Changes of Carbohydrate and Nitrogen Compounds With Growth in Tea Plant

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The growing period of tea plants mainly extends from April to October and the plants do not show any growth of shoots during winter. But the tea plant is evergreen, and photosynthesis is continued in the leaves throughout the year to produce carbohydrate.

The carbohydrate thus produced is used for the growth of shoots and roots and a part of it is also accumulated in the plant.

Nitrogen absorbed by the roots is translocated to every part of the plant and used for growth as well.

Therefore, it is very important to make clear these seasonal changes of chemical constituents in the plant for tea culture especially in relation to plucking and pruning.

In this paper the results of studies[4] carried out on the changes of carbohydrate and nitrogen compounds with growth in tea plants and on the changes of carbohydrate and various leaf characters in the tea plants after cutting and transplanting are dealt with.

Seasonal changes in the contents of carbohydrate and nitrogen compounds

A group of three-year-old tea plants were prepared as material and sample plants were taken from the group at regular intervals for a period of one year and seven months from September 1959. Each of the sample plants dug up was cut into three parts—leaf, stem and root—to determine the contents of total sugar, crude starch, total nitrogen and soluble nitrogen in each part.

The growing conditions of the tea plants used as material and the results of the analysis are shown in Figs. 1 and 2. Shoots grew

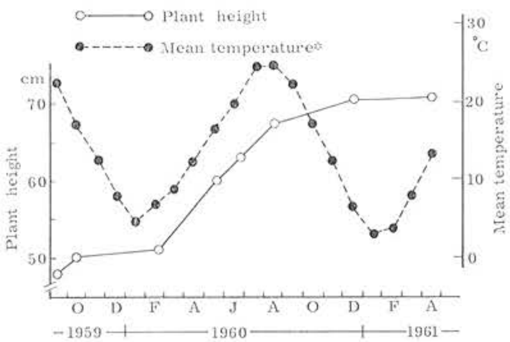

Fig. 1. Seasonal changes of plant height
Note: * Observed at Kanaya-cho, Shizuoka Prefecture (Tea Research Station)

vigorously from spring to summer. The total sugar content of a leaf gradually increased in percentage after the development of the leaf with its maturity, reaching a remarkable level in winter and decreased from spring to summer. Such an increase in the total sugar content of leaves has close relation to the cold resistance of tea plants.[1]

The content of total sugar in the stem increased in winter and rapidly decreased in spring with the growth of shoots showing almost the same seasonal changes as in the leaf.

The crude starch of the leaf and stem showed comparatively little changes in content, though a little increase was observed from

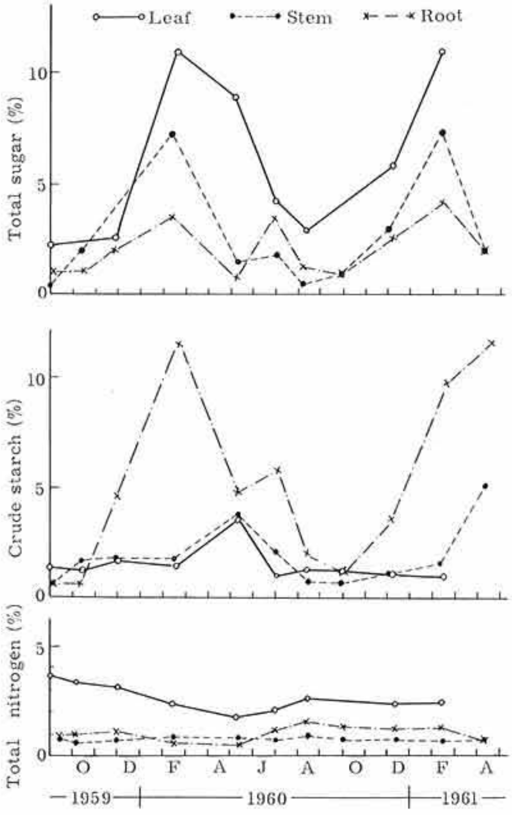

Fig. 2. Seasonal changes of internal constituents (in dry matter)

April to May in each part.

In contrast to the cases of the leaf and stem, the leading part of changes in the carbohydrate content of the root was played by crude starch. That is, the content of crude starch in the root was very low in September or so and began to increase rapidly from late autumn. After that it remained in the maximum level until about March and then decreased with the growth of shoots.

Such seasonal changes of crude starch in the root were microscopically observed as well by using the iodine reaction (Fig. 3), and it was found that the accumulation of crude starch in the main roots began near the center of the xylem, spreading to the periphery, and its decrease in spring proceeded in the reverse direction from the periphery to the center.

The accumulation of crude starch in the roots is considered to be due to the translocation of carbohydrate produced by photosynthesis in autumn. It has been proved by meausrements in grown tea plants that in autumn the photosynthesis of tea plants is active as in summer and the net production is larger than in any other season.[2]

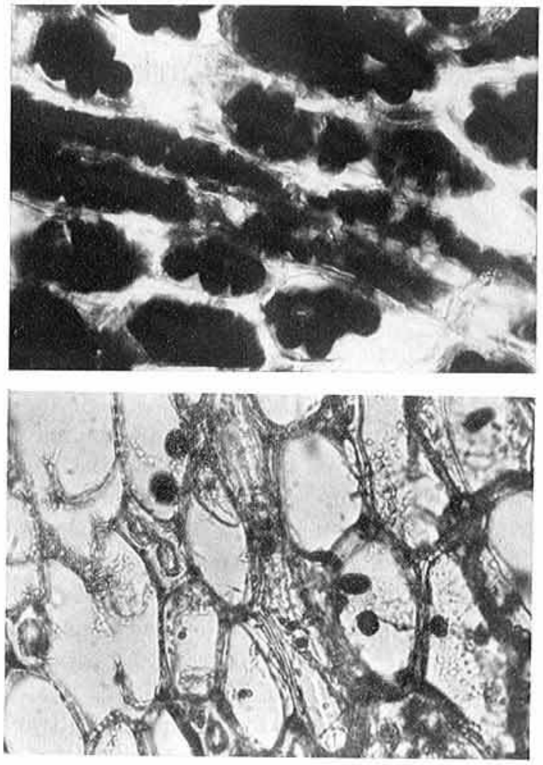
Fig. 3. Reserved starch in main root
Note: Above March
Below July

It is a well-known fact that roots of tea plants vigorously grow in autumn. Therefore, it seems that carbohydrate produced in leaves in autumn is primarily used for the growth of roots and the respiratory function, and secondarily accumulated as crude starch. Total sugar and crude starch accumulated in the plant during winter decreased in and after April, which shows that those are used for the growth of new shoots being partly consumed by respiration.[3]

From the above-mentioned investigations of carbohydrate, it is understood that tea plants grow up repeating seasonal changes in nutrients every year as follows: they enlarge their assimilative organs from spring to autumn by utilizing carbohydrate reserved in roots and others, and in autumn they accmulate the carbohydrate produced by these organs again.

Seasonal changes in the contents of nitrogen compounds were less remarkable as compared with those of carbohydrates. The total nitrogen content of the leaf was high in percentage at the beginning of its development and decreased with its maturity. The total nitrogen contents of the stem and root were very low in percentage and showed little seasonal changes except a tendency to increase in August. The leading part of the change was played by soluble nitrogen.

Changes in carbohydrate and photosynthesis after cutting

Cuttings with two leaves each were planted by an ordinary method on June 29, 1962 as material, and sample cuttings were taken from among them at regular intervals for about three months to examine the content of carbohydrate and the photosynthetic rate in them.

The cuttings began to take root about 30 days after cutting and rooting was observed in 96 per cent of the cuttings examined on the 91st day.

The leaves and stem of a cutting gradually increased in dry weight, and the ratio of assimilative organs to nonassimilative organs in the cutting changed from about 2:1 in the beginning to about 1:1 after three months (Table 1).

The crude starch content of the cutting decreased until the 30th day whereas total sugar showed a considerable increase, especially in the stem soon after cutting and then gradually decreased until the 60th day. The amount of available carbohydrate per cutting was calculated from the carbohydrate content and the dry weight of a cutting as shown in Fig. 4.

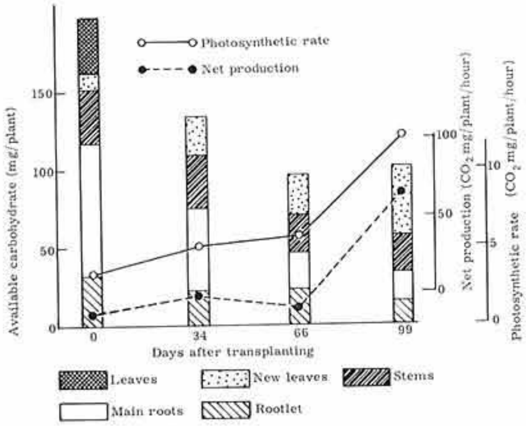

Fig. 4. Changes in available carbohydrate after cutting and its relation to photosynthesis

Table 1. Changes of dry weight and internal constituents

Item		Days after cutting					
		0	11	19	32	63	91
Dry weight (mg/plant)	leaves	340	390	396	371	375	386
	stems	180	211	224	240	285	317
	new shoots		6	14	17	33	41
	roots					63	102
	total	520	607	634	628	756	846
Total sugar (%)*	leaves	5.46	5.89	5.68	5.29	5.90	7.08
	stems	2.42	5.46	4.21	3.92	2.79	3.12
Crude starch (%)*	leaves	2.46	2.69	2.42	0.98	1.15	1.19
	stems	1.35	1.25	1.01	0.70	0.91	1.02
Total nitrogen (%)*	leaves	3.33	3.02	2.97	3.12	2.64	2.31
	stems	1.20	1.05	0.98	0.97	0.82	0.76

Note: * in dry matter

The distribution of total sugar and crude starch in the cutting was considerably different on the 32nd day from that in the beginning while the amount of available carbohydrate showed a little change on the 32nd day and an increase of 30 per cent on the 91st day. These facts indicate that the living of cuttings during this period did not merely depend on the reserved carbohydrate.

The photosynthetic rate was remarkably lower on the 32nd day than in the beginning but gradually increased after that. And the synthesis always exceeded the consumption by respiration, suggesting that the net production was maintained on a certain level in the cuttings during the period.

From the result mentioned above, it is considered that after cutting, crude starch in the cuttings changes into total sugar to be used for the growth of roots and shoots, and at the same time carbohydrate newly produced by leaves also takes an important part in the growth.

Changes in carbohydrate and nitrogen compounds and photosynthesis after transplanting

Two-year-old tea plants were transplanted on May 2, 1962 as material, and sample plants were taken from among them at regular intervals for about three months to examine the contents of carbohydrate and nitrogen compounds and the photosynthetic rate in them.

After transplanting, the plant lost weight considerably owing to the falling off of leaves and roots but it regained weight until the 66th day and gradually increased in weight thereafter (Table 2).

New roots appeared 30 days after transplanting, and a large number of them were observed on the 99th day. The ratio of the assimilative organs to the nonassimilative ones was 1:4 at the time of transplanting and changed to 1:6 on the 34th day, gradually recovering thereafter.

The content of carbohydrate changed as shown in Table 2, tending to decrease in every part of the plant, especially in the main roots.

The photosynthetic rate was low in old leaves existing from the time of transplanting. It was also low in new leaves at the beginning of their development but showed a considerable increase on the 99th day.

The photosynthetic rate per plant, which was calculated by multiplying the photosynthetic rates of these leaves by their respective leaf weights, always exceeded the respiratory rate per plant and gradually increased with

Table 2. Changes of fresh weight and internal constituents

Item		Days after transplanting					
		0	12	22	34	66	99
Fresh weight (%)		100.0	85.7	91.1	91.0	102.0	124.6
Total sugar + Crude starch (%)*	leaves	5.69	5.61	4.88			
	new leaves	5.06	6.81	5.66	5.14	3.65	3.81
	stems	2.90	3.39	2.95	2.25	1.54	1.48
	main roots	8.37	5.55	5.22	4.91	2.21	1.66
	rootlets	2.48	2.26	1.91	2.11	1.85	1.40
Total nitrogen (%)*	leaves	2.46	2.32	2.45	2.48		
	new leaves	5.00	4.14	3.87	3.63	3.58	3.22
	stems	1.02	0.90	0.96	0.84	0.76	0.71
	main roots	0.89	0.90	0.93	0.96	0.86	0.79
	rootlets	1.31	1.31	1.43	1.36	1.37	1.43

Note: * in dry matter

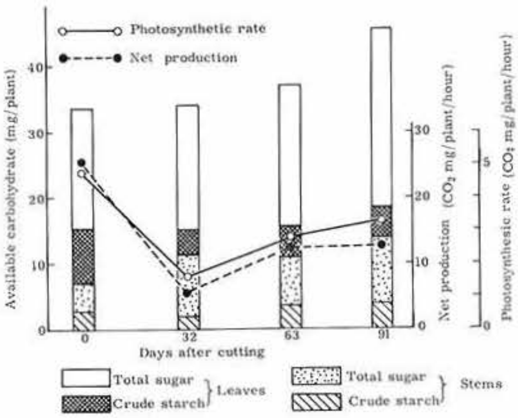

Fig. 5. Changes in available carbohydrate after transplanting and its relation to photosynthesis

the increase in the number of new leaves as shown in Fig. 5.

But the nonassimilative organs form a larger portion than the assimilative ones in the plant after transplanting as mentioned above, so the consumption by respiration in these parts is not a little in quantity.

Therefore, to examine the balance between synthesis and consumption, the net production per day was calculated and the values obtained proved to be of negative ones without exception until the 66th day.

This result seems to show that the photosynthetic production by leaves tended to be insufficient for the growth of plants during the period.

A rapid decrease in carbohydrate content after transplanting (Table 2) appears to supply the consumption in the plant. The amount of available carbohydrate per plant also tended to decrease until the 66th day.

The fact that the total nitrogen contents of the leaf, stem and root gradually decreased in percentage after transplanting respectively is regarded as an evidence showing the translocation of total nitrogen to new shoots and roots.

From the above-mentioned results, it is considered that the growth of tea plants in the beginning of living after transplanting mainly depends on carbohydrate accumulated in the plants, especially crude starch in the main roots.

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