The Influences of Source and Sink on Plant Production of *Ipomoea* Grafts

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In the study on dry matter production of crops, researches have been concentrated so far on the size and activity of the photosynthetic system. However, the activity and size of the sinks for photosynthates, e.g. tuberous roots[2,3,7], pods[5], ears[1], may also be very important as a determinant of plant production and crop yield. As a matter of fact, it is quite common that no correlations between photosynthetic activity and crop yields are found. This can be interpreted as indicating that yield is controlled not only by the photosynthetic production, i.e., the source of photosynthates, but also by the activity of the sink for the storage of photosynthates.

Whether the source or the sink is regulating the production is a difficult problem to solve in many cases, because the demand for photosynthates exerts a clear feedback effect on the photosynthetic activity. For example, in reciprocal graftings of cultivars and wild types of sweet potato plant, grafted plants with cultivar roots showed a greater apparent photosynthetic activity and root dry weight, less leaf area and top dry weight, and lower content of carbohydrate in the leaf lamina than those with wild type roots, irrespective of the type of top[2].

Since factors regulating crop yields or process involved in the determination of crop yields constitute a basic problem of crop science, the interrelationship between source and sink of photosynthates in crop production would deserve a priority research. In has been made clear already by the present author and his co-workers that in many modern cultivars some excellent properties related to source and sink function to control the production process[1,3,4].

Grafting method can be used as a useful tool for the research on the interrelationship between the source and the sink, because it does not inhibit the plant growth and production, unlike the removal or shading of organs. In addition, the grafting method can produce various types of plant by the combination of scions and stocks.

Among many crops, sweet potato is particularly suitable for this kind of study, because the top represents the photosynthetic part and tuberous root forms the storage part. Cultivars (*Ipomoea batatas* Poiret) and wild type plants (*Ipomoea trifida* (H.B.K.) Don.) can provide convenient materials.

In a preceding experiment[7], it was found that a cultivar had more total dry weight than wild type plant because of its larger tuberous root although their top weight was smaller.

To analyze whether the larger tuberous root of cultivar is a result or a cause of the greater total dry weight and the greater photosynthetic ability of cultivar, the dry matter production and translocation were studied using reciprocal grafts.

Grafting method and other experimental procedures

Grafting was conducted by "Wari-tsugi" (split grafting) method[2,3,8]. Scions having 4 or 5 fully developed leaves were grafted onto stocks. The grafted portion was wrapped with a tape to protect against drying. Two weeks

Table 1. **Combination in *Ipomoea* grafts**

Sample No.	Scion	Stock
1	IB 63005	Okinawa No. 100
2	IB 66403	Okinawa No. 100
3	IB 66502	Okinawa No. 100
4	Okinawa No. 100	Okinawa No. 100
5	IB 66403	IB 66502
6	IB 66502	IB 66502
7	Okinawa No. 100	IB 66502
8	IB 66403	IB 66403
9	IB 66502	IB 66403
10	Okinawa No. 100	IB 66403
11	IB 63005	IB 63005
12	Okinawa No. 100	IB 63005

Note: Okinawa No. 100; cultivar.
IB 63005 ; blended clone of K222 (wild type plant, *Ipomoea trifida* (H. B. K.) Don.).
IB 66403 ; interspecific hybrid between IB 63005 and cultivar.
IB 66502 ; back-cross clone of cultivar to interspecific hybrid.

after grafting, leaves of the stock were cut off. Any axillary buds developed subsequently were removed, and successful grafts were selected for planting in pots of 1/2000 are.

Leaf area was measured by weighing all leaves on each plant and converting leaf weight to leaf area. Plants were separated into lamina, petiole, stem, tuberous root, pencil type root, fibrous root, and roots were washed free from soil. Dry weights were measured after drying by the hot-air drier and carbohydrate content was determined by colorimetry of the Somogyi-Nelson's method.

Four grafts among twelve grafts were used for the determination of the rate of translocation of ^{14}C-photosynthates. Combinations in four grafts were as follows; Okinawa No. 100/Okinawa No. 100, IB66502/Okinawa No. 100, Okinawa No. 100/IB66502, IB66502/IB66502. The plants were subjected to the $^{14}CO_2$ assimilation treatments at the thickening stage of tuberous roots.

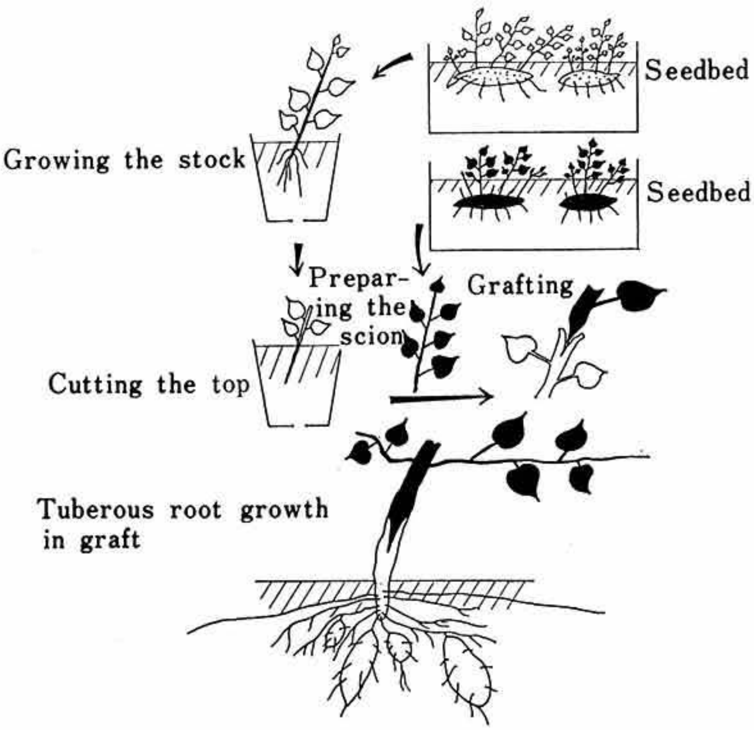


Fig. 1. The method of grafting

An aqueous solution of ^{14}C-labelled sodium bicarbonate was used as a source of $^{14}CO_2$. The $^{14}CO_2$ was fed to the top part of grafts in the transparent $^{14}CO_2$ assimilation chamber. The ^{14}C-radioactivity in plant organs was determined with the powdered dry material at an infinite thickness.

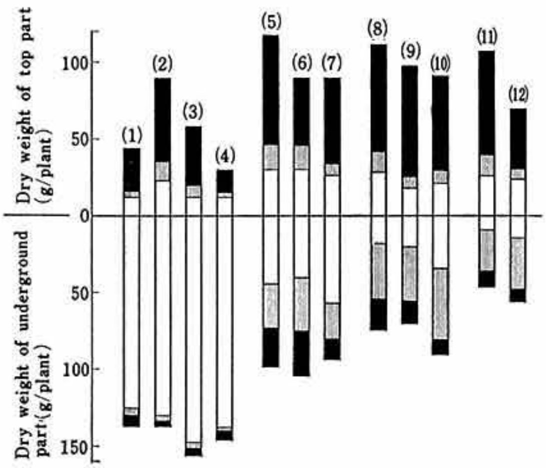
Dry matter production among the grafts

In regard to the dry weight of a whole plant, the grafts of Okinawa No. 100 stock and IB66502 stock showed large values compared with the grafts of IB66403 stock and IB63005 stock. The grafts of IB63005 stock gave very small values. The dry weight was ranked in order of the grafts of Okinawa No. 100 stock>grafts of IB66502 stock>grafts of IB66403 stock>grafts of IB63005 stock. Among the grafts with a same kind of scions, the dry weights of a whole plant was greater with the grafts on cultivar stock, whereas it was smaller with grafts on the stocks of wild type and interspecific hybrid plants.

Dry weight of top organs was small with grafts of Okinawa No. 100 scion whereas it was large with the grafts having scions of wild type plants. The dry weight of top part of grafts was found to be mostly determined by the dry weight of the stems.

The growth of tuberous roots was promoted in grafts on Okinawa No. 100 stock. On the contrary, it was small with grafts on the stocks of wild type and interspecific hybrid plants, although growth of pencil type roots and fibrous roots was promoted.

Irrespective of different scions used, the

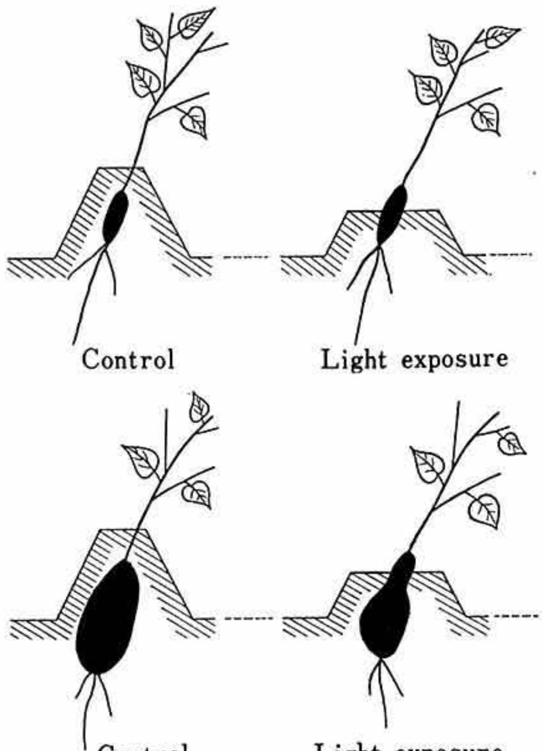


Note:

	Top part	Underground part
■	Stem	Fibrous root
▥	Leaf petiole	Pencile type root
□	Leaf blade	Tuberous root

Samples were taken on October 13th.
Numerical figures are the same as in table 1.

Fig. 2. Dry matter yield in twelve grafts[9]

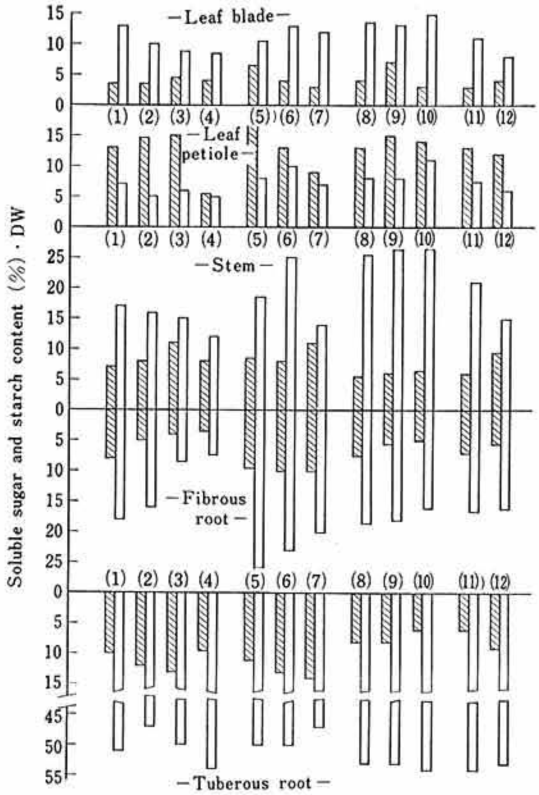


Note: Upper diagram; at the time of treatment.
Lower diagram; at the harvest time.
The top of plants was supported by inclined bamboo stakes.

Fig. 3. Schematic diagram showing the effect of light exposure treatment on tuberous root[9]

growth of the tuberous roots is found to be dependent on the variety and strain used as the stock. From the above facts, it can be considered that the growth of tuberous roots as a sink organ and the storage of photosynthates in stems are determined by the ability of varieties, used as stocks, to produce tuberous roots.

The growth of tuberous roots depends mostly on the cambial activity and tissue differentiation. For example, as shown in Fig. 3, when a part of a tuberous roots was exposed to the light, the thickening growth was inhibited at that part. But the translocation of photosynthates to the untreated part of root continued, resulting in the thickening of that part. At the treated part of root, the sclerenchymalization of parenchymatous cells near the primary cambium and decrease of number of parenchymatous cells in the central cylinder were apparently found[9]. Growth regulating substances are related to the morphogenesis of tuberous roots. Some of them are biosynthesized in the root and are known to promote the growth and development of roots[6]. Since these facts are related to the nature of tuberous roots themselves, it can be considered that the dry matter production and distribution to root are influenced by the thickening property of tuberous root, i.e., the sink activity of *Ipomoea* plant.



Note: ▧; soluble sugar, □; starch.
Samples were taken on October 12th.
Numerical figures; same as in Table 1.

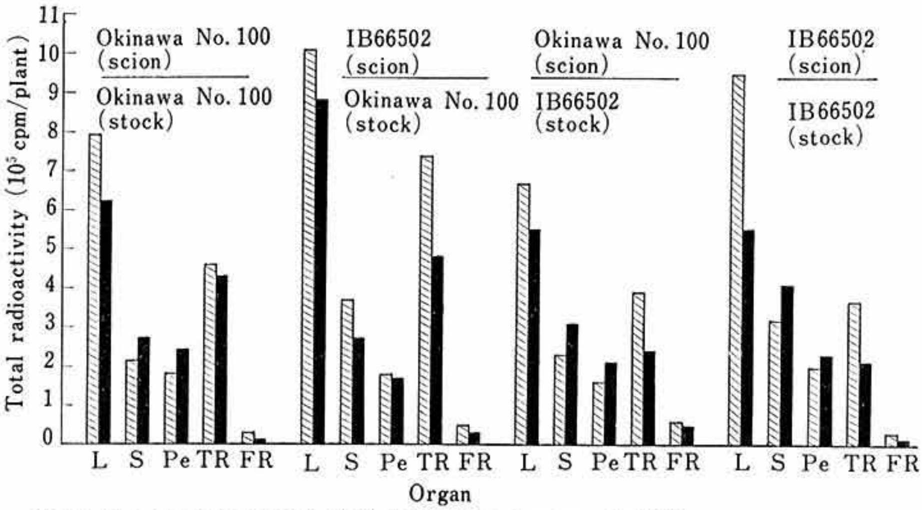
Fig. 4. Soluble sugar and starch content in twelve grafts[8]

Carbohydrate production among the grafts

The starch content in the tuberous roots was high in case of grafts on Okinawa No. 100 stock, notwithstanding their large tuberous roots. On the other hand, in case of grafts of wild type and interspecific hybrid stocks, the starch contents in leaf blades, leaf petioles, stems, and fibrous roots were higher than those of the grafts on cultivar stocks. Starch and soluble sugar in the top and fibrous roots can easily be mobilized and transported to tuberous roots if the tuberous roots require them. Therefore, high demand for carbohydrates in tuberous roots may cause low content of carbohydrates in the top. Thus, it is apparent that the concentration of carbohydrates in the top of grafts is controlled by the demand of tuberous roots for photosynthates. In other words, storage of carbohydrate in roots is a result of the balance between growth of top and that of root under a given photosynthetic production.

Translocation pattern of ^{14}C-photosynthates

Distribution of ^{14}C-photosynthates among different organs of grafts was examined at



Note: ▨ : plant harvested at 24 hours after exposure to $^{14}CO_2$ gas.

■ : plant harvested on the 7th days after exposure to $^{14}CO_2$ gas.

L: leaf blade, S: stem, Pe: leaf petiole, TR: tuberous root, FR: fibrous root.

Fig. 5. Total ^{14}C-radioactivity of each organ in four grafts[8]

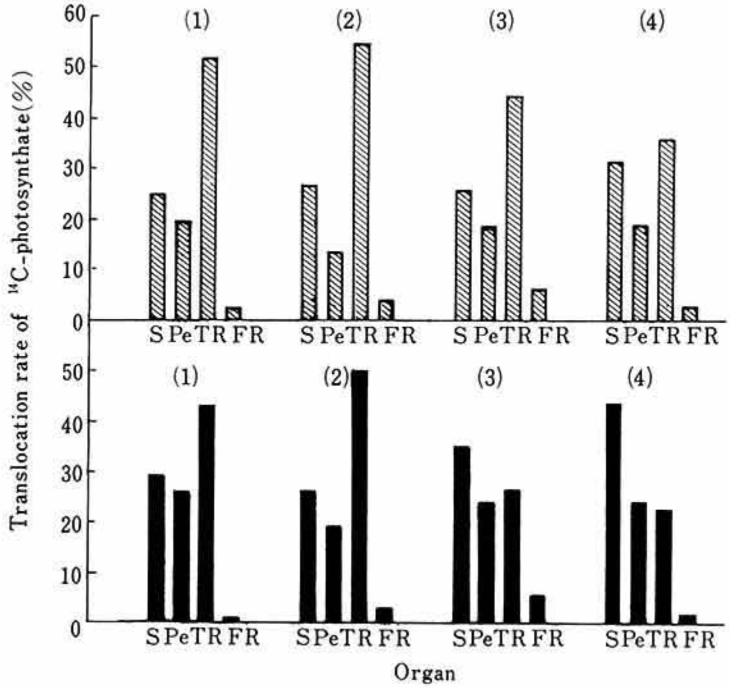
different stages of growth throughout the experimental period. The total ^{14}C-radioactivity of a whole plant was greater with the grafts on Okinawa No. 100 stock than those on IB66502 stock. In general, ^{14}C-photosynthates in respective organs of the plant were found to decrease very rapidly in 24 hr and then slowly disappeared by the 7th day after the $^{14}CO_2$-photosynthesis treatment. But, considerable differences were observed to exist among the grafts: very large disappearences of assimilated ^{14}C from the whole plant were found in IB66502/IB66502 grafts.

The storage of assimilated ^{14}C was found to be abundant in tuberous root, followed by leaf blade. In the grafts on Okinawa No. 100 stock an abundant storage of assimilated ^{14}C was observed in tuberous roots, while in the grafts on IB66502 stock, a remarkable storage of assimilated ^{14}C was found in top organs.

To examine in detail the difference in translocation of ^{14}C from the organ fed with $^{14}CO_2$ to other organs among the grafts, rates of translocation of ^{14}C were calculated and expressed as percentage. After 24 hr exposure to $^{14}CO_2$, large rates of translocation were found in tuberous roots followed by stems. The rates of translocation to tuberous roots in the grafts on Okinawa No. 100 stock were larger than those of the grafts on IB66502 stock. In the grafts on IB66502 stock, large rates were observed in stems: The direction of translocation changed from roots to stems during 7 days after the exposure to $^{14}CO_2$. From the above facts, it seems clear that the thickening property of tuberous roots is an important determinant of translocation pattern, i.e., distribution of dry matter, and the content of carbohydrates. However, since it is not yet known that what mechanism is involved in the competition among different organs (sinks) for a limited supply of photosynthates and how it regulates translocation patterns, it is still difficult to draw a firm conclusion.

Interrelationship between source and sink

The above results indicates that the early thickening of tuberous roots depends on the stock variety, being independent from the scion variety[3,7], and that the thickening of tuberous



Note: a) (1) Okinawa No. 100 (scion)/Okinawa No. 100 (stock)
(2) IB 66502 (scion)/Okinawa No. 100 (stock)
(3) Okinawa No. 100 (scion)/IB 66502 (stock)
(4) IB 66502 (scion)/IB 66502 (stock)

b) Translocation rate of ^{14}C-photosynthates to each organ was calculated from the following formula.

$$\text{translocation rate} = \frac{^{14}\text{C-radioactivity of each organ}}{^{14}\text{C-radioactivity of all organs, except leaf blades.}}$$

Fig. 6. Translocation rate of ^{14}C-photosynthate in each organ[8]

roots exerts an effect on the apparent photosynthetic activity of leaf blade of scions[2]. Dry matter production in *Ipomoea* grafts, in case when the cultivar Okinawa No. 100 was used as scions, showed small differences among the grafts while in case when wild type or interspecific hybrid plants were used as scions, the dry matter production was different with different stocks used: weight of a whole plant and tuberous root of grafts was small when a wild type plant was used as a stock whereas it increased when interspecific hybrids or cultivar were used as the stock.

Thus, the property of root thickening exerts an influence not only on the distribution of dry matter to each organs, but also on the dry matter production. The rate of translocation of ^{14}C-photosynthates to roots was high with tuberous roots which showed an excellent thickening. Thus, the presence of close interrelationship between source and sink of photosynthates was demonstrated in *Ipomoea* grafts. In case of wild type of *Ipomoea* or interspecific hybrids, there are several sinks competing each other: root growth, stem elongation, and leaf development. Consequently, photosynthates are distributed more or less uniformly among all of them. But, in the cultivar of *Ipomoea*, most of photosynthates were translocated to tuberous roots. Such a capacity of tuberous roots as a physiological sink might have developed in the history of crop evolution.

In the process of plant production, the feedback function between source and sink is considered to be interrelated, but depending on different kinds of source and sink or different kinds of crops one of them may be more influential than others in determining plant production. In case of *Ipomoea* plants, it was proved that the sink determines plant production, based on the fact that the influence of stock on plant production is apparently predominant.

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