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PHOSPHORUS FIXATION BY DIFFERENT CLAY MINERALS AS AFFECTED BY PHOSPHORUS SOURCES AND WATER REGIMES

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Phosphorus (P) fixation by clay samples containing montmorillonite (90%), beidellite (90%), vermiculite (90%), kaolinite (50-90%) and x-ray amorphous material as affected by P sources and water regimes was studied in the laboratories of Land Resources Section, National Agricultural Research Centre, Islamabad, Pakistan. Fixation of P was significantly greater in case of alternate flooding and drying than that for continuous flooding. Fixation was the least in case of montmorillonite and the maximum in case of x-ray amorphous material. However, there were non-significant differences in P fixation among x-ray amorphous material, beidellite, vermiculite and kaolinite. There was non-significant difference in P fixation from ammonium dihydrogen phosphate, potassium dihydrogen phosphate and calcium monohydrogen phosphate P sources.

INTRODUCTION

Only a portion of P fertilizers (5-20%) applied to supplement P supply in P deficient soils is used by the current crop while the rest being retained (fixed) by the soil (Hagin and Tucker, 1982). The so-called fixation of P by the soil is considered a serious problem, because it diminishes the short term efficiency of the fertilizer. Many factors are responsible for P fixation in various soils.

Ideally rice is grown under flooded lowland conditions. But due to the shortage of water, rice fields are subjected to alternate flooding and drying. Phosphorus fixation under alternate flooding and drying conditions has been studied by various researchers and it has been shown that P applied to the soil during a flooding and drying sequence is immobilized (Smith, 1969; Simpson and Williams, 1970) and P availability has been found to decrease within 7 days of flooding. Smith (1969) described this due to the transfer of P from an aluminium to an iron phosphate during the period of flooding. Simpson and Williams (1970) considered that P was immobilized by iron hydroxide gel formed after drying. Willet (1979) gave identical view.

Clay mineralogy of the upland rice soils has been identified by Bajwa (1982) and P fixation studied under upland rice conditions. The objective of this study was to investigate fixation of P by some clay minerals from different P sources under different watering regimes.

MATERIALS AND METHODS

This study was conducted in the laboratories of Land Resources Section, National Agricultural Research Centre, Islamabad. Clay minerals from 14 tropical rice soils of Philippine were identified by Bajwa (1982). Five clay samples predominantly containing montmorillonite (90%), beidellite (90%), vermiculite (90%) kaolinite (50-90%) and x-ray amorphous material were included in this study. One gram of each clay sample was taken in triplicate in 250 ml conical flasks. Sources of P used were $NH_4H_2PO_4$, KH_2PO_4 and $CaHPO_4$. Phosphorus treatment included P addition @ nil and 100 ppm in solution to various conical flasks. After the addition of P solution, all the flasks were covered with polyethylene and shaken for two hours on a shaker. Two moisture regimes were then created by adding additional 10 ml of distilled water to one set of the flask and the other set was left as such. The set receiving additional 10 ml water was kept continuously flooded by maintaining the water level. The other set was allowed to dry and then watered by adding 10 ml of water. In all the four cycles of drying and watering were used in this watering regime designated as alternate flooding. During the experimental period all the flasks were incubated at a constant temperature of 30 °C. The experiment was organized in a split plot design with moisture regimes in the main plot, soils in subplots and P sources in the sub-sub-plot. After 150 days, available P was extracted by 0.5 M $NaHCO_3$ (Olsen *et al.*, 1954) and P not extracted was considered as fixed P.

RESULTS

From the results (Table 1), it is quite evident that different treatments exhibited different effect on P fixation. different clay minerals varied in their abilities to fix P under the two watering regimes. Under continuous flooding, fixation ranged from 51.0 to 75.8% with a mean of 68.2%. Whereas under alternate flooding, it ranged from 79.9 to 86.0% with a mean of 83.9%. The overall fixation was significantly greater under alternate flooding than under continuous flooding. Under continuous flooding the order of P fixation by different clay minerals was: x-ray amorphous > beidellite > vermiculite > kaolinite > montmorillonite. Thus fixation was maximum in x-ray amorphous material and it was the least in case of montmorillonite.

Under alternate flooding and drying the differences in P fixation were not so great. However, like continuous flooding, montmorillonite fixed the least and x-ray amorphous material fixed the maximum amount of P. Virtually there was very little difference in P fixation among beidellite, vermiculite and kaolinite under alternate flooding. The overall P fixation was maximum in case of x-ray amorphous material (80.4%). However, the difference in P fixation among x-ray amorphous material, beidellite (78.5%), vermiculite (77.7%) and kaolinite (77.3%) were non-significant. Significantly the lowest fixation (66.3%) occurred in case of montmorillonite. As regards the effect of different P sources on P fixation, there was no significant difference among potassium dihydrogen phosphate, ammonium dihydrogen phosphate and calcium monohydrogen phosphate.

DISCUSSION

Rice is mostly grown under submerged conditions, but in areas where the irrigation water is scarce, rice growers resort to alternate flooding and drying. The results of this study revealed that P fixation by different clay minerals was significantly greater under alternate flooding than that under continuous flooding. These results agree with those of Smith (1969) and Simpson and Williams (1970). These authors found a decrease in P availability with drying period of 1-7 days. Smith (1969) ascribed this to the transference of P from an aluminium to iron phosphate during the drying period. Conversely Simpson and Williams (1970) considered this due to immobilization by iron oxide gel formed after drying. Increased P fixation under alternate flooding and drying

Table 1. Phosphorus fixation (%) by different clay minerals as affected by phosphorus sources and water regimes

P source	Continuous flooding					Mean for P sources	Alternate flooding					Mean for P sources
	S1	S2	S3	S4	S5		S1	S2	S3	S4	S5	
KH_2PO_4	54.9	71.9	69.7	69.4	75.7	68.3	80.1	84.9	83.8	84.8	85.2	83.8
$NH_4H_2PO_4$	51.0	72.9	72.3	70.6	75.8	68.5	79.9	84.2	83.3	85.1	85.0	83.5
CaH_2PO_4	51.4	71.4	72.4	68.9	74.8	67.8	80.9	85.5	84.8	85.2	86.0	84.5
Mean for clay minerals	52.4	72.1	71.5	69.6	75.4		80.3	84.9	84.0	85.0	85.4	
Mean for water regimes			68.2 b						83.9 a			

Clay minerals	Overall means for clays: S1	S2	S3	S4	S5	P source	Overall means for P sources: KH_2PO_4	$NH_4H_2PO_4$	$CaHPO_4$
P fixation (%)	66.3 b	78.5 a	77.7 a	77.3 a	80.4 a	P fixation (%)	76.0 a	76.0 a	76.2 a

S1 = Montmorillonite (90%); S2 = Biedellite (90%); S3 = Vermiculite (90%); S4 = Kaolinite (50-90%); S5 = x-ray amorphous.

has also been reported by Mandal and Khan (1975).

On the other hand, continuous flooding resulted in significantly lesser fixation than alternate flooding. This lesser fixation has been attributed to decreased P sorption (Roy and De Datta, 1985). Thus rice crop can be benefitted due to increased P availability in rice soils where $CaCO_3$ is absent (Broeshart *et al.,* 1965). This enhanced availability of P under flooded soils has been attributed to release of ferric-bonded P.

The maximum P fixation occurred in case of x-ray amorphous. Anyhow, there was non-significant difference in P fixation among x-ray amorphous material, beidellite, vermiculite and kaolinite, which followed the order. All of these minerals are believed to be the high fixers of P. However, non-significant differences in P fixation due to various P sources need further investigations.

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