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A CUMULATIVE EFFECT OF PHOSPHATIC FERTILIZERS ON THE 'A' VALUE OF SOILS UNDER RICE CULTIVATION

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Abstract. Residual availability of P was investigated in three soils using rice plant for three consecutive years under greenhouse conditions. The 'A' values of the three soils measured in different years were significantly higher than their respective preceding years and that of the first year (1964) compared to Olsen's $NaHCO_3$–P extracted from the original soils. Comparatively larger amounts of residual P were available in the Kala Shah Kaku loamy soil during all the years. A reverse tendency was observed in the Tando Mohammad Khan clay loam soil having the highest content of clay and carbonates.

The fractions of P derived from the added P and per cent of superphosphate fertilizer utilized by the rice plants decreased as the availability of residual P in soils increased. Only slight fixation of P occurred in Tando Mohammad Khan soil in the first as well as the second year and in Dokri soil during the second year only otherwise large additional amounts of P released from all the soils over and above the P applied. This indicates a very negligible fixation of P in soils particularly the loamy ones grown to rice.

Phosphorus when added to soils undergoes a series of chemical reactions, the formation of resultant complexes and their utilization by plants depends upon several factors.[1–4] In calcareous soils, availability to plants of residual P decreases due to the formation of insoluble P complexes.[2] However, Olsen *et al.*[5] reported that the availability of residual P in calcareous soils was dependent on the initial levels of available P of such soils. Soil organic matter, as a result of chelating effect on the elements[6,7] and microorganisms, because of the temporary absorption for their body development,[6] exert a great influence on the availability of applied as well as native P in soils. Consequently P is not completely utilized by a single crop and the remaining portion of the added P slowly becomes available to the succeeding crops. Several workers[1,2,8–10] have reported this as residual effect of added P in soils and a thorough knowledge of this effect is needed for the judicious use of P fertilizers.

The crop yields and P content of plants increased as long as 3–10 years after P fertilization indicating the availability of residual P in soils.[1,2,9] Thomas[3] and Kamprath[11] recorded an increase in the 'A' value indexes of soil P following the addition of P thereby indicating the residual effect of P in soils.

The chemical methods for the determination of available soil P are as accurate, depending on the nature of extractants, as Fried and Dean's 'A' value technique[5,12–14] but they could not be used for all type of soils as reported by Thomas[3] and Grunes *et al.*[14]

Present investigation was undertaken to determine the cumulative effect of P fertilizer by 'A' value technique.

Materials and Methods

Three soils (0–6 in) were collected from three rice growing tracts (Kala Shah Kaku, Tando Mohammad Khan and Dokri) in the summer of 1964. The soils were air-dried and ground to pass through a 2 mm sieve. Some physicochemical properties of the original soils are reported in Table 1. Total P was extracted with HNO_3–H_2SO_4–$HClO_4$ ternary acid mixture[15] and available P by Olsen's $NaHCO_3$ procedure.[16] Total as well as available extracted P were determined by Jackson's method[15] using ammonium molybdate and 1,2,4-aminonaphthol sulphonic acid. Organic matter was determined by Walkley and Black's method as outlined by Jackson[15] and total carbonates by Puri's procedure as given by Piper.[17] Total soluble salts were determined with conductivity meter and pH was measured on a pH-meter using a glass-electrode.[15] Fractions of sand, silt and clay were determined with pipette method.[17]

Five pounds of each soil were taken in one-gallon earthen pots. Labelled P^{32} in the form of superphosphate was added as P at the rate of 26 lb/acre in the first year (1964) and 44 lb/acre during each subsequent year. Nitrogen and potassium were applied as sulphates every year at the rate of 50 and 33 lb/acre respectively. The fertilizers were mixed in the dry soils. The treatments were replicated six times and completely randomized. The pots were flooded with water and three rice seedlings (variety kangni-27) were transplanted in each pot on the following day. Pots were watered to an inch level above soil surface thrice a week until maturity.

The plants were harvested at maturity about an inch above soil surface, dried at 70°C in an oven for 24 hr and weighed for total dry matter.

Entire plant material from each pot was digested with HNO_3–H_2SO_4–$HClO_4$ and the digest was taken up into 1N HNO_3. Total P in the digest was determined by the method of Jackson.[15] Suitable aliquots were counted for P^{32} with well type Geiger–Muller detector attached to a Bendix Ericsson (U.K.) scaling unit type-1221C.

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Results and Discussion

Available P Indexes of Soils. Available P indexes of the three rice soils measured by Fried and Dean 'A' value technique[18] are given in Table 2. Each year, the 'A' value indexes recorded from different soils increased as compared to the respective preceding year. Moreover, the 'A' values obtained from the various soils in the first year (1964) were higher than Olsen's $NaHCO_3$ extractable P.

In the Kala Shah Kaku soil the 'A' values in the second year (1965) and third year (1966) were significantly higher than the respective preceding year. In Tando Mohammad Khan and Dokri soils, the 'A' values only in 1966 were significantly greater but in 1964 and 1965 the 'A' values were not signiffcantly higher than the preceding year (Table 2). Many investigators[1,2,9–11] attributed such effects to the availability of residual P both from an applied as well as the native source of soils.

The results show comparatively higher amount of available P in the Kala Shah Kaku loamy soil than the other two clay loam soils particularly in the first two years (Table 2). It may be due to the lighter texture of the Kala Shah Kaku soil (Table 1) which enhanced its P supply capacity as compared to the Tando Muhammad Khan and Dokri soils. The same reason probably holds good in case of Dokri soil as compared to the Tando Mohammad Khan soil since the latter soil has higher percentage of clay than the Dokri soil. Campbell[1] and DeDatta *et al.*[19] also reported similar results.

In the Kala Shah Kaku soil, 'A' values trippled in the second year and there was more than five-fold increase in the third year as compared to the first year The other two soils (from Tando Mohammad Khan and Dokri sites) showed more than two- and seven-fold increase in available P in the second and the third year respectively compared to the first year. This indicates that flooded conditions make soil native P more available for plants since such significant increases in the 'A' values of soil P were not observed in another experiment on upland soils grown to wheat.[10] Shapiro[20] and DeDatta *et al.*[19] also showed that the availability of soil P was higher in the flooded soils as compared to that of upland soils grown to rice.

Fraction of P from Added P and Per Cent Fertilizer Utilized. Table 3 presents the fractions of P taken up from the added P and the per cent of superphosphate fertilizer utilized by the rice plants grown on three different soils. There is a general tendency of decreasing uptake of added P during each subsequent year by the rice plants grown on all the three soils. Pronounced differences in the per cent of P derived by plants from the applied P were marked between the Kala Shah Kaku and the other two soils but not between the Tando Mohammad Khan and Dokri soils during the first two years. However, the fractions of P derived by plants from the added P were almost similar in the Kala Shah Kaku (17.0%) and Dokri (18.3%) soils but the plants comparatively removed more P (23.2%) from the added P in Tando Mohammad Khan soil during the third year. Probably the lower clay constituents[1,19] higher level of organic matter,[19] lower carbonate contents[21] and to some extent greater initial amounts[5] of both total and

TABLE 1. SOME PHYSICAL AND CHEMICAL PROPERTIES OF THREE ORIGINAL RICE SOILS.

Properties measured	Kala Shah Kaku	Tando Mohammad Khan	Dokri
Total P (lb/acre)	1155·0	950·0	1000·0
Available P (lb/acre)	7·0	4·0	5·0
Organic matter (%)	2·0	1·6	1·4
Total carbonates (%)	1·8	7·5	6·7
Total soluble salts (%) 1:1 (soil : water)	0·10	0·06	0·14
PH 1 : 1 (soil: water)	8·2	8·2	8·3
Sand (%)	35·5	16·8	26·5
Silt (%)	36·5	36·2	25·8
Clay (%)	23·4	34·6	26·0
Texture	Loam	Clay loam	Clay loam

TABLE 2. AVAILABLE P INDEXES BY FRIED AND DEAN A VALUE TECHNIQUE OF THREE SOILS GROWN TO RICE UNDER GREENHOUSE CONDITIONS, 1964–66.

Years	P/super-phosphate added (lb/acre)	Soils used ('A'values lb/acre)		
		Kala Shah Kaku	Tando Mohammad Khan	Dokri
1. 1964	26/60	41	23	27
2. 1965	44/100	134	55	63
3. 1966	44/100	215*	173	208*
LSD		39·7 }	43·1	86·0 }
(P0·05)		41·6 }		87·3 }

*Average of 5 replicates (one replicate missed P32 addition)

TABLE 3. FRACTIONS OF P FROM ADDED P AND PER CENT OF SUPERPHOSPHATE FERTILIZER UTILIZED BY RICE PLANTS GROWN UNDER GREENHOUSE CONDITIONS, 1964-1966.

Year	P/super-phosphate added (lb/acre)	Soil used					
		Kala Shah Kaku		Tando Mohammad Khan		Dokri	
		P from P added(%)	Fertilizer utilized(%)	P from P added(%)	Fertilizer utilized(%)	P from P added(%)	Fertilizer utilized(%)
1. 1964	26/60	39.2	16.8	52.8	8.1	50.0	14.8
2. 1965	44/100	26.8	3.3	44.8	5.7	42.6	3.4
3. 1966	44/100	17.0	0.7	23.2	0.5	18.3	0.6

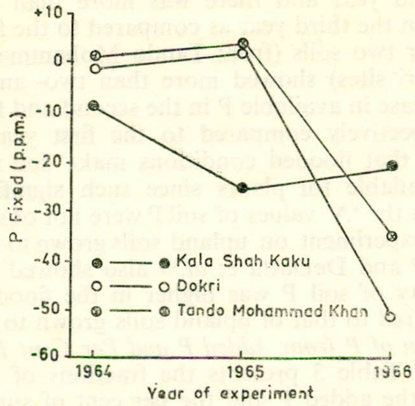

Fig. 1. P fixation patterns of three soils grown to rice under greenhouse conditions, 1964–66.

available P in the Kala Shah Kaku soil helped releasing more P for plant absorption from the native P sources compared to the other two soils. On the other hand, higher per cent of carbonates[21] and clay contents[1,19] in the Tando Mohammad Khan and Dokri soil possibly kept P in these soils temporarily tied up into less soluble phosphate complexes. This effect is particularly noticeable in the first two years (Table 3) hence making the plants to fulfill their P requirements mostly from the fertilizer during these years.

Data in Table 3 also show that the per cent of superphosphate fertilizer utilized by the rice plants grown on the various soils decrease as the 'A' values of soil P increase in each subsequent year. Both the fractions of P derived from the added P and the per cent of superphosphate fertilizer utilized by the rice plants decreased during each subsequent year. This indicates that more and more P from soil sources becomes available with the lapse of time.[1,9,11]

Fixation of P in Soils. Patterns of P fixation shown by the various soils over three consecutive years are drawn in Fig. 1. Amounts of P fixed by different soils during each year are assessed with the formula mentioned by Tahir *et al.*[10] in a similar investigation on soils under wheat cultivation.

Both Tando Mohammad Khan and Dokri soils showed similar trends of P fixation but the Kala Shah Kaku soil did not resemble in its P fixation patterns with the other two soils.

Tando Mohammad Khan soil in the first year and both Tando Mohammad Khan and Dokri soils in the second year showed a small but insignificant fixation of P. But both these soils in the third year and the Kala Shah Kaku soil during all the years did not fix any P rather additional P released over and above the P applications to soils during these years. In the Kala Shah Kaku soil low percentage of carbonate, which forms a less soluble carbonate–phosphate complex,[21] possibly favoured the release rather than the fixation of P. Moreover, low clay content in Kala Shah Kaku soil[1,19] and comparatively more organic matter, which holds P into an easily available form through chelation[6,7] can also not be ignored from assuming their influence in the reduction of P fixation in this soil. However, such characteristics lacked in Tando Mohammad Khan and Dokri soils which had comparatively low organic matter content and higher percentages of carbonate and clay in them. However, the availability of P in Tando Mohammad Khan and Dokri soils during the third year (Table 2) is quite higher compared to the first two years. Possibly flooding water conditions maintained for rice plants for three consecutive years slowly discohered the P from less soluble phosphate complexes thus resulting in a cumulative release of P from soils in the third year.

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