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RHIZOSPHERE INFLUENCE AS AN EXPLANATION FOR THE LACK OF RESPONSE OF LOWLAND RICE TO PHOSPHATE FERTILIZATION

A.K. ALVA, S. LARSEN and S.W. BILLE

Department of Soil Fertility and Plant Nutrition, The Royal Veterinary and Agricultural University, Thorvaldsensvej 40, Entrance 8, Copenhagen V, Denmark

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Summary

Our recent investigation on P transformations in lowland rice rhizosphere revealed that P is being mineralized during the early growing period followed by its immobilization. This has a significant role in P nutrition of lowland rice. The extent of respective processes depends on crop growth (P requirement) and level of P application (P availability). Such a regulatory mechanism, apparently due to unique physiological characteristics of lowland rice plants, is mainly responsible for the lack of response of lowland rice to P fertilization.

We want to report an experiment which may shed light on the well-known fact that lowland rice generally does not respond to phosphate fertilization[1]. Neither soil test data nor phosphate fractionation studies in submerged soils have shed much light on the underlying mechanism. The studies conducted so far have led to the conclusion that increase in available phosphate in flooded soils, due to reduction of ferric phosphate and hydrolysis of phosphate compounds, is the reason for the poor response of lowland rice to phosphate fertilization. However, not much attention has hitherto been given to the influence of rice plants on the availability of phosphate in flooded soil.

The present study shows that phosphate in flooded soils under rice cultivation, undergoes various changes during the growing period due to the presence of roots, and this has a remarkable influence on the phosphate nutrition of lowland rice crop. Brackish water alluvial soil, a lowland paddy soil of pH 4.2 was taken from Klong Luang, Thailand, and sandy, loamy soil, a well drained soil of pH 7.3 was from Denmark. Both soils were treated with 0, 30 and 60 ppm P (super phosphate 7.9%)

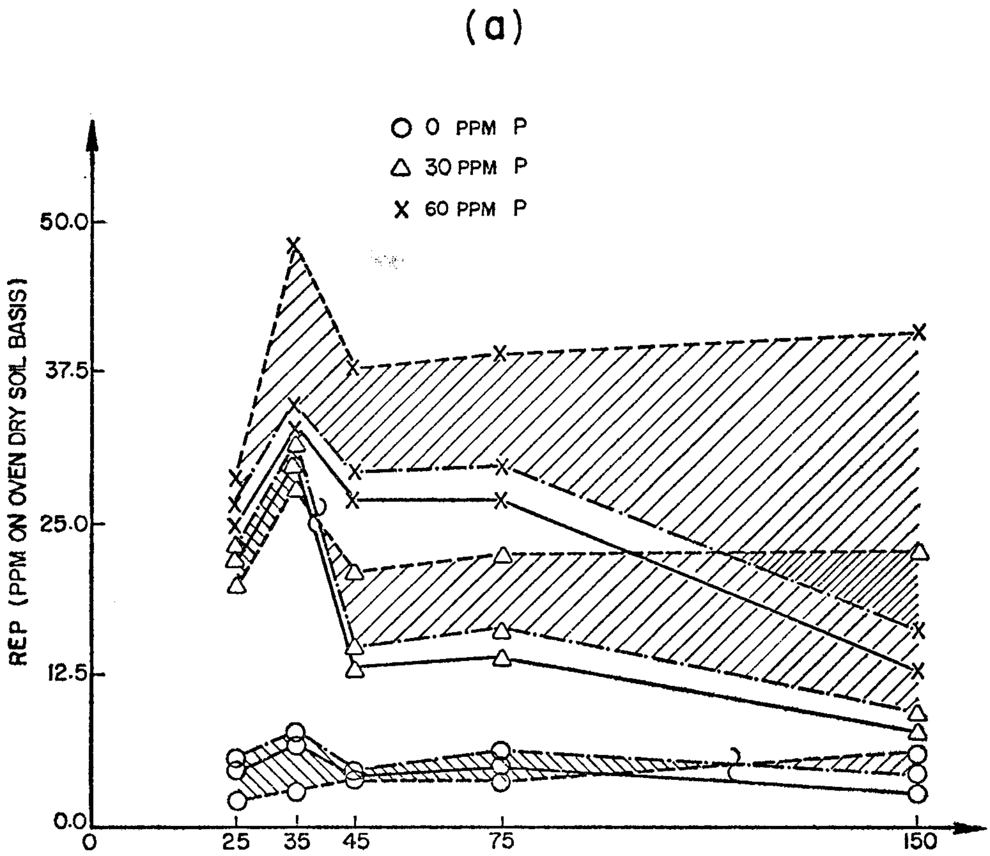
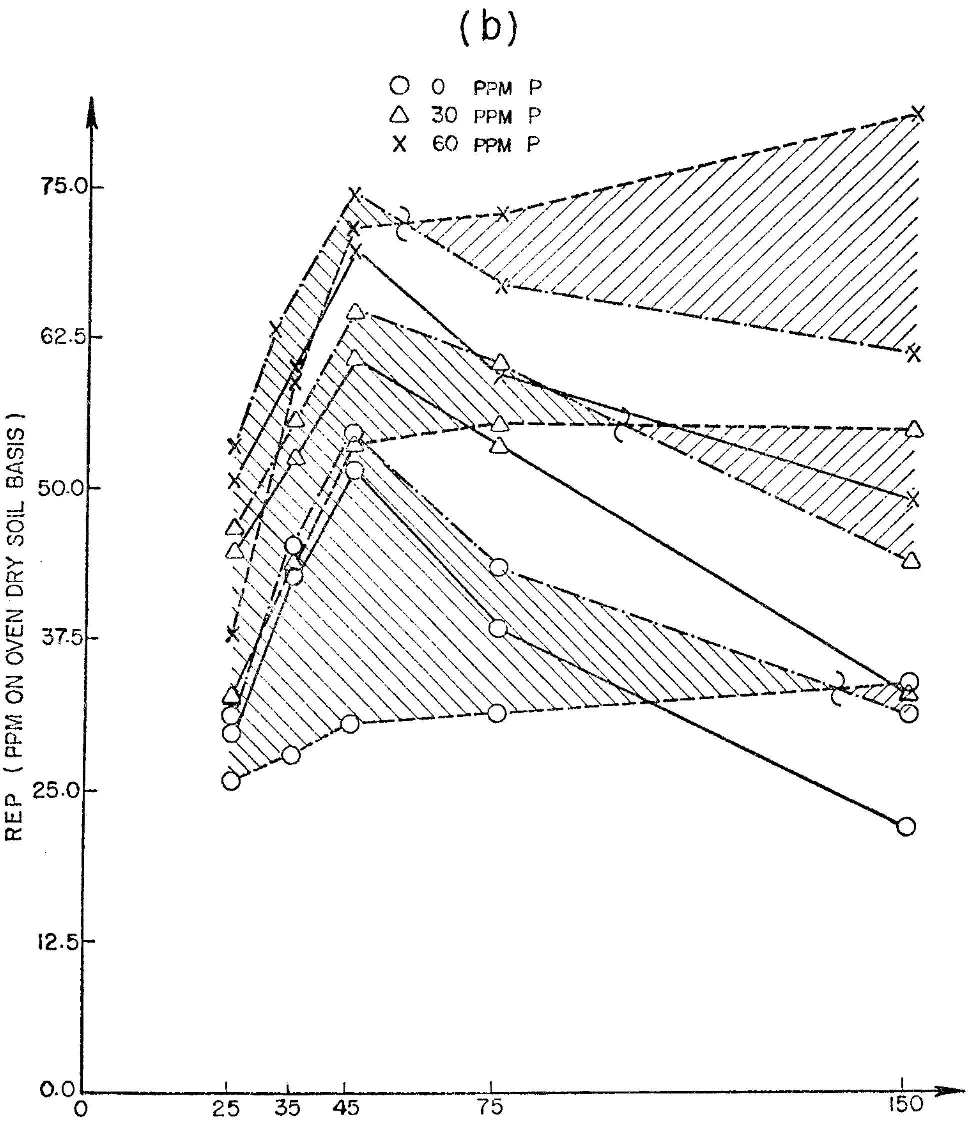


Fig. 1. Resin extractable phosphate (REP) in (a) brackish water alluvial soil, a lowland paddy soil from Klong Luang, Thailand, pH 4.2 and (b) sandy loamy soil, a well drained soil from Denmark, pH 7.3. REP in uncropped soil, cropped soil, and cropped soil plus P uptake by the plants are shown by (– – – – – –), (————) and (–.–.–.–) curves, respectively. The mobilization and immobilization of P are indicated by (\\\\\\\\\) and (///////////) marked areas, respectively, with the sign (≀) showing the transition point from P mobilization to immobilization.


(b)
O 0 PPM P
△ 30 PPM P
X 60 PPM P
REP (PPM ON OVEN DRY SOIL BASIS)
75.0
62.5
50.0
37.5
25.0
12.5
0.0
0
25
35
45
75
150

and puddled. Rice seedlings (variety RD–1, 30 days after emergence) were then transplanted. Standing water (5 cm) was maintained throughout the growing period. Soils were identically treated, but for the absence of crop, and incubated under flooded condition. Soil samples were taken 25, 35, 45, 75 and 150 days after transplanting from cropped and uncropped soils, and resin extractable phosphate (REP) in moist soil was determined by following the resin bag technique[2]. Simultaneously, plant samples were also taken to determine P uptake by the plants at each sampling time From Fig. 1a and b it may be seen that the amount of REP increased until 5–7 weeks, depending on the soil, after flooding. This is probably due to the reduction of ferric phosphate and hydrolysis of phosphate compounds. During the later period the available phosphate showed little change in the alkaline soil, while in the acid soil there was a high rate of phosphate refixation.

The curves showing REP in cropped soil plus phosphate uptake by the plants at each level of phosphate compared to REP curves for the uncropped soil at the respective levels form the basis for identifying the influence of cropping on REP (Fig 1a and b). Apparently, the presence of rice plants mobilized phosphate during the initial growing period followed by its immobilization later during the growing period. The period of the respective processes depended on phosphate levels as well as the soil types. With the increasing phosphate levels the mobilization decreased, while immobilization increased. These contrasting changes in the available phosphate in cropped soils is due to the presence of growing roots and therefore referred to as "rhizosphere influence".

The presence of growing roots encourages physiologically more active microflora[3,4]. The phosphate availability under submerged soil conditions is mainly governed by the solubility of iron phosphate[5]. Several studies on fractionation of the inorganic phosphorus in submerged soils have revealed the dominance of iron phosphate[1]. The reduction of iron phosphate is a consequence of anaerobic metabolism of bacteria and chiefly a chemical reduction by bacterial metabolites[6]. Thus, with the increasing soil microflora due to the presence of growing roots the reduction of ferric phosphate is faster, resulting in an increased mobilization of phosphate as compared to uncropped soils.

On the other hand, rice being an aquatic plant is capable of translocating oxygen from the aerial parts to the root system. During the later part of the growing period the translocation of oxygen is so rapid, that a part of it is excreted into the rhizosphere. Thus, in this oxygenated rhizosphere, ferrous iron is oxidized to ferric iron, consequently phosphate is being immobilized by co-precipitation with ferric oxide.

Apart from the fact that the presence of rice plants in flooded soils induces mobilization and immobilization of phosphate, it is also evident that these two processes are governed by the phosphate uptake by the crop and the level of available and applied phosphate. That is to say that a prolonged mobilization of phosphate at lower levels of phosphate application (0 and 30 ppm P) enables the rice plants to meet their phosphate requirement. Conversely, the excess of applied phosphate at higher phosphate level (60 ppm P) is being immobilized during the prolonged period of immobilization.

The capacity to regulate the extent of phosphate mobilization and immobilization seems to be a unique physiological phenomenon of lowland rice plants and probably of other aquatic plants This is the main reason for the little or no response of lowland rice to phosphate fertilization. A fuller report of the above work will be published elsewhere.

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บทคัดย่อ

พบว่า P transformations ในบริเวณ rhizosphere มี P mineralization ในขณะที่พืชยังมีอายุน้อย แล้วจึงตามด้วย P immobilization ปรากฏการณ์นี้มีบทบาทสำคัญต่อการใช้ P ของข้าวมาก และขึ้นกับการเจริญเติบโตของข้าวอันมีผลไปถึงระดับความต้องการ P และยังขึ้นอยู่กับการใส่ปุ๋ย P อันจะมีผลไปถึงการใช้ available P ของข้าว ดังนั้นอาจสรุปได้ว่า ข้าวที่ปลูกกันในที่ลุ่มมีลักษณะทางสรีรวิทยาที่เด่นออกไป คือตอบสนองต่อปุ๋ย P น้อย