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Nutrient Uptake by Plants from Representative South Indian Soils in Relation to Root Cation Exchange Capacity
I. Soil Properties and Neubauer Test

by

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Introduction: The subject of uptake of nutrients by crops has received intensive and extensive treatment in recent years. Analysis of soils, before and after the growth of crops, may give information regarding the uptake of nutrients by these crops as influenced by their root cation exchange capacities and soil properties. An attempt was made to study the role of root cation exchange capacity and soil properties on the removal of nutrients, with special reference to phosphorus, by two crops viz., *ragi* and *daincha* from two major types of South Indian soils, namely red and black soils, and also the availability of different phosphatic fertilisers in these soils as indicated by Neubauer test. The results of this study are reported in this paper.

The availability of nutrients particularly phosphorus, both native and applied is known to be influenced by soil properties. Chapman (1936) indicated that acid nitrogenous fertilisers increased availability of phosphorus in calcareous soils. Joos and Black (.950) stated that the availability of rock phosphate was increased by highly acid nature of the soil. Bircm (1951) found that with increasing base saturation of the soil, the availability of phosphorus became poor.

Franklin and Reisenauer (1960) were of the opinion that chemical characteristics of soil, mainly exchangeable and citric acid soluble aluminium, were of important consideration in phosphorus availability. Nair (1961) reported that the yield of *ragi* was better in red soil than in black soil and both these soils did not respond to phosphorus fertilization. Simpson's (1961) experiments on potato showed that a linear relationship existed between phosphorus uptake and potato yields in low phosphorus soils.

Rudra Setty (1962) reported that the yield of *ragi* was maximum in black soil, followed by red soil. Experiments conducted in Madras State between 1958 and 1963 indicated that all phosphorus fertilisers performed well in non-calcareous soils.

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Neubauer test has been found to be a good index of phosphorus availability. Iyengar (1963) reported that significant correlation was obtained between available phosphorus in the soil and the uptake of phosphorus by Neubauer seedlings and so the uptake of phosphorus by Neubauer seedlings could be taken as a fairly dependable index of phosphorus availability. Vijayachandran (1966) indicated that the treatments involving different forms of phosphorus had no significant effect on the dry weight of Neubauer seedlings, but superphosphate was found to be superior to dicalcium phosphate and control in the uptake of phosphorus by seedlings.

Material and Methods: Two soils representing the major groups of soils in Madras State, were taken for experiments. A typical black soil was collected from Saibaba Colony, near Coimbatore Town and the red soil from Semmankuliyur, a few miles west of Coimbatore. The soil samples were dried in the shade and powdered to pass through 2 mm sieve. The sieved material was used for pot culture experiment and for initial analysis. Physical constants, chemical constituents and mechanical components of the soils were estimated by standard methods.

A pot culture experiment was conducted using red and black soils. *Ragi* (Co. 7) was grown with a basal dressing of N:P:K=40:20:20 and *daincha* with N:P:K=0:45:0. Nitrogen and potassium were applied to all pots as ammonium sulphate and potassium chloride respectively. Phosphorus was applied to both the crops in three forms viz., ammonium phosphate, superphosphate and rock phosphate keeping one set as control. The crops were harvested after their maturity.

Soil samples were taken from the pots after harvest of the crops and analysed for their nutrient content.

Neubauer test was performed with the black and red soils. One hundred g of soil, in each case, was mixed with 50 g acid washed quartz sand and placed in dishes of 11 cm diameter and 7 cm depth. Three P fertilisers viz., ammonium phosphate, superphosphate and rock phosphate were applied at 20 lb per acre as basal dressing, keeping one set as control. N and K were also applied at 40 lb and 20 lb per acre respectively as ammonium sulphate and potassium chloride. One hundred seedlings of *ragi* were allowed to grow in the dishes for 17 days. At the end of the period, they were removed and analysed for P. The amount of P present in the plant was taken to represent the available P in the soils.

Results:

I. *Analysis of original Soils:* The mechanical analysis figures showed that clay content was appreciable in black soil, while red soil contained more of coarse and fine sand fractions. While the physical properties of the two soils did not vary much, the moisture constant values brought out the fact that the values for sticky point moisture, moisture equivalent and water holding capacity of the black soil were higher than those of red soil. The silica-sesquioxide ratio of the black soil was almost two times that of red soil. Lime and magnesia contents of the black soil were much higher than those of red soil. Regarding the nutrient status, black soils excelled the red soil. Black soil gave considerably high values for total cation exchange capacity, exchangeable calcium and magnesium while red soil recorded low values. The pH of the black soil was higher than that of red soil.

II. *Analysis of soils after harvest of crops:*

A. *Ragi:* 1. *Total nitrogen:* The total nitrogen content of the post-harvest soil samples recorded a decrease from the value for the original soils, the maximum decrease iu black soil being in the case of soil treated with rock phosphate followed by control, ammonium phosphate and superphosphate. The maximum decre ase in red soil was in the soil treated with superphosphate, followed bycontrol, ammonium phosphate and rock phosphate.

2. *Available nitrogen:* The maximum decrease in black soil was in superphosphate treatment followed by ammonium phosphate, control and rock phosphate. In the case of red soil the maximum decrease was in control followed by superphosphate, rock phosphate and ammonium phosphate.

3. *Total phosphoric acid:* The phosphoric acid values recorded a fall from the values of the original soils. The maximum decrease in black soils was in the case of superphosphate followed by control, ammonium phosphate and rock phosphate. In red soil, theorder of decrease was as follows:

Superphosphate > Ammonium phosphate > Control > Rock phosphate.

4. *Available phosphorus:* In black soil, the maximum decrease was in the case of ammonium phosphate treatment, followed by superphosphate, control and rock phosphate. In red soil, the fall was in the following order:

Superphosphate > Ammonium phosphate > Rock phosphate > Control.

5. *Potash:* The order of decrease was as follows in black soil: Superphosphate > Control > Ammonium phosphate > Rock phosphate; and in red soil: Control > Ammonium phosphate > Rock phosphate > Superphosphate.

6. *Lime:* The figures revealed the following order of decrease for black soil: Control > Rock phosphate > Superphosphate > Ammonium phosphate and for red soil: Control > Ammonium phosphate > Rock phosphate > Superphosphate.

TABLE 1. *Chemical Analysis of soil after harvest of crops* (On moisture free basis)

Treatments	Total Nitrogen %		Available Nitrogen (PPM)		Total phosphorus (P_2O_5) %		Available phosphorus (P) (PPM)		Potassium (K_2O) %		Calcium (CaO) %		Magnesium (MgO) %	
	Ragi	*Daincha*	*Ragi*	*Daincha*	*Ragi*	*Daincha*	*Ragi*	*Daincha*	*Ragi*	*Daincha*	*Ragi*	*Daincha*	*Ragi*	*Daincha*
Black Soil														
Ammonium phosphate	0.070	0.083	87	68	0.062	0.056	4.4	5.5	1.72	1.74	4.58	4.55	1.38	1.37
Super phosphate	0.074	0.084	86	77	0.048	0.064	5.3	6.4	1.70	1.75	4.46	4.52	1.40	1.39
Rock phosphate	0.058	0.081	94	70	0.064	0.123	6.0	6.4	1.73	1.73	4.42	4.47	1.40	1.36
Control	0.058	0.081	92	60	0.057	0.064	5.5	5.9	1.70	1.75	4.34	4.56	1.37	1.38
Red Soil														
Ammonium phosphate	0.036	0.024	135	85	0.055	0.049	4.0	4.4	0.80	0.82	0.17	0.21	0.45	0.36
Super phosphate	0.028	0.034	116	99	0.050	0.042	6.7	5.0	0.80	0.83	0.15	0.26	0.37	0.34
Rock phosphate	0.038	0.035	127	104	0.063	0.067	4.1	4.6	0.79	0.82	0.15	0.25	0.34	0.31
Control	0.033	0.037	107	110	0.062	0.042	4.5	5.1	0.78	0.82	0.18	0.20	0.38	0.35

7. *Magnesia:* The values for magnesia of the post-harvest soil samples showed a decrease from the value of original black soil and the decrease was of the order: Control > Ammonium phosphate > Superphosphate > Rock phosphate. The decrease in the case of red soil was of the order: Rock phosphate > Superphosphate > Control > Ammonium phosphate.

B. *Daincha:* 1. *Total Nitrogen:* The values of the post-harvest soil samples for total nitrogen showed a decline from the values of the original soils, though the decline was not appreciable. In the case of black soils, the decrease followed the order: Rock phosphate > Control > Ammonium phosphate > Superphosphate and in red soils: Ammonium phosphate > Superphosphate > Rock phosphate > Control.

2. *Available Nitrogen:* The fall of available nitrogen in the post-harvest black soils from the values of original soil indicated the following order: Control > Ammonium phosphate > Rock phosphate > Superphosphate, while the order of decrease in the case of red soil was the same as for the total nitrogen values.

3. *Total phosphoric acid:* While the black soil treated with ammonium phosphate, superphosphate and control showed a decrease of total phosphoric acid from the value of original soil in the same order, the soil treated with rock phosphate recorded an increase over the original soil. In the case of red soil also, the rock phosphate treatment produced an increase in the total phosphoric acid, while the treatments superphosphate, control and ammonium phosphate produced the fall in the same order.

4. *Available phosphorus:* The order of decrease of available phosphorus values from that of original soil was as follows for black soil: Ammonium phosphate > Control > Superphosphate > Rock phosphate and for red soil: Ammonium phosphate > Rock phosphate > Superphosphate > Control.

5. *Potash:* The order of decrease was as follows for black soil: Rock phosphate > Ammonium phosphate > Control > Superphosphate and for red soil: Rock phosphate > Control > Ammonium phosphate > Superphosphate.

6. *Lime:* Lime content of the post-harvest soil samples also showed a decrease from that of the original soils. The decrease for the black soil was in the following order: Rock phosphate > Super phosphate > Ammonium phosphate > Control, while in the case of red soil, the order of decrease was control, followed by ammonium phosphate, rock phosphate and superphosphate.

7. *Magnesia:* The decrease in magnesia content was more in the case of red soils than in the case of black soils. The decrease was of the following

order in black soils: Rock phosphate > Ammonium phosphate > Control > Superphosphate and in red soils: Rock phosphate > Superphosphate > Control > Ammonium phosphate.

III. *Neubauer test* (Table 2):

1. Dry weight of Ragi seedlings: Neither the treatments nor the soils had any significant influence on the dry weight of the ragi seedlings grown for Neubauer test.

2. Percentage of phosphorus: In the case of black soil, the superphosphate treatment recorded the highest percentage of phosphorus in the *ragi* seedlings followed by rock phosphate, ammonium phosphate and control. In red soil also, similar trend was observed.

TABLE 2. *Results of Neubauer Test*

Treatments	Green weight of seedlings per dish (g)	Dry weight of seedlings per dish (g)	Content of phosphorous (P) %	Uptake of phosphorous (P) by seedlings per dish (mg)
Black Soil				
Ammonium phosphate	1.6067	0 1975	0.118	0.23
Super phosphate	1.7977	0.1816	0.396	0.72
Rock phosphate	1.8820	0.1813	0.163	0.29
Control	1.5826	0.1787	0.123	0.22
Red Soil				
Ammonium phosphate	1.2668	0.1345	0.180	0.24
Super phospate	1.4062	0.1735	0.702	0.83
Rock phosphate	1.2109	0.1642	0.513	0.80
Control	1.4563	0.1738	0 701	0.12

3. Uptake of Phosphorus (Table 3): Red soil was significantly superior to black soil in the uptake of phosphorus by *ragi* seedlings. Among the treatments in red soil, superphosphate was significantly superior to rock phosphate, ammonium phosphate and control which were on a par. In blaek soil, superphosphate and rock phosphate were significantly superior to ammonium phosphate and control, but superphosphate and rock phosphate were on a par while ammonium phosphate and control were on a par.

TABLE 3. *Uptake of phosphorus. [Mean values of soils and phosphates (mg/dish)]*

Soils	Phosphates				Means of soils
	Ammonium phosphate	Super phosphate	Rock phosphate	Control	
Black	0.2316	0.7187	0.2932	0.2189	0.3656
Red	0.2414	0.8384	0.7955	0.1218	0.4992
Mean of phosphates	0.2365	0.7785	0.5444	0.1704	—

C.D.	*Soils*	*Phosphates*	*Interaction*
	0.0696	0.983	0.1391

Conclusion:

Soils, Red, Black

Phospates: Super, Rock, Ammo, Control

Interaction: (i) *Phosphates* *Soils*

Ammo.	Red, Black
Super	Red, Black
Rock	Red, Black
Control	Black, Red

(ii) *Soils* *Phosphates*

Red	Super, Rock, Ammo, Control
Black	Super, Rock, Ammo, Control

Discussion :

I. Depletion of Nutrients from soil by crops :

Analysis of soil samples after harvest of the crops showed that total nitrogen in soil was depleted to a greater extent by *ragi* than *daincha*. This suggests that daincha should have depleted more of nitrogen from the soil than *ragi*, but the loss might have been, to some extent, compensated for by fixation of atmospheric nitrogen. The phosphorus content decreased from the original soil more in soils in which *ragi* was grown than in soils in which *daincha* was grown. *Ragi* depleted potassium more than *daincha* in both the soils. This observation agrees with the earlier findings that plants with low root Cation Exchange Capacity take up more potassium than plants with high root Cation Exchange Capacity.

There was not much difference between *ragi* and *daincha* in the depletion of calcium and magnesium. Though it is logical to expect that *daincha*, a high root CEC plant, should deplete more of divalents than *ragi*, the above observation can be accounted for by the higher dry matter production of ragi and consequent greater depletion of these divalent cations. This can be alternatively explained by the fact that calcium and magnesium are present in more than required level in both the soils and so the differences in the uptake of these divalent cations between higher and lower root CEC plants are evened out.

II. Yield of crops and uptake of nutrients as influenced by soil properties:

Soils did not have any significant influence on the yield of *ragi*. However, in the case of yield of *daincha*, black soil was superior to red soil. This can be explained on the basis that black soil is richer in nutrient than red soil. The uptake of phosphorus by *ragi* was higher in red soil than in black soil, possibly due to higher fixation of phosphorus in black soil by calcium and its ultimate unavailability to the crop. Calcium and magnesium uptake by *ragi* was higher in black soil than in red soil evidently because calcium and magnesium are abundant in black soil. Uptake of all nutrients viz., nitrogen, phosphorus, potassium, calcium and magnesium by *daincha* was higher in black soil than in red soil, though the contents of nitrogen, phosphorus and potassium in *daincha* were higher in red soil than in black soil. The higher yield of *daincha* in black soil over red soil evened out the effect of high contents of nitrogen, phosphorus and potassium in *daincha* raised on red soil, in the matter of uptake.

III. Neuber test as an index of phosphorus availability

None of the three phosphates tried had significant influence on the dry weight of the Neubauer seedlings. However, in the matter of uptake of phosphorus, superphosphate was superior to the other two phosphates and control. Rock phosphate was superior to ammonium phosphate and control, which were on a par. When the uptake of phosphorus by Neubauer seedlings was taken to represent the available phosphorus, then red soil was superior to black soil. In red soil, superphosphate seemed to be more available than rock phosphate and ammonium phosphate. But in black soil, there appeared to be no significant difference between superphosphate and rock phosphate in availability, while they were superior to ammonium phosphate and control. Peculiarly, in both the soils, ammonium phosphate was on a par with control. Comparatively, rock phosphate seemed to be more available in red soil than in black soil.

Summary and Conclusion: The influence of root CEC on the uptake of nutrients with special reference to the difficultly available nutrient, phosphorus, was investigated comparing the common crops, *ragi* (Co. 7) and *daincha* grown on two major groups of South Indian soils, viv., red and black soils. Recommended doses of fertilisers were applied to both crops. Phosphorus was applied in three forms viz, ammonium phosphate, superphosphate and rock phosphate keeping one set of control. Soils were analysed before and after the growth of crops. A Neubauer test was conducted employing the two soils and three fertilizers used in the main experiment, keeping one set of control for each soil, to ascertain the relative availability of fertilizers in each soils.

The results indicated that the nitrogen content of soils was not much decreased by the growth of daincha when compared to *ragi*, probably because *daincha* compensated for its relatively high depletion of total nitrogen in soils by fixation of atmospheric nitrogen, to some extent. Though *daincha* took up more of phosphorus than *ragi*, the available phosphorus content of the soil after harvest of *daincha* was not much affected, probably because *daincha* solubilised and converted some of the locked up forms in the soils into available forms.

Neubauer test indicated that superphosphate was more available than the other two phosphates. Rock phosphate appeared to be more available in red soil than in black soil. In the matter of available phosphorus, red soil was superior to black soil.

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