Available Phosphorus Content of Soil and Absorption of Phosphorus by Tea Plants

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As a result of various experiments carried out by the use of phosphate fertilizer labeled with radioactive ^{32}P, it has been confirmed that the manuring time to make the ratio of applied fertilizer phosphorus to total phosphorus (A-P/T-P ratio) nearly the highest in new leaves, that is, the most effective manuring time of phosphorus for the production of new leaves is 40 to 45 days before plucking new leaves of tea plants.[1),2)]

The total phosphorus content of new leaves is lower in the second and third crops than in the first crop, and the A-P/T-P ratio in new leaves gradually decreases or remains on the same level from the first to the third crop[2)] though there is a little variation of content according to the kind of soil.

It has also been found that the A-P/T-P ratio decreases in tea leaves when the available phosphorus content of soil is increased by soil improvement.[3)]

On the basis of these results, the present study[4)] was carried out to clarify the relation between the available phosphorus content of soil and the absorption by tea plants of applied fertilizer phosphorus in expectation of setting a standard or target of rational manuring, soil improvement or soil fertility for tea plantations.

In this study the available phosphorus content of soil was determined by Truog's method. This is in general use in this country among the various measuring methods.

Relation between available phosphorus content and absorption of applied fertilizer phosphorus by tea plants in different kinds of soils (pot experiment)

Diluvial red yellow soil, "Kuroboku" soil and humic volcanic ash soil were used for this experiment as typical soils of tea plantations in Japan. Each soil was put in 1/5000—a Wagner pot and monocalcium phosphate was added to them at the rates of 0, 0.5, 1.0 and 4.0 g per pot as P_2O_5, respectively to prepare different phosphorus contents of each soil.

Chemical properties of the soils are shown in Table 1. After the addition of phosphate, the soils were incubated in upland conditions for a month, and then the available phosphorus contents were determined by the

Table 1. Chemical properties of soils used as material (in dry matter)

Soil	pH		Exchange acidity	Total N	Total org. C	C/N	Humus	Available phosphorus	Phosphate absorption coefficient
	H_2O	KCl							
Red yellow soil	5.58	4.05	3.95	0.10%	3.10%	31.0	5.3%	14.0 mg/100 g	770
Kuroboku soil	4.55	4.05	7.30	0.27	9.56	35.4	16.5	2.6	2100
Volcanic ash soil	4.95	4.30	1.60	0.51	8.97	17.6	15.5	2.0	2070

Table 2. Available phosphorus content of soil in each experimental plot (P_2O_5 mg/100 g in dry matter)

Soil	Amount of phosphorus added (P_2O_5 g/pot*)			
	0	0.5	1.0	4.0
Red yellow soil	14.0	15.0	21.0	42.5
Kuroboku soil	7.0	9.0	19.5	27.5
Volcanic ash soil	4.5	5.0	10.5	15.7

* 1/5000 a in area.

Truog's method (Table 2).

After the treatments mentioned above, a nursery tea plant (Yabukita variety) was planted in each pot and, after rooting, nitrogen and potassium were applied to it at a rate of 0.5 g/pot as N and K_2O in the forms of $(NH_4)_2SO_4$ and K_2SO_4, respectively.

The plants were grown under ordinary cultivating conditions thereafter, and diammonium phosphate labeled with radioactive ^{32}P was applied to them at a rate of 0.5 g/pot (192 μCi in radioactivity) as P_2O_5 three months after the planting.

Fifty days later, the tops of each plant were collected as material for analysis. The top of the tea plant was cut into three parts, new leaf, mature leaf and young trunk, and dry weight was obtained for each part to compare the amount of growth.

Then the samples were dried, pulverized and decomposed by wet oxidation with a H_2SO_4—HNO_3 mixture to precipitate phosphate phosphorus as $(NH_4)_3PO_4$-$12MoO_3$-HNO_3-$2H_2O$, respectively. The A-P/T-P ratio was calculated from the radioactivity of the precipitate and the total phosphorus content determined otherwise.

When the effect of phosphorus on the growth of tea plants is examined, it is noticed that the top of a plant increased in dry weight with the available phosphorus content of each soil. But the critical point of the increase could not be observed in this experiment.

Total phosphorus content, applied fertilizer phosphorus content (phosphorus labeled with ^{32}P) and the A-P/T-P ratio were determined

Table 3. Total phosphorus contents of new and mature leaves and trunk and ratios of applied fertilizer phosphorus content to total phosphorus content

(in dry matter)

Soil	Available P. content of soil mg/100 g	New leaf			Mature leaf			Trunk		
		Total P. mg/100 g	Applied P. mg/100 g	A-P/T-P* %	Total P mg/100 g	Applied P mg/100 g	A-P/T-P %	Total P mg/100 g	Applied P mg/100 g	A-P/T-P %
Red yellow soil	14.0	480	94.7	19.7	185	18.7	10.1	543	84.7	15.6
	15.0	500	63.1	12.7	195	18.0	9.2	566	63.9	11.3
	21.0	560	53.7	9.6	260	17.2	6.6	587	63.9	10.9
	42.5	620	15.7	2.5	340	10.3	3.0	592	29.0	4.9
"Kuroboku" soil	7.0	651	30.2	46.4	275	25.0	9.1	62	32.0	53.3
	9.0	665	15.9	23.9	300	13.5	4.5	111	29.0	26.4
	19.5	669	5.5	8.2	345	7.2	2.1	147	0.9	0.6
	27.5	675	2.4	0.3	391	3.1	0.8	154	0.7	0.4
Volcanic ash soil	4.5	642	14.4	22.4	225	6.9	3.1	91	16.0	17.6
	5.0	661	6.8	10.3	235	6.8	2.9	166	7.8	4.7
	10.5	660	2.9	4.4	260	3.1	1.2	168	7.1	4.2
	15.5	675	1.1	1.6	340	1.7	0.5	175	1.5	0.9

* $\frac{\text{Applied phosphorus}}{\text{Total phosphorus}} \times 100$

in each part of the tea plant as shown in Table 3.

These data indicate that the total phosphorus content of each part increased with the available phosphorus content of each soil. In red yellow soil, the A-P/T-P ratio was not less than 9.6% in each of the new leaf and the young trunk when the available phosphorus content of soil was 21.0 mg/100 g or more, while the ratio was so low as to be 2.5% in the new leaf and 4.9% in the young trunk when available phosphorus content was 42.5 mg/100 g.

In the mature leaf, when the available phosphorus content of soil was 14.0 mg/100 g, the A-P/T-P ratio was 10.1%, being lower than in the new leaf and the young trunk, and the ratio decreased accordingly as the available phosphorus of soil increased.

In "Kuroboku" soil, when the available phosphorus content of soil was 7.0 mg/100 g, the A-P/T-P ratio was 46.6% in the new leaf, showing that a remarkably large amount of applied phosphorus was utilized. When available phosphorus content was increased to 19.5 mg/100 g, the A-P/T-P ratio decreased to 8.2%.

In "Fuji" volcanic ash soil, when available phosphorus content was 4.5 mg/100 g, the A-P/T-P ratio was 22.4%, while the rate decreased to 4.4% when available phosphorus content was increased to 10.5 mg/100 g.

In each of these soils, the A-P/T-P ratio was remarkably lower in the mature leaf than in the new leaf, but its changes showed the same tendency as in the new leaf. In the young trunk total phosphorus content was lower than in each of the new and the mature leaves, but the A-P/T-P ratio was the same as in the new leaf.

On the basis of the above-mentioned results, the relation between the available phosphorus content of soil and the A-P/T-P ratio in the new leaf was examined by soils as shown in Fig. 1.

In this way, it has been made clear that when available phosphorus content determined by the Truog's method is 30 to 40 mg in red yellow soil, not less than 20 mg in "Kuroboku"

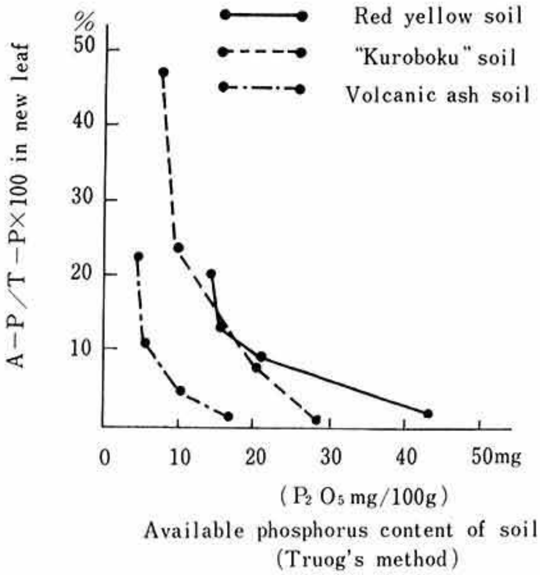

Fig. 1. Relation between the available phosphorus content of soil and the ratio of applied fertilizer phosphorus content to total phosphorus content in the new leaf.

soil and 10 mg or more in volcanic ash soil as P_2O_5 per 100 mg of dry soil, phosphorus newly applied to the soil as fertilizer is scarcely utilized by tea plants at the time of application.

Accordingly, it seems that the values of available phosphorus contents mentioned above can be adopted as standards of phosphorus fertility or targets of soil improvement in the three kinds of soils of tea plantations.

Available phosphorus content of soil and the distribution of phosphorus absorbed from fertilizer in different forms of compounds in the plant (field experiment)

In this field experiment ("Kuroboku" soil) a mixture of 5 g (2.48 m Ci), as P_2O_5, superphosphate labeled with ^{32}P, 24 g ammonium sulfate and 10 g potassium sulfate was applied as an amount per plant to the surface layer of the soil between the rows in each of the two experimental plots, low-phosphorus (7.2 mg/100 g in available phosphorus

Table 4. Total phosphorus contents of new and mature leaves and ratios of applied fertilizer phosphorus content to total phosphorus content ("Kuroboku" soil)

(in dry matter)

Plot	Available phosphorus content of soil: P_2O_5 mg/100 g	2nd Crop			3rd crop		
		Total P mg/100 g	Applied P mg/100 g	A-P/T-P %	Total P mg/100 g	Applied P mg/100 g	A-P/T-P %
		New leaf					
low-P	7.2	905.0	302.3	33.4	500.0	161.0	32.2
high-P	44.5	975.0	42.9	4.4	570.0	30.2	5.3
		Mature leaf					
low-P	7.2	700.0	179.2	25.6	500.0	26.0	5.2
high-P	44.5	775.0	36.4	4.7	575.0	12.7	2.2

content) and high-phosphorus (44.5 mg/100 g in available phosphorus content) after the first crop (May 15, 1968), and total phosphorus content and phosphorus content coming from fertilizer as well as the form of phosphorus were investigated in the new and the mature leaves by using the second crop (June 27) and the third crop (August 10) as material. The results obtained are as follows:

As shown in Table 4, the total phosphorus contents of both new and mature leaves were lower in the low-phosphorus plot than in the high-phosphorus plot, respectively. Phosphorus content coming from fertilizer was distinctly higher in the low-phosphorus plot than in the high phosphorus. The A-P/T-P ratio of the new leaf was so high in the low-P plot as to be 33.4% in the second crop and 32.2% in the third crop, while it was very low in the high-P plot: 4.4% in the second crop and 5.3% in the third crop. This result indicates that the available phosphorus content of soil, 7.2 mg/100 g, in the low-P plot was insufficient in amount for the crops.

As for the mature leaf, the A-P/T-P ratio in the low-P plot was 25.6% in the second crop and very low in the third crop. The cause of such a variation is unknown. In the high-P plot the ratio was very low: 4.7% in the second crop and 2.2% in the third crop.

The A-P/T-P ratio was investigated by forms of phosphorous compounds in each of the new and the mature leaves as shown in

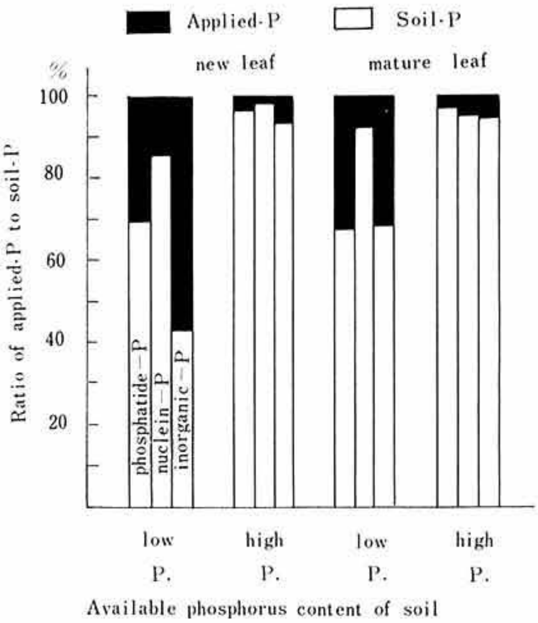

Fig. 2. Ratio of applied-P to soil-P in each type of phosphate in the new and the mature leaves.

Fig. 2. It is seen in this figure that the A-P/T-P ratio is higher in the low-P plot than in the high-P plot irrespective of the age of leaves and the form of phosphorous compounds.

In the new leaf, the A-P/T-P ratios in inorganic phosphorus, phosphatide and nuclein were lower in this order. In the low-P plot, the A-P/T-P ratios of inorganic phosphorus and phosphatide were 57.3% and 30.6% respectively. This result seems to show that when phosphorus is insufficient in amount, inorganic phosphorus in tea leaves is metabolized into organic-P, and if it is still deficient, phosphatide-P is decomposed to supply a demand for phosphorus to make nuclein-P, resulting in a deficiency of phosphatide-P.

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