Phosphorus Problem in Mulberry Field in Japan

NOBUYUKI MORI

Chief, Laboratory of Soil, Chemistry Division,
Sericultural Experiment Station

G. Daikuhara, a famous soil chemist researcher of the exchange acidity of soil, reported in 1908 that there was no need of applying phosphorus fertilizer to the mulberry field. This, however, was due to the fact that farmers reared silkworms on a small scale at that time mainly availing the fertile land around their residences for mulberry fields in Japan, and the fields were mostly of alluvial soil brought by rivers.

Thereafter, mulberry fields were expanded from the lowland to the upland where volcanic ash soil was widely distributed accompanied with the favorable increase in raw silk export. In 1921 Y. Mimuroto carried out fertilizer experiments in the upland field of volcanic ash soil, and found that phosphorus had a greater influence on the growth of mulberry trees than nitrogen. Under a number of such scientific and other guidances sericulture had developed in Japan so that silk had accounted for 40% of the total exports, and had played an important part for obtaining foreign money.

The contradictory results mentioned above on phosphorus are due to the difference in the soil of mulberry fields tested. In Japan soil surveys have been carried out along with studies on the improvement of fertilization throughout the country, and the soils of mulberry fields are classified into 36 soil groups by M. Ito, showing their distribution all over the country.

The results of experiments on the rate of the application of phosphorus and potash to mulberry fields proved that the effect of phosphorus was evident in 65% of volcanic soil tested and in 50% of non-volcanic soil. Phosphorus was effective to 12 of the 17 volcanic soil groups and to 6 of the 14 non-volcanic ones among 31 soil groups examined, showing that phosphorus has a prominent effect on volcanic soils and is also effective to such non-volcanic ones, as red and yellow soils of fine texture, and eroded soils of mountain areas.

When much nitrogen is applied to mulberry trees under the condition of phosphorus deficiency, arginine accumulates in the mulberry leaves, according to S. Kurose. And silkworms fed on such leaves show severe damage of growth, often being killed finally. Phosphorus has a great influence not only on the mulberry tree but also on the growth of silkworms in this way.

Absorption rate of applied phosphorus

The absorption rate of phosphorus contained in applied fertilizer has been reported to be 20% or so in the mulberry field.

Table 1. Percentage recovery of applied phosphorus in relation to method in Experiment

	Pot experiment	Field experiment		
		Spring	Autumn	Total
Percentage of applied Phosphorus absorbed	% 32.4	% 0.25	% 1.55	% 1.80

T. Ushioda made experiments on the absorption rate by means of radioactive phosphorus applying superphosphate to the mulberry tree in the field and in the pot containing the same soil of the field, showing that the rate is 32% in the pot experiment and only 1.8% in the field experiment in the total of spring and autumn as shown in Table 1. The author's result obtained by the field experiment applying radioactive superphosphate to the alluvial soil is shown in Fig. 1. It shows that the absorption rate

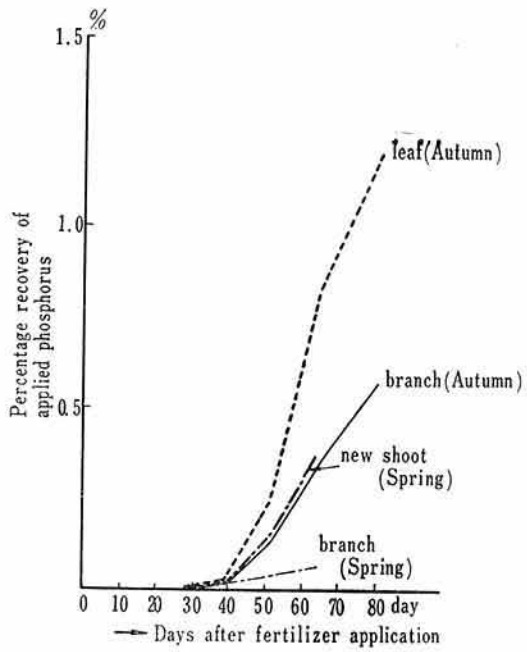

Fig. 1. Percentage recovery of phosphorus from the fertilizer.

is only 0.43% in the spring and 1.76% in the autumn season.

It is estimated that the rate is only 3% or so in the total of roots and stems. This result means that the mulberry tree absorbs more than 95% of necessary phosphorus from the soil. Accordingly, it is especially important to enrich the soil with phosphorus and to improve the way of the application of phosphorus fertilizers in the mulberry field.

Reason of the low adsorption rate of ferilizer phosphorus

To know the reason of the low absorption rate of phosphorus contained in fertilizers, studies were made on the behavior of the phosphorus in the soil and on the absorption of phosphorus by the mulberry tree from the soil.

The behaviors of applied phosphorus in the soil are classified into two, physical movement and chemical change. There are many studies on the latter. The mulberry tree can actively absorb phosphorus compounds at the condition soon after the formation before the progress of crystallization, or not occluded by aluminum or iron. The ratio of effectivity was 75 for aluminum phosphate and iron phosphate, and more than 80 for calcium phopohate as against 100 for superphosphate.

In the experiment field shown in Fig. 1. the absorption rate was extremely low, though there were about 7% of the applied phosphorus which remained in the water soluble form more than one month later. This fact shows that the low absorption rate is not mainly due to the chemical change of applied phosphorus.

In the next place, the distribution of applied phosphorus in the soil was studied

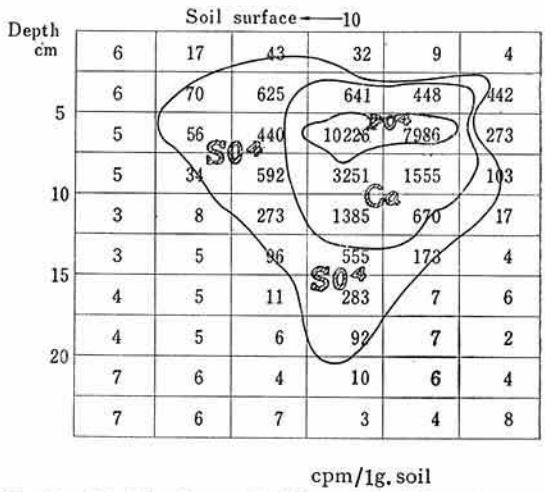

Fig. 2. Distribution of SO_4, Ca, PO_4 from superphosphate in the soil.

in various fields by means of autoradiography using the soil embedded in resin. The result obtained evidences that phosphorus moves considerably from the place where it was applied in the gravelly and sandy soils, but only slightly diffuses in the volcanic ash and heavy texture soils. An example is shown in Fig. 2.

In this case superphosphate triple labeled with ^{32}P, ^{45}Ca and ^{35}S was applied to the sloping mulberry fieled in band along the contour line, and the movement of the phosphate, calcium and sulphate ions was examined one month and a half later. The figure and autoradiogram show that sulphate ion moves to the farthest area from the place where it was applied followed by calcium ion, and phosphate ion moves little.

It is understood from these results that superphosphate applied to the crops with wide root zones, as the mulberry tree, in band can contact with only a limited number of roots, and the positional availability, an optnion put forward by Fraps (1906), is extremely low.

Accordingly it is necessary to investigate where the mulberry tree actively absorbs nutrients in various (mulberry) fields. The mulberry tree usually absorbs nutrients most actively from the soil of 10-20 cm in depth in the field of alluvial soil or red and yellow soils, while the zone differs with the yearly distribution of rainfall in the volcanic ash soil, being active at a depth to 15 cm in one year and in the layer of 15-30 cm or deeper in another.

The positional availability and thereupon the absorption rate can be raised by the application of phosphorus to the actively absorbing zone. Further investigations, however, are needed for the effective application of phosphorus to the wide sphere of the root zone. For example, mulching of the field with organic matters promotes active absorption of nutrients by the mulberry tree from the surface layer of soil.

The application of phosphorus and nitrogen in mixture with organic matters is also a good way to raise the effect of phosphorus because the roots are active in the absorption of nutrients in and around the organic matters, and develop well in case nitrogen is kept at a favorable concentration.

Adsorption of phosphorus by the mulberry tree

The mulberry tree needs phosphorus not only in the early period of the growth but also in the later period as shown by water culture, so it is desirable to supply it sufficiently through the entire period of the growth. The harvesting season of leaves and branches falls on the period of maximum growth in the mulberry tree, and the absorption of nutrients by the tree is suspended for one to one and half month after the harvest.

The suspension was investigated by labeling the field with ^{32}P as shown in Fig. 3. This is a result of pruning practiced in a summer in neighboring place of Tokyo. The

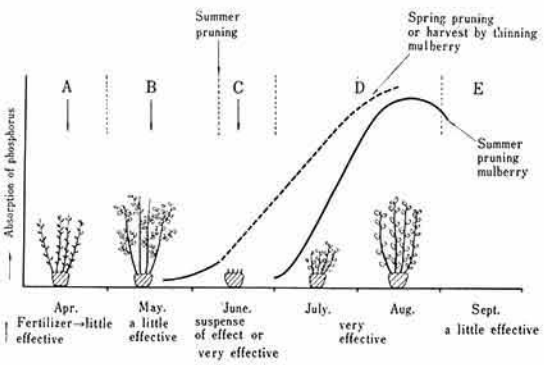

Fig. 3. Effect of harvest of mulberry tree on absorption of phosphorus from the field

absorption of phosphorus becomes active from the middle or latter part of May in spring, and suspends for about one month after the summer pruning at the early part of June. It becomes again markedly active from the middle part of July accompanied with the growth of new shoots.

In the figure, "C" represents the physiological disorder induced by the cut of all the branches at the same time in the period of maximum growth. The shock at "C" can be kept off, when several branches are left

without cutting for use in summer rearing.

Active absorption continues in the tree thus treated even in the stage "C" and "D" as shown by the broken line, resulting in raising the absorption rate of phosphorus.

Enrichment of soil with phosphorus.

As mentioned at the beginning, the mulberry tree depends on the soil for more than 90% of its necessary phosphorus. Accordingly it is important to enrich the soil with phosphorus.

The soil of the mulberry field is different from that of the ordinary field in management, that is, the trees planted keep for many years their positions, and management is usually practiced between the rows in their direction. When mulberry trees are planted a large quantity of organic matters is often applied to the planting trench in Japan. And in many cases fertilizers are also applied in band in between the row so the subsoil is apt to become acidic locally as shown in Fig. 4. Both total and available phosphorus are distributed much in the surface layer of soil and less in the subsoil. Available phosphorus is especially little in amount in the acidic part of the subsoil. Therefore, it is necessary to increase the amount of (available) phosphorus in the subsoil of mulberry fields. Application of a large quantity of phosphorus at the time of planting or renewal of mulberry trees is important to increase the amount of available phosphorus in the subsoil and to have a good harvest of mulberry leaves.

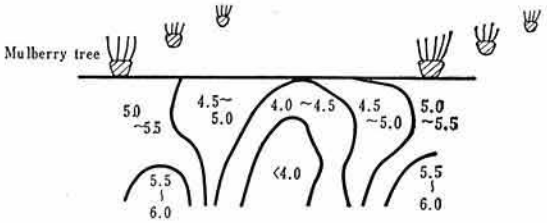

Fig. 4. Distriibution of PH (H_2O) in mulberry field soil profile.