# Effect of Phosphorus Fertility of Soils and Phosphate Application on Lowland Rice

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Generally, phosphate application to paddy fields is not so effective in increasing grain yields. However, it was reported that phosphate application was very important in cool regions[2] and very effective in the fields derived from volcanic ash soil[3] and furthermore grain yields began to decrease after many years of cultivation without phosphates even in warm regions[1]. The effect of phosphate application is variable according to the phosphorus fertility of soils and climatic conditions. The availability of soil phosphorus changes under flooded conditions, being influenced by soil temperature. Consequently, to find out the most effective methods of phosphate application or management of phosphorus fertility of soils, it is necessary to know the changes of phosphorus availability under flooded conditions as well as the responses of rice plants to the available phosphorus in soils under different climatic conditions.

## Measurement of phosphorus supplying ability of paddy soils

Seventeen soils including alluvial, peat and volcanic ash soils with various phosphorus fertility were used. To measure the phosphorus supplying ability of these soils, a pot culture experiment using $^{32}P$ under a flooded condition and a seedling test without phosphate application under flooded and upland conditions were carried out. The amounts of native phosphorus taken up by rice plants were determined. The tendency of the phosphorus uptake in the pot culture was similar to the one in the seedling test under a flooded condition.

Amounts of phosphorus extracted from air-dried soils and the soils flooded for the same period as in the seedling test with seven soil test solutions, i.e., 0.2 N HCl, the Bray No. 2, 2.5% acetic acid, Truog, the Bray No. 1, Morgan, and Olsen method, which were arranged from low to high in pH, were determined. Phosphorus concentrations in the equilibrium solution with air-dried soils and flooded soils were also measured.

Correlation coefficients between the phosphorus uptake by rice plants and amounts of phosphorus extracted with these solutions are indicated in Table 1. Correlations between the phosphorus uptake from the flooded soils and the amounts of phosphorus extracted from the air-dried soil were not so high except for the Olsen method in which the correlation coefficient was 0.77. However, these correlations were clearly improved when low pH extractants were applied to flooded soils. The highest value of correlation coefficient was 0.90 with the Bray No. 2 extraction in the pot experiment and 0.91 with 2.5% acetic acid extraction in the seedling test.

In the seedling test, more amount of phosphorus was taken up under the flooded condition than the upland condition in the majority of the soils. Correlations between the ratios of the amounts of phosphorus taken up from flooded soils to the ones from upland soils and the ratios of the amounts of phosphorus extracted from flooded soils

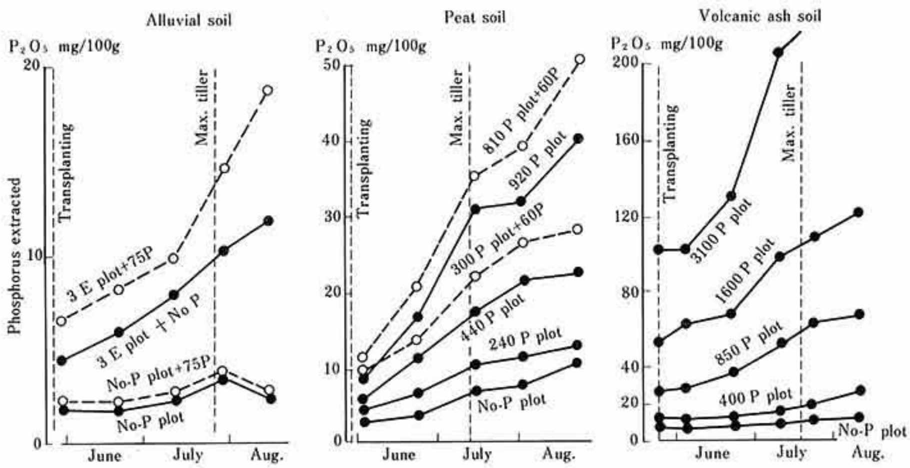
**Table 1. Correlation coefficients between the phosphorus uptake by rice plants and the amounts of phosphorus extracted with soil test solutions**

| Conditions of rice cultivation | Pot culture under flooded | | Seedling test in beaker under flooded | | Seedling test in beaker under upland |
|---|---|---|---|---|---|
| Soil conditions at the time of extraction | Air-dried | Flooded† | Air-dried | Flooded† | Air-dried |
| N/5 HCl | 0. 33 | 0. 83*** | 0. 25 | 0. 57 | 0. 49 |
| Bray No. 2 | 0. 59* | 0. 90*** | 0. 35 | 0. 71** | 0. 73** |
| 2. 5% acetic acid | 0. 61* | 0. 82*** | 0. 37 | 0. 91*** | 0. 84*** |
| Truog | 0. 66* | 0. 79** | 0. 37 | 0. 75** | 0. 87*** |
| Bray No. 1 | 0. 56 | 0. 64* | 0. 30 | 0. 68* | 0. 79** |
| Morgan | 0. 73** | 0. 61* | 0. 66 | 0. 73** | 0. 78** |
| Olsen | 0. 77** | 0. 58 | 0. 52 | 0. 43 | 0. 90*** |
| Equilibrium [P] | 0. 27 | 0. 41 | 0. 33 | 0. 69* | 0. 66* |
| log [P] | 0. 57 | 0. 60* | 0. 55 | 0. 90*** | 0. 74*** |

† Flooded at 30°C for 30 days.

to the ones from air-dried soil were high when dilute acidic solutions were applied for the extraction.

These results indicated that dilute acidic solutions such as the Bray No. 2 or 2.5% acetic acid can probably be used to estimate the phosphorus supplying ability of paddy soils, when the soils are under the similar conditions to the soils on which rice plants are growing.




Legend (1) Plot : Field plots with different amount of P applied in previous years prior to the experiment (39 years for the alluvial soil, 7 years for peat soil and 4 years for volcanic acid soil).
3 E plot : NPK applied
No-P plot : No P applied
240 P plot, 300 P plot,...... : 240 kg/ha, 300 kg/ha......of $P_2O_5$ applied.
(2) + : Figures prefixed with + indicate $P_2O_5$ kg/ha applied at the year of experiment.

Fig. 1. Amounts of phosphorus extracted with Bray No. 2 solution from various kinds of flooded soils under field conditions

## Changes of the amount of extractable phosphorus in various soils under field conditions in Hokkaido[6]

Amounts of phosphorus extracted with the Bray No. 2 and the 2.5% acetic acid solutions from flooded soils were determined at the successive growth stages of rice plants in three kinds of experimental fields, i.e., alluvial soil, peat soil and volcanic ash soil, composed of several plots with different amounts of phosphate applied in previous 39 years.

Extractable phosphorus content in flooded soils clearly increased during the tillering stage (Fig. 1). Soil pH and ferrous iron content also increased, indicating that reduction of flooded soil had started from an early growth stage even in the cool regions. Amounts of phosphorus extracted with both methods corresponded to the amount of phosphorus applied to each plot in previous years.

## Phosphorus content and growth of rice plants as related to the amounts of phosphorus extracted from flooded soil

Number of tillers in the tillering stages and phosphorus contents at various stages of growth corresponded to the amounts of phosphorus extracted with both methods. The phosphorus contents of rice plants during the tillering stage could explain well the differences of growth and indicated relatively stable values in each treatment. Relationships between phosphorus contents of rice plants at around the maximum tillers stage and the amounts of extracted phosphorus at two different stages were indicated in Fig. 2.

Logarithmic curves were obtained between the phosphorus contents and the amounts of extracted phosphorus at each stage. However, large variations were observed in the relationship when the soils at the transplanting stage were used, in which the amounts

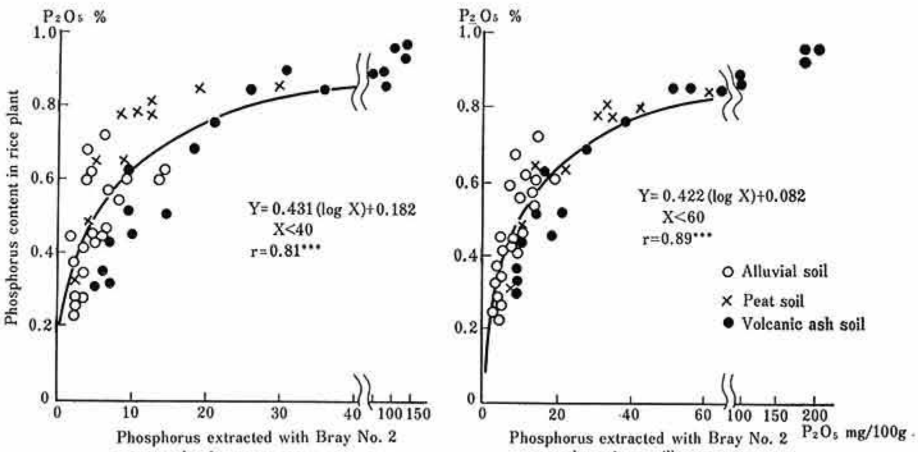



Fig. 2. Relations between the amounts of phosphorus extracted with Bray No. 2 solution at different stages of growth and the phoshorus contents of rice plants at around the maximum tillers stage

of extracted phosphorus were almost the same as ones extracted from the soils under upland conditions. The correlation was clearly improved by extracting phosphorus from the reduced soils at around the maximum tillers stage. The correlation coefficient of the latter was 0.89 in case of the Bray No. 2 extraction within the range of the rectilineal relation. With 2.5% acetic acid (Fig. 3) the correlation coefficient was 0.93. The relatively low correlation in the Bray No. 2 extraction was due to the high value of extracted phosphorus in the volcanic ash soils. The results confirmed the previous conclusion obtained from the seedling test and pot experiment, indicating that the 2.5% acetic acid extraction might be better than the Bray No. 2 extraction at the tillering stage under field conditions when various kinds of soil were included.

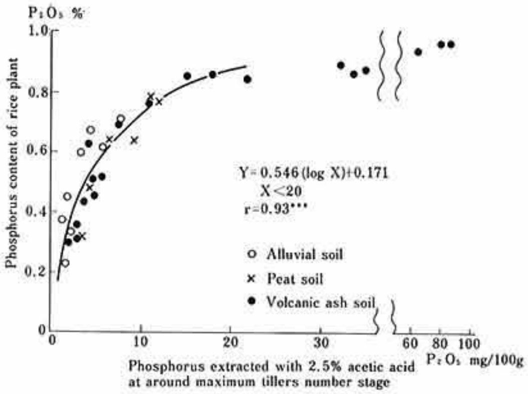



Fig. 3. Relations between the amounts of phosphorus extracted with 2.5% acetic acid solution and the phosphorus contents of rice plants at around maximum tillers stage

## Relationships between growth, grain yields and phosphorus contents of rice plants

Tiller numbers per unit area at the maximum tillers stage increased until the phosphorus content of rice plants reached around 0.8% $P_2O_5$. Panicle numbers and grain yields, however, reached the upper-most limit

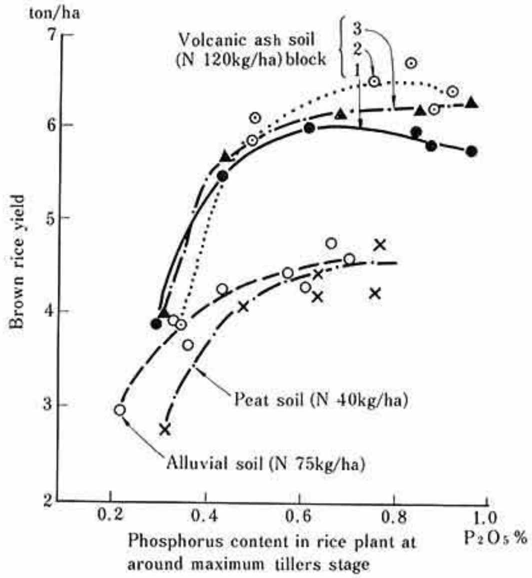



Fig. 4. Relations between the phosphorus contents of rice plants at around maximum tillers stage and grain yields

as the phosphorus contents at the maximum tillers stage reached 0.6~0.7% (Fig. 4).

## Phosphorus fertility of soils and efficient phosphate application

Amount of extractable phosphorus required for increasing $P_2O_5$ content of plants to 0.65%, an intermediate value of 0.6~0.7%, at around the maximum tillers stage was computed to be 22 mg $P_2O_5$/100 g dry soil in the case of the Bray No. 2 solution and 7.6 mg in the 2.5% acetic acid solution by using the regression equations in Fig. 2, 3 and 4. The grain yields in the plots, where the amounts of extractable soil phosphorus were around these values, approached the upper-most limits in each experiment (Fig. 5). As a result, it is estimated that the level of soil phosphorus fertility required for getting an ordinary level of grain yield in a cool region is around 22 mg $P_2O_5$/100 g dry soil in the Bray No. 2 extraction and around 7.6 mg in the 2.5% acetic acid extraction when the flooded soils at about maximum tillers stage are used.

An example in which various amounts of

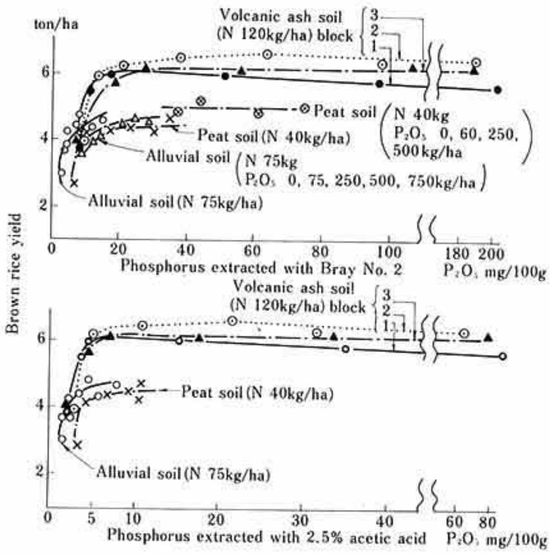



Fig. 5. Relations between the amounts of phosphorus extracted from flooded soil at around maximum tillers stage and grain yields

phosphate were applied to the field with low phosphorus fertility was illustrated in Fig. 5. The tendency of the increase of the grain yields resembled to the ones of the experiments without phosphate application, corresponding similarly to the amount of phosphorus extracted. No response of grain yields to the phosphate application occurred in the fields where the phosphorus extracted was over 30 mg $P_2O_5$/100 g dry soil with the Bray No. 2 solution, as indicated in Fig. 5.

These results suggest that phosphate fertilizer should be applied with an aim of raising the extractable phosphorus to the critical level indicated above, in order to get higher grain yields with efficient use of the fertilizer in a cool region.

## Regional differences in yield respone to phosphorus fertility

It was reported that the phosphorus content of rice plants at the tillering stage required for getting a sufficient number of panicles was 0.45% $P_2O_5$ in the Tōhoku district[3,7], slightly warmer than Hokkaido, and that, in Hiroshima Prefecture of south-western Japan, grain yields reached the upper-most limit when amounts of phosphorus extracted by the Bray No. 2 solution from flooded soil were 5~6 mg $P_2O_5$/100 g dry soil. This suggests that a lower level of extractable phosphorus might be enough in warmer regions. Further experiments will be needed to find out accurately levels of phosphorus fertility desirable in each region.

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