\text{starch phosphorylase}}{\rightleftarrows} \text{amylose} + H_2PO_4^-$$

Starch thus might be degraded to reducing sugars or non-reducing sugars in mature plants depending on low temperature treatments.

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中文摘要

種子春化有效者（蘿蔔），由低溫處理而糖分增加。種子春化無效者（球莖甘藍）其低溫處理不能增加糖分。綠植物春化型（green plant vernaliation type）作物（如球莖甘藍），於植株完成基本營養生長後就與種子春化型（seed vernaliation type）作物（如蘿蔔）一樣，於低溫處理時糖類增加。

種子低溫有效者似含有較高之可移動性糖類，種子低溫無效者，似含不可動糖類。於生長過程中，可移動性糖類的逐漸增加而達到低溫感應。成株之糖類無論為種子低溫感應型或綠植物春化型，都具含有較高之可移動性糖類，因此低溫條件下皆能完成其感應性。