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The relative agronomic efficiency of rock phosphate and single super phosphate separately and in combination of phosphorous sources in maize-groundnut cropping sequence in an Alfisols

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Abstract
A field experiment was conducted with maize - groundnut cropping sequence. Rock phosphate and its combination with SSP were used as nutrient sources during Rabi 2016-17 (maize taken up in Kharif 2016). The study was carried out in the Central Farm, OUAT with the help of a field experiment laid out in Randomized Block Design with seven treatment T_1 Control, T_2 100% P(RP), T_3 100% P(SSP), T_4 75% P(RP) + 25% P(SSP), T_5 50% P(RP) + 50% P(SSP), T_6 25% P(RP) + 75% P(SSP) and T_7 100% P(SSP) +Lime @0.2 LR and replicated in thrice. The soil of the experimental field was loamy acidic (pH 5.2) having Bray's P of 15.68 kg ha^{-1}. The different combinations with SSP were evaluated for their effectiveness in the cropping system. In addition to P applied @50 kg P_2O_5 ha^{-1} and 40 kg P_2O_5 ha^{-1} to maize and groundnut crops respectively from various sources, N was added @ 150 $kgha^{-1}$ to maize and 20 $kgha^{-1}$ to groundnut crop in the form of urea and K @50 and 40 kg K_2O ha^{-1} was added to maize and groundnut crop in the form of MOP. Highest maize grain yield (5.03 t ha^{-1}) was produced due to addition of 100%P (SSP) +Lime @0.2LR and highest pod yield (2.77 t ha^{-1}) of groundnut was also due to 100%P (SSP)+Lime @0.2LR. The total biomass produced by cropping system ranged from 9.66 -18.82 (t ha^{-1}) with control and 100% P (SSP) +Lime @0.2 LR. Combined maize and groundnut equivalent yield produced by cropping system ranged from 2072 - 5728 (kg ha^{-1}) with control and 100% P (SSP) +Lime @0.2 LR. Apparent P recovery (62.52%) was highest in100%P (SSP) Lime @0.2LR for the cropping sequence. The same treatment also recorded the highest uptake of nutrients Phosphorous. The total phosphorus use efficiency of the cropping sequence was maximum (93) received in 100%P(SSP) +Lime @0.2LR. The highest Relative Agronomic efficiency of the cropping sequence(149) was recorded with 100%P(SSP) +Lime @0.2LR followed by RP:SSP(1:1) (139).

Keywords: Low grade rock phosphate (RP), single super phosphate (SSP), lime requirement (LR), loamy acidic soil, maize-groundnut crop, murate of potash (MOP)

Introduction
Phosphorus is regarded as the master "key" element in crop production because of its pivotal role in the normal growth and establishment of root system, Seed formation and harvesting of the crop maturity besides being an essential constituent of nucleic acids (Mangel and Kirkby, 1987) [5]. It also plays any important role in photosynthesis, nitrogen fixation and other vital processes (Uchida, 2000) [15]. In the soil, P is present in the soil solution, soil organic matter or occurs as in organic P. Unlike nitrogen phosphorus cannot be fixed from the atmosphere. It is generally regarded as the nutrient that is most limiting in tropical soils including Malawain soils (Phiri *et al*, 2010) [9]. The work on phosphorus nutrition of plant carried out in India suggest that about 15-25 percent applied P is only utilized by the crop, the fertilizer use efficiency being on the lower side when the soil is acidic (Tandon, 1987) [13].
Rock phosphate is out of the basic raw material for the manufacture of commercial phosphatic fertilizers. Its usefulness for phosphatic fertilizer production depend on its chemical and mineralogical composition. Phosphatic rock and apatite are referred to micro-crystalline calcium fluroapatite of sedimentary origin and microcrystalline fluroapatite of igneous origin respectively. Rock phosphate of sedimentary origin is generally reactive and very much suitable for low pH, low calcium saturation and low available P status. Besides phosphate rock, sulphur is the other raw material required for the manufacture of H_2SO_4 which is imported and used for production of phosphatic fertilizer resulting in a marked increase in the cost of nutrient phosphorus is processed phosphatic fertilizer.

After decontrol of phosphatic fertilizer and consequent increase in its price reduce phosphatic fertilizer use in India as a result fertilizer consumption has became more imbalanced.

In India, about 49 million hectors of cultivated area are considered acidic, out of which 26 million hectors have pH below 5.6 and 2.3 million hectors between 5.5 and 6.5 (Bhumbla and Mandal, 1972) [1].

The high content of exchangeable Al limits root growth and decrease crop production due to Al toxicity (Watanabe *et al*., 2006) [17]. In addition to Al toxicity, deficiency of P is one of the important obstacles to farming acid dry land (Vitousek *et al*., 2010) [16]. In acid soils, the majority of P added to the soil will be transformed into forms of Al - P and Fe - P (Trevisan *et al*., 2010) [14]. The forms are relatively insoluble in the soil, thus the availability of P in acid soils is relatively low (Setiawati *et al*., 2009) [11]. The acidic soils develop physical, chemical, nutritional and biological constraints for crop production in terms of soil crusting (affecting seed germination), high infiltration rate, low water holding capacity, high permeability, low pH, low cation exchange capacity (due to dominance of 1:1 type of clay), low base saturation (16-67%), high Al, Fe and Mn saturation percentage, high P fixing capacity (92%) (Pattanayak and Misra, 1989) [8].

Restoration of lost basic cations, amelioration of acidity, supplementation of different nutrients as per crop requirement, judicious use of chemical fertilizers can help in management of acid soils. Liming of acid soil is the way to raise pH, base status, cation exchange capacity, inactive Al, Fe and Mn in soil solution and reduce P fixation. To create a favourable environment for uptake of other essential nutrients and higher crop yields, liming is an important management option in acid soils.

Materials and Methods

The efficiency of Rock Phosphate namely sourced from FCI Aravali Gypsum & Minerals India Ltd., Jodhpur alone and its different combination with Single Super Phosphate (SSP) in Maize - Groundnut cropping sequence during Kharif - Rabi session 2016-17 was studied with the help of a field experiment. The experimental site is located in the Central Farm, OUAT, Bhubaneswar which lies at 85^0 47’ 18” E latitude 20^0 16’ 51" N longitudes with an elevation of 25.9 meter above mean sea level. The summer months from March to May/ June are hot and humid. The mean minimum and maximum temperature were 22.6 ºC and 32.6 ºC respectively. Temperatures drop to approximately 15 °C during these months.

The physico-chemical properties of the soil of experimental site were loamy texture with pH 5.2 and Exchangeable Ca^{2+} 0.89 [cmol (p^+) kg^{-1}]. The soil had the available Bray’s P 15.68 kg ha^{-1} (medium), Available Nitrogen 239 kg ha^{-1}(low), Available Potassium 150 kg ha^{-1} (medium) and Organic carbon 3.4 g kg^{-1} Soil.

Experimental Details

Field experimental design laid out in Randomized Block Design with seven treatment T_1 Control, T_2 100% P(RP), T_3 100% P(SSP), T_4 75% P(RP) + 25% P(SSP), T_5 50% P(RP) + 50% P(SSP), T_6 25% P(RP) + 75% P(SSP) and T_7 100% P(SSP) + Lime @0.2 LR and replicated in thrice times**.**

Crop Information and Inputs

Test Crop	Maize	Groundnut
Variety	PAC-752	TAG-24
Duration	120 days	120 days
Season	Kharif	Rabi
Fertilizer dose ($N-P_2O_5-K_2O$)kg/ha	150-50-50	20-40-40
Lime	@ 0.2 L.R	@ 0.2 L.R

Collection and Processing of Soil and Plant Samples

The soil samples were dried under shade, grinded with wooden hammer and sieved through 2 mm sieve. The soil samples were preserved in polythene bags with proper labels for analysis. Five plants from each treatment were selected randomly (avoiding boundary line). After washing with deionised water and sun drying the samples were kept inside the oven at 75 ^{0}C temperature till constant weight was attained. The plant samples were grinded in a wiley mill to pass through 20 mesh sieve and were preserved in paper envelopes for analysis.

Method of Analysis

The soil samples were analyzed for different physico-chemical parameters by adopting following standard methods. The sand, silt and clay content of the soil samples were determined by Bouyoucos Hydrometer method as described by Piper (1950) [10]. Soil pH was determined in 1:2.5 soils: water ratio by pH meter as described by Jackson (1973) [4]. The Organic carbon content of soil was determined by wet digestion procedure of Walkley and Black as outlined by Page *et al.*, (1982) [6]. Available nitrogen in soil was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 1956) [12]. Available phosphorous in the soil was determined by Bray’s 1 method (Bray and Kurtz, 1945) [2] as out lined by page *et al.*, (1982) [6]. Available potassium was determined by extracting the soil with neutral normal ammonium acetate solution and estimated by flame photometer. The NH_4OAc extract was evaporated to dryness, treated with aquarejia (HCl: HNO_3 - 3:1) again evaporated to dryness and diluted with distilled water to suitable volume. The Calcium were determined by using EDTA (Versenate) complexometric titration by using Calcon indicators as outline by Hesse (1971) [3].

The plant and grain samples were analyzed for determination of Phosphorous concentration. The Phosphorous were determined by pre-digested in diacidmixure [HNO_3: $HClO_4$ (3:2)]. Aliquot was collected, dilution was made. The Phosphorous were estimated by Calorimetric method help of spectrophotometer (Jackson, 1973) [4].

Statistical Analysis

The experimental data pertaining to biometric observations, nutrient uptake, yield were recorded, compiled in appropriate tables and analyzed statistically as per the procedure appropriate to the design (Panse and Sukhatme, 1978) [7].

Emperical Formulae

$$\text{(1) Nutrient uptake (Kg ha}^{-1}\text{)}: \frac{\text{Nutrient conc.(\%) X Dry matter (Kg ha}^{-1}\text{)}}{100}$$

$$\text{(2) Apparent Nutrient Recovery (\%)}: \frac{\text{Uptake of } N_F - \text{Uptake of } N_{C} \text{ X 100}}{\text{Amount of Nutrient Applied}}$$

$$\text{(3) Agronomic Efficiency: } \frac{\text{Grain Yield}_F - \text{Grain Yield}_C}{\text{Amount of Nutrient Applied}}$$

$$\text{(4) Relative Agronomic Efficiency: } \frac{\text{Total biomass yield}_F\,(\text{kgha}^{-1}) - \text{Total biomass yield}_C\,(\text{kg ha}^{-1})}{\text{Total biomass yield STD}_F\,(\text{kgha}^{-1}) - \text{Total biomass yield}_C\,(\text{kgha}^{-1})}$$

Where, F, C, N and STD denote Fertilized, Non-fertilized control plots, Standard plot and Nutrient applied

Results and Discussion

Total biomass production

The total biomass production in maize which ranged from 5.59-11.15 t ha^{-1} with the treatment control and 100% P (SSP) +Lime@ 0.2 LR respectively. The highest biomass yield was produced by the treatment received 100% P (SSP) +Lime@ 0.2 LR (11.15 t ha^{-1}).

The same trend was observed in total biomass production in groundnut which ranged from 4.07 - 7.67 t ha^{-1} the total biomass produced by cropping system ranged from 9.66-18.82 (t ha^{-1}) with control and 100% P (SSP) +Lime@0.2 LR. The treatment received 50% (RP) +50%SSP followed the 2nd highest.

Combined equivalent yield

The total combined equivalent yield of maize -groundnut cropping system which ranged from 2072-5728 (kg ha^{-1}) with control and 100% P (SSP) +Lime@0.2 LR.

Phosphorus use efficiency (PUE)

The Phosphorus use efficiency in case of Maize was highest (1.99) in the treatment received 100% P (SSP) +Lime@ 0.2 LR. The same trend was also observed in Phosphorus use efficiency of groundnut which ranged from 46 – 63.

The total PUE of the cropping sequence was maximum (93) in the treatment received 100% P(SSP) +Lime@ 0.2 LR followed by treatment received 50%P(RP)+50%P(SSP) (88).

Table 1: Total biomass production (t ha^{-1}), combined equivalent yield and Phosphorus use efficiency in the cropping sequence as affected by different P-sources

Treatment		Biomass production (t ha^{-1})										
		Maize				Groundnut				Maize + Groundnut	Combined	
		Grain	Stover	Total	PUE	Pod	Haulm	Total	PUE	Total biomass (t ha^{-1})	Equivalent yield (kg ha^{-1})	PUE
T_1	Control	2.44	3.15	5.59		1.67	2.40	4.07		9.66	2072	-
T_2	100% P(RP)	4.13	5.21	9.34	77	2.47	3.37	5.83	46	15.17	4050	50
T_3	100% P(SSP)	4.35	5.80	10.15	88	2.23	3.80	6.03	32	16.18	4516	62
T_4	75%P (RP)+25% P(SSP)	4.90	5.97	10.87	113	2.50	3.87	6.37	47	17.24	4677	66
T_5	50%P (RP)+50% P(SSP)	4.94	5.83	10.77	115	2.60	4.73	7.33	53	18.10	5544	88
T_6	25%P (RP)+75%P (SSP)	4.30	4.90	9.20	85	2.10	3.50	5.60	25	14.80	4208	54
T_7	100%P (SSP)+ Lime@ 0.2LR	5.03	6.12	11.15	119	2.77	4.90	7.67	63	18.82	5728	93
	SE(m)±	0.12	0.15	0.16	-	0.21	0.34	0.05	-	-	-	-
	CD (0.05)	0.35	0.44	0.49	-	0.62	1.02	0.14	-	-	-	-

Uptake of Phosphorus and Apparent Phosphorus Recovery (APR)

Phosphorus uptake by maize crop was more than groundnut. Uptake by maize crop was 4.1 to 21.3kg P ha^{-1} while that by groundnut was 4.04 to 11.41 kg P ha^{-1}. Both the crops together removed P in the range 8.14 to 32.71 kg ha^{-1} in the same order of treatments.

The Apparent P recovery of various P sources ranged from 27.15 to 62.52 per cent. However, increase in APR was observed as a result of combination of RP with the soluble source. It was maximum (62.52) with the treatment 100% P (SSP)+Lime@0.2 LR.

The uptake (X) was significantly related to total biomass production (Y) as $Y = 0.140x^2 - 1.525x + 9.921$ with R^2=0.971.

Table 2: Phosphorus uptake and Apparent Phosphorus Recovery (APR) from different P sources in maize- groundnut crop cropping sequence Uptake of Phosphorus (kg ha^{-1})

Treatment		Maize	Groundnut	Total	APR (%)
T_1	Control	4.1	4.04	8.14	-
T_2	100% P(RP)	9.4	9.41	18.81	27.15
T_3	100% P(SSP)	13.2	8.41	21.61	34.27
T_4	75%P(RP)+25% P(SSP)	14.8	10.62	25.42	43.97
T_5	50%P(RP)+50% P(SSP)	15.6	10.45	26.05	45.57
T_6	25%P(RP)+75%P (SSP)	11.9	7.40	19.30	28.40
T_7	100%P(SSP)+Lime@ 0.2 LR	21.3	11.41	32.71	62.52
	SE(m)±	0.262	0.88	-	-
	CD (0.05)	0.807	2.57	-	-

Relative Agronomic Efficiency of P- sources in cropping sequence

Maize crop

For Maize crop the RAE varied between 88-136. It was highest in treatment received form 100%P (SSP)+ Lime@0.2 L.R and lowest in the treatment 100%P(RP). Compaction of rock phosphate with water soluble source increases the efficiency depending upon the type and amount of acid released by them.

Groundnut crop

In addition to its own dose of P, groundnut crop had utilized the residual P of maize crop. The RAE of P source for groundnut crop varied between 77 to 194. The efficiency showed an increase in the compacted source.

Maize - Groundnut

Considering the yield of both the crops in the cropping sequence the RAE of the P sources varied from 93 to 149. The lone RP source was more efficient than the lone source of SSP. Their efficiency increased as a result of different combination with SSP. Based on RAE P sources can be arranged as 100%P(SSP)+ Lime@0.2 LR > 50%P(RP)+50% P(SSP) >75%P(RP)+25% P(SSP) >100% P(RP) >100%P(SSP)> 25%P(RP)+75%P (SSP). The maximum RAE (149) was achieved with the treatment 100% P(SSP)+ Lime@0.2 LR.

Table 3: Relative Agronomic Efficiency of various P- sources in the Cropping sequence

Treatment		RAE		
		Maize	Groundnut	Maize - Groundnut
T_1	Control	-	-	-
T_2	100% P(RP)	88	141	101
T_3	100% P(SSP)	100	100	100
T_4	75%P(RP)+25% P(SSP)	129	147	133
T_5	50%P(RP)+50% P(SSP)	131	165	139
T_6	25%P(RP)+75%P (SSP)	97	77	93
T_7	100%P(SSP)+ Lime@0.2 LR	136	194	149

Conclusion

Highest maize grain yield (5.03 t ha^{-1}) was produced due to addition of 100%P (SSP) +Lime @0.2LR and highest pod yield (2.77 t ha^{-1}) of groundnut was also due to 100%P (SSP)+Lime@0.2LR. The total biomass produced by cropping system ranged from 9.66 -18.82 (t ha^{-1}) with control and 100% P (SSP) +Lime@ 0.2 LR. Combined maize and groundnut equivalent yield produced by cropping system ranged from 2072 – 5728 (kg ha^{-1}) with control and 100% P (SSP) +Lime@0.2 LR. Apparent P recovery (62.52%) was highest in100%P (SSP) +lime@0.2LR for the cropping sequence. The same treatment also recorded the highest uptake of nutrients Phosphorous. The total phosphorus use efficiency of the cropping sequence was maximum (93) received in 100% P(SSP) +Lime@0.2LR. The highest Relative Agronomic efficiency of the cropping sequence (149) was recorded with 100% P(SSP) +Lime@0.2LR followed by RP:SSP(1:1) (139). Of the lone sources evaluated, SSP+Lime@0.2LR was found to be superior to SSP and lone source of RP was found to be superior to SSP. Compaction of the rock phosphate with water soluble source improved their efficacy over the lone RP source.

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