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Effect of Intensive Cropping and Fertilizer Use on the Inorganic Forms of Phosphorus in a Typic Ustochrept Soil

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An investigation was made to see the effect of seven years of multiple cropping and soil test based fertilizer use on the inorganic forms of phosphorus in a Typic Ustochrept soil. Under unmanured cultivation, the depletion of the phosphorus forms as compared to fallow soil, followed the order : reductant soluble-P (39.4%) > iron-P (22.7%) > saloid bound-P (22.0%) > aluminium P (15.2%) > calcium P (9.2%). Nitrogen alone further accelerated the loss of reductant soluble P. Addition of phosphate raised the level of all the forms including the occluded-P. FYM enhanced the saloid bound form and superphosphate that of Al-P. There was a progressive build up of P in aluminium bound and reductant soluble fraction with the raise in graded doses of phosphate.

Several researches (Thomas and Peaslee, 1973; Singh *et al.*, 1977; indicated that aluminium and calcium bound phosphates were the available forms in acidic range of soil pH and saloid bound, aluminium and to some extent iron phosphates in neutral and alkaline conditions. Soon after the application of soluble phosphate, Ca-p and Al-P are more likely to be formed because of their higher ion activity but with time there will be gradual transformation into Fe-P which is the least soulable (Chang and Jackson, 1958; Chang and Chu, 1961). However, in neutral and calcareous soils which are subjected to regular application of phosphate, Ca-P predominates (Werner and Wiechman, 1972 Fuleky, 1975). With passage of time, Fe and Al-P get occluded in iron oxide coatings (Chang and Jackson, 1958; Chang and Chu, 1961; Shelton and Coleman, 1968). However, in some long term trials there has been no appreciable change in the content of occluded-P (Manning and Salomon, 1965; Raju).

In view of this, an investigation was undertaken to see the effect of intensive multiple cropping and soil test based fertilizer additions on the inorganic fractions of phosphorus in a slightly alkaline alluvial soil (Typic Ustochrept).

MATERIAL AND METHODS

A long term fertilizer experiment at the Indian Agricultural Research

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Institute Farm, New Delhi was initiated in winter 1971 under an All India Coordinated Research Project (I.C.A.R) with a fixed rotation of pearl millet (*Pennisetum typhoides*), wheat (*Triticum aestivm*) and cowpea (*Vigna sinensis*) in sequence The soil was sandy loam in texture (clay 15%, silt 16% Sand 69%). slightly alkaline in reaction (pH 8 0) and low in free calcium carbonate (0.85%) and CEC (10.6 me/100g). The soil belongs to Mehrauli series under the family Typic Ustochrept. Analysis of the soil clays isolated from an adjoining area had revealed the predominance of illite along with the presence of kaolinite, chlorite and chloritized montmorillonite (Ghosh, 1964). Initial soil test values of the experimental area showed that it was low in organic carbon (0.44%) while medium in available P (16 kg/ha) and available K (155 kg/ha).

The experiment was laid out in a randomised block design with 10 treatments (Table I) replicated four times and the plot size was 21m × 8m. The optimum recommended NPK being 120 : 60 : 40 for pearl millet and wheat and 20 : 40 : 20 for cowpea. Chemical weed control measures were taken up in case of wheat and pearl millet crops in all the plots except the one where hand weeding was done (T_4). The other details of the experiment were described elsewhere (Subba Rao and Ghosh, 1980). In May 1978, after seven years of continuous cropping, soil samples were collected from individual plots to a depth of 15 cm using a sampling tube. Four comparable samples were also drawn from an adjacent fallow land. Fractions of inorganic phosphorus were determined according to the method of Chang and Jackson (1957) as outlined by Peterson and Corey (1966). The P in the different extractants was estimated by ascorbic acid method (Watanabe and Olsen, 1965) with suitable modifications to avoid interferences (John, 1970). The P in the plant samples was determined by vanadomolybdic yellow colour method after digesting the samples with nitric acid and perchloric acid (Jackson, 1973).

RESULTS AND DISCUSSION

The high level of production maintained in the intensive multiple cropping system can be judged from the average dry matter yield, well over 11.0 tonnes per year, obtained from three crops viz., pearl millet, wheat and cowpea (Table I) in all the treatments except control. The uptake of P by a rotation including all the three crops and the amounts added through fertilizers have been presented in Table I. The amounts of P removal were far less than the amounts added, especially in 150 per cent NPK and 100 per cent NPK plus FYM treatments. Hence, there has been a greater scope for the accumulation of P in the soil.

The data pertaining to the inorganic fractions of P in the soil

TABLE I Additions and removal of phosphorus and inorganic phosphorus fractions in soil under intensive multiple cropping.

Treatment	Drymatter t/ha (8 years mean)	P in kg/ha (8 years mean)		P in kg/ha (after 7 years of cropping)					
		Additions	Removal	Saloid bound-P	Aluminium-P	Iron-P	Calcium-P	Reductant soluble P	Occluded-P
50% of the optimum NPK	11.2	35.0	20.4	16.1	64.9	97.4	321.5	76.2	39.5
100% of the optimum NPK	13.9	70.0	26.8	21.4	80.1	104.7	365.4	95.2	47.9
150% of the optimum NPK	15.6	105.0	30.5	24.2	91.9	110.9	391.1	141.1	49.0
100% of the optimum NPK and hand weeding	13.9	70.0	26.2	20.7	78.4	108.7	355.9	98.6	49.6
100% of the optimum NPK plus 10 kg $ZnSo_4$/ha (only to wheat)	14.0	70.0	26.3	23.1	80.6	100.0	355.9	96.3	49.3
100% of the optimum NP	13.2	70.0	25.1	22.5	85.7	105.8	361.8	98.0	45.8
100% of the optimum N	11.2	0	19.2	11.5	47.1	56.5	278.9	39.8	32.8
100% of the optimum NPK plus FYM 15 tonnes/ha (only to pearl millet)	14.9	97.0	29.1	24.9	84.6	100.3	356.2	95.8	45.1
100% of the optimum NPK with sulphur (P and S through single superphosphate)	14.7	70.0	28.1	19.2	93.6	101.9	370.7	94.1	49.9
Control (no fertilizer)	7.3	0	12.4	10.9	43.7	54.3	286.7	49.9	33.1
S.Em. (±)	—	—	—	1.22	3.52	3.81	11.31	3.44	1.69
C.D. at 5% level	—	—	—	3.5	10.2	11.0	32.8	10.0	4.9
Fallow	—	—	—	14.0	51.5	66.6	315.8	82.3	33.8

TABLE II Correlations between phosphorus fractions and crop yield and per cent P

Phosphorus fraction	'r' value					
	Cowpea (dry fodder)		Pearl millet (dry matter)		Wheat (grain)	
	Yield	Per cent P	Yield	Per cent P	Yield	Per cent P
Saloid bound-P	0.800**	0.758**	0.820**	0.860**	0.732**	0.774**
Aluminium-P	0.710**	0.765**	0.750**	0.807**	0.741**	0.602**
Iron-P	0.640**	0.770**	0.791**	0.829**	0.760**	0.664**
Calcium-P	0.570**	0.624**	0.650**	0.663**	0.640**	0.831**

** Significant at 1% level

determined after seven cycles of multiple cropping has been presented in Table I. In this slightly alluvial soil Ca-P was the predominent fraction followed by reductant soluble P, Fe-P Al-P, occluded-P and saloid bound P As reported by some investigators (Singh *et al.*, 1977;) cropping alone depleted all the four active forms viz., saloid bound-P (22.2%), Fe-P (22.7%), Al-P (15 2%) and Ca-P (9.2%) in comparison to an adjacent fallow soil. The greater crop removal of saloid bound P, Fe-P and Al-P in relation to Ca-P is in line with the findings on neutral and alkaline soils (Thomas and Peaslee, 1973; Singh *et al.*, 1977). Interestingly, the relatively inert reductant soluble-P has also declined by 39.4 per cent, under unmanured cropping. Similarly nitrogen fertilization significantly lowered the level of reductant soluble-P. This could possibly be due to 'local acidity,' reductant from the organic acids which were liberated during the decomposition of roots and stubbles of the crops in soil. Under acid environment iron oxide coatings are subjected to dissolution and may release Al-P and Fe-P which will be available to plants under alkaline conditions (Thomas and Peaslee, 1973).

Added phosphate enhanced the status of all fractions of phosphorus including occluded from (Table I). The accumulation of P in saloid bound, Al-P, Fe-P and Ca-P is in agreement with the earlier studies on neutral and alkaline soils (Werner and Wiechman 1972; Fuleky, 1975). In contrast to some findings (Manning and Salomon, 1965) there was a build up in both reductant soulble and occluded P. This could be due to transformation of Al-P and Fe-P into these forms over a seven years (Shelton and Coleman, 1968). The significant improvement in the contents of saloid bound-P with FYM incorporation is in line with the hypothesis that FYM interferes in the formation of octa-calcium phosphate from dicalcium phosphate which is the from mostly recovered as saloid bound P (Cooke, 1967). There has been a greater formation of Al-P in superphosphate treated plots (T9) as compared to that of diammonium phosphate (T_2). This may be examined keeping in view that superphosphate creates a high initial acidity (pH 1.0 to 1 5) of the saturated solution in comparison to diammonium phosphate (pH 8.1) as has been reported by Cooke (1967).

There was a significant improvement in all forms of P even with sub-optimal dose (53% NPK) where as 100 per cent NPK enhanced all except iron phosphate. In soil Al-P could increase irrespective of the reaction (Fuleky, 1975) and so its content has shown incremental rise with graded doses of P. Iron phosphate did not show any raise with 100 and 150 per cent NPK doses, indicating that it has transformed into some other form. Quite interestingly, there was a corresponding increase in reductant soluble P, confirming that at high doses of added phosphate, Fe-P has occluded into iron oxides with passage of time. Calcium bound P did not exhibit any increase beyond 100 per cent level of NPK. This could be attributed to the low status of free calcium carbonate (0.85 per cent) in the soil.

Simple correlations were worked out between the active fractions of P and yield and P content of crops raised during 1978 — 79 rotation (Table II). All the fractions exhibited highly significant (1% level) relationships with both yield and per cent P in all the test crops. Thus, there was a close association between the changes occurring in the P forms and their effects on the crop composition and yield.

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