BEHAVIOR OF $^{14}$C PHOTOSYNTHETIC PRODUCTS DURING THE REPRODUCTIVE GROWTH IN BROAD BEAN PLANT

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A study on the behavior and role of $^{14}$C photosynthate assimilated at three stages (Treatment I, II, and III) of the flowering to seed maturing was conducted using cultivar "Sanuki-nagasaki" as material.

The specific $^{14}$C radioactivity at the time of $^{14}$CO$_2$ feeding was superior in leaf blades to other organs and heightened accompanying with the growth advanced. Though the change was extensive within 7 days, the activity declined generally exclusive of stems and roots of Treatment I and roots and seeds of Treatment III.

The translocation of $^{14}$C photosynthetic products from leaf blades was found mainly in vegetative organs with plants fed $^{14}$CO$_2$ at the flowering (Treatment I) and in turn in pods and seeds accompanying with later $^{14}$CO$_2$ feeding trials (Treatment II and III), with the exception of stable accumulations in roots. The retranslocation of $^{14}$C stored in stems, roots, and later pods into seeds varied also with the various growth processes: these percentages out of the total $^{14}$C assimilate were 5, 12, and 40 with plants of Treatment I, II, and III, respectively.

Judging from the results, it may be reassessed that the photosynthates assimilated during the flowering to pod developing are mainly concerned in building vegetative organs and thenceforth these contribute toward the seed production.
Introduction

Although there are many factors which determine the seed yield of crops, the assimilation and movement of carbon in plants are of vital importance. As the physiological status of plant varies with the growing process, however, detailed data of the translocation, accumulation, distribution and consumption of photosynthates assimilated at various growing stages is necessary to explain the seed production. With this aspect of the physiology of growing process, many tracer experiments have been made with cereal and pulse crop plants\(^{(1,2,3,10,11,12,13,14)}\).

The previous investigations on the physiology of the growing process of broad bean plants have established two important findings: (1) the condition of leaf blades as the assimilatory organ closely relates to the growth of plants and (2) stems, roots, and pods play the role as a temporary storing organ for the chemical components in seeds, and these are substantially stable to undesirable conditions such as the inadequate soil moisture and light, the lack of nutrient element, and even occupying inadequate biological space\(^{(15,16,17,18,19,20,21)}\).

Therefore, the object of this study was to clarify quantitatively the behavior and role of photosynthetic carbon assimilated during the flowering to seed maturing stage with special reference to the seed formation by using \(^{14}\text{C}\) as a tracer.

Materials and Methods

Broad beans (\emph{Vicia faba}), cultivar "Sanuki-nagasaya" were sown at nursery bed on November 7, and seedlings were transplanted two plants per pot on December 11. Each pot received 2.9 g ammonium sulfate, 4.8 g superphosphate, and 1.9 g potassium sulfate. Soil moisture was maintained about 70 to 75% of the field capacity.

For the labelling with \(^{14}\text{C}\), whole plants were exposed to \(^{14}\text{CO}_2\) gas at three stages of growth: the start of flowering (Treatment I), the end of flowering (Treatment II, 25 to 30 days

![Fig. 1. Changes in growth status](image1)

![Fig. 2. Changes in dry weight of organs per plant and of hundred-seed-weight](image2)
Behavior of $^{14}$C Photosynthate in Broad Bean Plant

after the start of flowering), and the seed maturing (Treatment III, 60 days after the start of flowering), (Figs. 1 and 2). Plants enclosed underground vessel with vinyl film were transferred into a chamber enveloped with vinyl film and exposed $^{14}$CO$_2$ (liberated from $^{14}$C-carbonate by adding excess amounts of 0.1 N HCl, the CO$_2$ at an initial concentration 450 ppm) for 4 to 2 hours under natural conditions of the sun light. Excess $^{14}$CO$_2$ was absorbed by 2N KOH solution.

Plants were sampled at the time of $^{14}$CO$_2$ feeding (4 hours after), 7th day after feeding, the green pod maturing, and the time of maturity for Treatment I and II, and also the time of feeding, 7th day, and the time of maturity for Treatment III. On harvesting, after washing roots, 1) plants were killed with boiling water and made as herbarium specimen and prepared for the autoradiographic experiment, and 2) dry powdered samples of various organs were made by sampling techniques as same as the previous papers$^{(18,19,20)}$. These samples were treated for liquid scintillation counting using the wet combustion method with Lindenbaums' apparatus and the solution of toluene containing hyamine, P. P. O., and P. O. P. O.

Results

The variations of the specific $^{14}$C radioactivity of various organs are shown in Fig. 3. At $^{14}$CO$_2$ feeding, practically four hours after assimilation, the activity in leaf blades was superior to other organs throughout all treatments of three stages. It was also high with those of later treatment and of upper or younger sections$^{(20,22)}$ (Figs. 7 and 8). Within 7 days after

![Graphs showing variations of specific $^{14}$C radioactivity in each organ and amount of $^{14}$C radioactivity in each organ.](image-url)

Fig. 3. Variations of specific $^{14}$C radioactivity in each organ
A: at the time of $^{14}$CO$_2$ feeding
B: at the 7th day after $^{14}$CO$_2$ feeding
C: at the green pod maturing
D: at the time of maturity

Fig. 4. Variations of amount of $^{14}$C radioactivity in each organ
A: at the time of $^{14}$CO$_2$ feeding
B: at the 7th day after $^{14}$CO$_2$ feeding
C: at the green pod maturing
D: at the time of maturity
assimilation, however, the activity declined rapidly in various organs exclusive of stems and roots of Treatment I and roots and seeds of Treatment III. The behavior of specific radioactivity from 7th day to the time of maturity showed, in general, the tendency of gradually declination in various organs, opposite to be excellent in increase with seed of Treatment III.

Figure 4 shows the variations of the amount of the assimilated $^{14}$C in various organs per plant. In Treatment I, much of the $^{14}$C translocated from leaf blades to stems and roots within 7 days after the assimilation and afterward $^{14}$C was retained in vegetative organs with in minute quantity distributing in pods and seeds at harvest. On the contrary, the decrease of $^{14}$C of leaf blades, stems, and roots, and the increase of $^{14}$C of seeds were evidently recognized in Treatment II and III. Moreover, this tendency was emphasized along with the later treatment.

The fate of $^{14}$C assimilated at different stages of growth is shown in Fig. 5. And figure 6 shows the changes in the distribution of dry matter and $^{14}$C of various organs. So far as the pod was made almost entirely in shape, of the total $^{14}$C assimilated, over 50 per cent was released or disappeared and the remainder translocated mainly to the vegetative organs, especially in stems. While, after this process, the amount of all remaining $^{14}$C with the exception of releasing products of 45 per cent, seemed to shift directly from leaf blades into seeds.

With regard to the distribution of dry matter, the high percentage was established in stems throughout the end of flowering to the green pod maturing stage, and then was superseded by seeds. The distributed $^{14}$C, in fact, was centered in stems with plants of the early treatment, Treatment I, and later one in seeds. As for the changes in the distribution of $^{14}$C for roots, however, the accumulation was constant among three plants treated at different stages.

Fig. 5. The fate of $^{14}$C assimilated at three stages of growth
FIG 6 Changes in the distribution of dry matter and $^{14}$C assimilated

A: at the time of $^{14}$CO$_2$ feeding
B: at the 7th day after $^{14}$CO$_2$ feeding
C: at the green pod maturing
D: at the time of maturity

Discussion

The stem length, leaf number, and dry weight of vegetative organ of broad bean plant at the start of flowering are, in general, accomplished only half of those maximum value. On the other hand, as for the growth of reproductive organ, there begins rapid elongation and development in pod after 30 days from the start of flowering, when the pod begins to decrease in number 3 to 5 per stem, and afterward from more 20 days later of this time seeds continued to develop till 70 to 80 days from the start of flowering (Figs. 1 and 2). Therefore, the role of photosynthetic products in plant is supposed to vary with various growing processes.

The authors pointed out in the previous papers, that (1) in order to build up new vegetative organ and simultaneously to develop the young or green pod, during the flowering to pod developing, a considerable amount of chemical components was beforehand stored in vegetative organs, especially stems and roots, despite encountering with undesirable surroundings. (2) Chemical components in seeds consisted of photosynthates mostly assimilated during the seed maturing and partially translocated from vegetative organs and later pods. Accordingly, in order to support these physiological phenomena concerning with the temporary storing or retention, translocation, accumulation and reformation of materials, a large amount of assimilated carbon may be necessary for the release or consumption including the respiration.

The present experiment showed that a large proportion of $^{14}$C was released from plants; 55 and 45 per cent of the total $^{14}$C with plants fed $^{14}$CO$_2$ at the start and/or the end of flowering (Treatment I and II), and at the seed maturing (Treatment III), respectively. And it was clear that these proportions were able to distinguish by the degree of participating for
the seed maturation. Moreover, a large proportion of the release occurred very rapidly soon after 14C assimilation whenever 14CO2 fed for plants. The amount of the release from plants within a short period, 7 days, was 45 per cent of the total release with plants assimilated at the start and the end of flowering. With plants treated at the seed maturing (Treatment III), however, it was contrastively over 80 per cent. With this connection authors already pointed out the respiration of pods including inner seeds was considerably high (22). Therefore, the physiological meanings of the release or consumption by respiration seemed to vary fundamentally with the developing process of vegetative or reproductive organs and with functional process of low or high molecular compound synthesis in the organs accompanying with the growth advanced.

Meanwhile, the behavior of the remaining carbon, the translocation of photosynthetic products in plants, is very closely related to the mutual relationship between the source and sink at various growing processes. Although the specific 14C radioactivity of leaf blades and stems was unlike among many node orders (20, 22) at every 14CO2 feeding trials, these results were reassessed the different photosynthetic activity of leaf blades mentioned in the previous papers (9, 18, 22). 14C photosynthates, however, seemed to translocate to elsewhere within same organ and to another ones as shown in autoradiograph. With regard to the translocation of 14C between some organs and another ones, sinks were stems and roots with Treatment I, were roots, pods, and later seeds with Treatment II, and with Treatment III it became mainly seeds and again roots. Though there are various sinks of different in kind, size, and distance between the two organs, throughout the whole growing process, the activity seems to depend mainly upon the existence of sink in accordance with the change of growing processes (2, 3, 4, 5, 6, 7, 8, 23). As for the 14C accumulation to roots, there have been reported many papers with plants of sweet potato (6), tomato (5, 6), rice (10), wheat (13), pea (1), kidney bean (10), and broad bean (4, 5). The leguminous crops, above all, must be continuously supplied the carbonaceous materials for support to the activity of nitrogen fixing bacteria, so roots are very important sink throughout the growth, especially the later growing process of seed ripening. Especially this fact may be of vital importance for the annual pulse crops as broad bean plants is noteworthy. Moreover, the facts of high 14C radioactivity with pods at the time of 14CO2 feeding, were reassessed that pods have some photosynthetic activity (1, 6, 22), and it seems to complicate the status of the translocation.

Thus, 14C materials of temporary storing in stems, roots, and later pods, seemed to be retranslocated into seeds accompanying with the development of the reproductive organs advanced. Finally, the percentages of 14C remained at the time of maturity in stems plus roots out of the total 14C assimilated, were 30.4, 18.6, and 2.9 with plants of Treatment I, II, and III, respectively. And those translocated in seeds were also 51, 12.0, and 40.4. Moreover, the percentages of 14C retranslocated from temporary storing vegetative organs plus pods into seeds were 19.2, 40.3, and 41.1 with Treatment I, II, and III, respectively.

Therefore, it may be reassessed that the photosyntheate assimilated during the flowering to pod developing are mainly concerned in building vegetative organs, and henceforth photosynthetic materials contribute mainly toward the seed production including the retranslocation from vegetative organs.
Behavior of $^{14}$C Photosynthetic in Broad Bean Plant

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