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Evaluation of Performance of Crop ProductionUsingLow Grade Fine Sized Rock Phosphate with Ammonium Sulphate In Alkaline Soil

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Abstract: Experiments were carried out on clayey loamy alkaline soil to evaluate the agronomic efficiency of fine sized low grade phosphate rock and it was further compared with that of soluble phosphate fertilizer (di-ammonium phosphate). *Cicerarietinum, Vignamungo*and *Vignaradiata* were the test crops subjected to treatments of absolute control, di-ammonium phosphate and low grade rock phosphate with varying concentrations of ammonium sulphate or ammonium nitrate to determine the optimum composition of this mixed fertilizer. The experiments were conducted during 2013-2014 in the bid to study the growth rate, biomass and yield of crop. Tests were also performed to determine the residual effects of the fertilizers on the crops. The results indicated that the combined use of low grade rock phosphate and ammonium sulphate or ammonium nitrate at 16 kg N/ha (when compared to di-ammonium phosphate), resulted in a significant growth rate and a better yield in the test crops and was found to be a more attractive management option when compared to di-ammonium phosphate.
Keywords: Rock phosphate, fertiliser, di-ammonium phosphate, residual test, relative agronomic efficiency.

Introduction

Improving and maintaining soil fertility is essential to meet the demands of food production for an ever-increasing population. Decline in productivity has put sustainability of agricultural production systems in danger. As the land resources available for food production are finite, the assessment of soil productivity is essential to determine soil quality and sustainability of production systems[1,2]. Although an adequate nutrient availability to plants ensures good soil fertility management, the assets of soil in terms of nutrients (nitrogen, phosphorus, potassium and sulphur) are limited[3]. The ever increasing burden of agricultural production results in an over-exploitation of soil resources which leads to a nutrient shortage. This insufficiency can be fulfilled, partially or completely, by applying adequate amount of inorganic or organic fertilizers. Thus, the use of fertilizers has become an integral part of the agricultural production system.

The most commonly used inorganic nitrogen fertilizers are ammonium sulphate and ammonium nitrate, of which the former is widely used in alkaline soils. Phosphorus (P) is an essential and limiting macronutrient in the production of vegetables, cereals and leguminous crops. It stimulates root growth, flower development and seed formation besides enhancing vigorous and early maturity in these crops. It is absorbed from soil almost exclusively in the form of soluble phosphate anions[4]. This pool of available phosphorus is often insufficient for maximum crop growth and must be replenished regularly using conventional P-fertilizers[5]. However, the use of these fertilizers is highly limited in developing countries since they are expensive and hence not affordable for the resource-poor farmers[6].Thus, the use of locally available low-grade rock phosphate (RP) is now being advocated[7,8,9]. Despite the progress made in methods to enhance the quality and performance of locally available low grade RP (such as partial acidulation with mineral acids, composting with organic manures, compaction with super phosphate and incorporation of additives), the results were not satisfactory[10, 11, 12,13,14,15].

Composting of RP with agricultural wastes is known to increase the solubility of RP[16]. Decomposing organic matter releases humic acid which converts insoluble soil phosphates into soluble forms. In such cases, farmyard manure (FYM) or other organic manures, if applied with high-grade phosphate minerals work very effectively[17]. It has been reported that high grade RP (+34% P_2O_5), in fine size (d80 at 23 microns), if applied with FYM shows better agronomic efficiency than di-ammonium phosphate when applied on equal P_2O_5 basis. The extent of solubilisation of a given RP varies with the nature of waste and the rate of decomposition. Recent studies have shown that high grade RP with wool waste at 25 or 50 kg/ha and bio gas slurry at 10 ton/ha, yields a higher biomass when compared to di-ammonium phosphate. The process of decomposition of the organic matter is hastened by adding nitrogen through oil cakes or waste from wool industry. However using organic nitrogenfertilizers, on a large scale, is not very convenient due to its unavailability. Hence inorganic nitrogen fertilizers, like ammonium sulphate or ammonium nitrate, can be good substitutes for organic nitrogen fertilizers.

The use of high grade RP is preferred over low grade RP because the latter contains carbonate gangue minerals which neutralize the acidity generated in the soil that is required for phosphate solubilisation. Although, significant studies on high grade RP have been proved successful, attention was mainly given to the process of beneficiation of RP. Hence more efforts can be applied to improve the performance of low grade RP, since it is available locally in large volumes. Despite the earlier researches, to the best of our knowledge, relatively sparse data currently exist in terms of addition of inorganic nitrogen fertilizers to low grade RP. Thus, the basic objective of this study was (1) to analyze low grade RP in fine size along with ammonium sulphate or ammonium nitrate as a viable substitute for di-ammonium phosphate in alkaline soil, (2) to determine the effect of the mixed fertilizer on the biomass of plants, (3) to study the residual effects of the mixed fertilizer on biomass of plants, and (4) to calculate the effect of the mixed fertilizer on the yield of plants.

Materials and Methods

Materials

Low grade RP was obtained from Eshidiya mines of Jordan phosphate mines company limited, Jordan. The chemical composition of the RP samples (d80 size particles) contained 43.8% Tri calcium phosphate (P_2O_5: 20.05%), 30.58% Acid insoluble residues and 9.88% chlorine. Commercially available di-ammonium phosphate containing 46% P_2O_5 and 18% Nitrogen was used for the study. Ammonium nitrate procured from Central drug house (P) limited, New Delhi, Indiaand ammonium sulphate from Hi Media laboratories limited, Mumbai, India were used. The test crops used in this study were chick pea (*Cicerarietinum*) obtained from the local super market, black gram (*Vignamungo*) and green gram (*Vignaradiata*), obtained from the seed centre, Tamilnadu agricultural university, Coimbatore, India.

Soil and climate

The study was conducted at the research farm of VITUniversity, in Vellore, India (12.93°N; 79.13°E; 216 m). During the experimentation period (2013-14), the annual rainfall was 1208 mm at the experimental site. The mean annual temperature was 27°C, with a minimum of 17°C (November) and maximum of 43°C (April). A major part of the rain was received between August and September while the average sunshine duration was 10-13 h per day. The soil samples were analysed prior to the commencement of the experiments. The soil was clayey loamy, medium and reddish brown in nature with 4.35% gravel, 92.85% sand and 2.8% fines, having pH 8.12, and electrical conductivity of 385µS/cm.

Experimental procedure

Sieved soil samples were filled in plastic trays of dimensions 44 x 32 x 14 (L x B x H in cm). The experiments were performed in triplicate to observe the effect of the fertilizers on the biomass of plants and the yield of crop.The details of the experiments conducted are as mentioned in Table 1.

Table 1. Summary of experiments conducted with low grade fine size rock phosphate.

Sl. No	Test conducted	Test crop	Duration / Period of study
1	Proof of concept (plant biomass)	*Cicerarietinum*	12 days / Mar – Apl 2013
2	Test for residual effects (plant biomass)	*Cicerarietinum*	12 days / Mar – Apl 2013
3	Proof of concept (yield of crop)	*Vignamungo*	106 days /Aug – Nov 2013
4	Test for residual effects (yield of crop)	*Vignaradiata*	104 days / Dec – Mar 2014

Studies on Biomass of plants

Cicerarietinum was chosen as the test crop since legumes are better utilizers of phosphate from RP through accelerated dissolution by the roots. Also, the climatic conditions existing during the study were favourable for the cultivation of *Cicerarietinum.* Seven different treatments were studied, which include: 1) Absolute control; 2) RP (20.04/14.74) at 60 kg P_2O_5/ha; 3) di-ammonium phosphate at 60 kg P_2O_5/ha (control); 4) RP (20.04/14.74) at 60 kg P_2O_5/ha + ammonium sulphate at 16 kg of N/ha; 5) RP(20.04/14.74) at 60 kg P_2O_5/ha + ammonium sulphate at 32 kg of N/ha; 6) RP(20.04/14.74) at 60 kg P_2O_5/ha + ammonium nitrate at 16 kg of N/ha; and 7) RP(20.04/14.74) at 60 kg P_2O_5/ha + ammonium nitrate at 32 kg of N/ha. All seven treatments were performed in triplicate and the average values were used for further analysis of data on the biomass of plants. Table 2 shows the amount of fertilizers and nutrients applied to the soil, in accordance with the surface area of the trays used.

Table 2. Amount of Fertilizer applied in the trays in accordance with the Surface Area

Sl. No	Fertilizer	Quantity	P_2O_5	N	K
1	DAP	1.84 g	0.846 g	0.331 g	0 g
2	RP	4.215 g	0.846 g	Negligible	0 g
3	AS (at 16kg N/ha)	1.06 g	0 g	0.224 g	0 g
4	AN(at 16kg N/ha)	0.64 g	0 g	0.224 g	0 g

Prior to the experiments, the fertilizers were thoroughly mixed with the soil to ensure a uniform distribution of essential nutrients. Further, the trays were watered regularly and conditioned for two days to ensure proper dissolution of the fertilizers in soil. The trays were divided into four slots and initially twelve seeds of *Cicerarietinum* were sown in each slot. Later the seedlings were thinned to ten per slot. The trays were watered regularly to maintain the moisture content at optimum levels. It was also ensured that the trays were uniformly exposed to sunlight. For the study of proof of concepts for determining the biomass of plant, the duration was deliberately kept short (12 days), after which the plants were cropped. Even in this short period, the *Cicerarietinum* crops showed considerable growth in terms of their height and biomass. This was also one of the reasons for choosingwhy *Cicerarietinum* as the test crop. To evaluate the effect of the residual fertilizers in soil, the next batch of seeds was sown after seven days, without the addition of any fertilizer. The methodology followed for this test was similar to that followed in the earlier test. The biomass of plants obtained from both the tests was compared for further analysis.

Studies on the yield of crops

Two sets of experiments were conducted, in which the first set of experiments were conductedin the absence of farmyard manure (FYM), while the second set of experiments were conducted in the presence of FYM. The effect of various treatments on the yield of the test crop was evaluated for *Vignamungo* and *Vignaradiata*(leguminous plants). The weather conditions prevailing through the duration of the experiment were an important consideration while choosing the test crops. The treatments studied in the first set of experiments wereas follows; 1) Absolute control; 2) di-ammonium phosphate at 60 kg P_2O_5/ha (control); 3) RP (20.04/14.74) at 60 kg P_2O_5/ha; 4) RP(20.04/14.74) at 60 kg P_2O_5/ha + ammonium sulphate at 16 kg N/ha; 5) RP(20.04/14.74) at 60 kg P_2O_5/ha + ammonium nitrate at 16 kg N/ha. The experiments conducted in the presence of FYM include 1) FYM at 4 ton/ha; 2) di-ammonium phosphate at 60 kg P_2O_5 /ha + FYM at 4 ton/ha; 3) RP(20.04/14.74) at 60 kg P_2O_5 /ha + FYM at 4 ton/ha ; 4) RP(20.04/14.74) at 60 kg P_2O_5 /ha + ammonium sulphate at 16 kg N/ha + FYM at 4 ton/ha; 5) RP(20.04/14.74) at 60 kg P_2O_5 /ha + ammonium nitrate at 16 kg N/ha + FYM at 4 ton/ha.

The procedures followed to study the biomass of plant and theyields of crop were similar. Three seeds of *Vignamungo* were planted in each slot and the seedlings were thinned to one per slot after four weeks. An optimum moisture level was maintained in the soil. After the crops matured, they were harvested and the yield of *Vignamungo* for each treatment was recorded. After five days, a fresh batch of seeds of *Vignaradiata* was sown to study the residual effects of the fertilizers. The yields obtained in both the tests were compared for further analysis. It was ensured that the trays were watered uniformly and were kept free of weeds throughout the study.

Percentage biomass increase and relative agronomic efficiencies

The relative agronomic efficiencies of the treatments were then estimated to indicate their agronomic effectiveness relative to di-ammonium phosphate. The percentage biomass increase for various treatments was computed using absolute control as the standard while di-ammonium phosphate was considered as the standard for determining relative agronomic efficiencies (Eqn. 1 and 2).

$$\text{Percentage Biomass Increase} = \left(\frac{B_t - B_{ac}}{B_{ac}} \right) \text{x} \, 100 \qquad (1)$$

$$\text{Relative Agronomic Efficiency} = \left(\frac{B_t - B_{ac}}{B_{DAP} - B_{ac}} \right) \text{x} \, 100 \qquad (2)$$

where, B_t, refers to the biomass of plants in treatment (g), while B_{ac} and B_{DAP} represents the biomass of plants in absolute control and in di-ammonium phosphate respectively.

Soil Analysis

After the biomass of plants study, the sieved soil samples were analysed for pH and electrical conductivity. However, during the study of the yield of plant, soil samples were analyzed for the pH after every 14 days. Soil pH and electrical conductivity were determined in a 1:2 soil/water using pH 600 pocket sized pH meter (Milwaukee Electronics Kft., Szeged, Hungary) and water analyzer (Model 371, Systronics (India) limited, respectively. Double distilled water was used for the analysis.

Results and Discussion

Studies for biomass of plants

Every nutrient plays an important role in the proper functioning of the mechanisms necessary for survival and growth of a plant organism. The effectiveness of a fertilizer can be measured in terms of the growth and development of the plant, by the amount of dry matter accumulated and partitioned in different plant organs[18]. Thus to compare the growth of plants, the fresh biomass (excluding the roots) produced in each tray was measured.

Table 3: Direct application of Rock Phosphate along with N containing fertilizers: Study with chick pea, during proof of concept and residual effect tests

Ttm. No.	Treatment	Biomass per plant (grams)		% Biomass increased (w.r.t absolute control)		Relative agronomic efficiency index (DAP)		pH		Electrical Conductivity (μS/cm)	
		Proof of concept	Residual Effect	Proof of concept	Residual Effect	Proof of concept	Residual Effect	Proof of concept	Residual Effect	Proof of concept	Residual Effect
1	Absolute Control	1.249	1.587	--	--	--	--	8.1	8.1	385	405.5
2	Di-ammonium Phosphate @ 60 kg P_2O_5 / ha	2.738	3.112	119.21	96.09	--	--	7.9	7.7	467	473.3
3	Rock Phosphate. PR (20.04/14.04) @ 60 kg P_2O_5 / ha	1.786	1.921	42.99	21.04	0.360	0.219	8.1	8.0	390	418
4	Rock Phosphate. PR (20.04/14.04) @ 60 kg P_2O_5 / ha + Ammonium Sulphate @ 16Kg N/ha	2.581	2.839	106.64	78.89	0.894	0.821	8.0	7.9	394	430
5	Rock Phosphate. PR (20.04/14.04) @ 60 kg P_2O_5 / ha + Ammonium Sulphate @ 32Kg N/ha	2.652	2.984	112.32	88.02	0.972	0.916	7.9	7.8	414	441.3
6	Rock Phosphate. PR (20.04/14.04) @ 60 kg P_2O_5 / ha + Ammonium Nitrate @ 16Kg N/ha	2.451	2.721	96.23	71.45	0.8072	0.7435	8.0	7.9	413	419
7	Rock Phosphate. PR (20.04/14.04) @ 60 kg P_2O_5 / ha + Ammonium Nitrate @ 32Kg N/ha	2.298	2.511	83.98	58.22	0.7045	0.6059	8.0	7.8	426	433.6

In the proof of concept studies, a significantly higher percentage biomassincrease was obtained using di-ammonium phosphate (119.2%) compared to low grade RP (42.99%) (Table 3). This substantial difference in the percentage biomass increase was due to the low phosphate content of RP. Moreover, the solubility of phosphate, especially in alkaline soils, is found to be considerably low. However, the percentage biomass increase elevated drastically when ammonium sulphate was applied along with RP. This may be due to rhizosphere-acidification which improves the nutrient uptake and suppresses the spread of root diseases. The acidification is a result of the nitrification of ammonium ion to nitrate ion carried out by *Nitrosomonas* and

Nitrobacter[19]. This acidification was imminent through the lowering of pH of soil (Table 3). Since the exp -eriment was conducted for a short period, the change in pH was not high in magnitude. When ammonium sulphate was applied at rates of 16 kg N/ha and 32 kg N/ha, along with RP, the biomass obtained per plant was 2.581g and 2.652 g, respectively. Though the rate at which ammonium sulphate was applied to the soil was doubled, the increase in biomass was not proportionate. This suggested that 16 kg N/ha is a more favourable rate for application of ammonium sulphate to the soil. Ammonium nitrate added along with low grade RP also showed an increase in biomass as compared to low grade RP. The application of ammonium nitrate at 16 kg N/ha and 32 kg N/ha resulted in biomass of 2.451 g and 2.298 g respectively. It is interesting to note that ammonium nitrate applied at 32 kg N/ha did not substantially support the growth of the crops as much as ammonium nitrate applied at 16 kg N/ha.

Table 4. Height and dry biomass of plants in test for biomass of plants

Ttm. No.	Treatment	Plant Height		Dry Biomass	
		Proof of concept	Residual Effect	Proof of concept	Residual Effect
1	Absolute control	25.88	26.86	0.652	0.832
2	Rock phosphate. RP (20.04/14.04) at 60 kg P_2O_5 / ha	26.07	27.02	1.623	1.813
3	Di-ammonium phosphate at 60 kg P_2O_5 / ha	26.83	28.01	0.921	1.073
4	Rock phosphate. RP (20.04/14.04) at 60 kg P_2O_5 / ha + ammonium sulphate at 16 kg N/ha	27.70	28.58	1.331	1.519
5	Rock phosphate. RP (20.04/14.04) at 60 kg P_2O_5 / ha + ammonium sulphate at 32 kg N/ha	27.91	28.75	1.486	1.720
6	Rock phosphate. RP (20.04/14.04) at 60 kg P_2O_5 / ha + ammonium nitrate at 16 kg N/ha	27.12	28.15	1.172	1.437
7	Rock phosphate. RP (20.04/14.04) at 60 kg P_2O_5 / ha + ammonium nitrate at 32 kg N/ha	26.24	27.48	1.032	1.322

The use of low grade RP along with ammonium sulphate resulted in relative agronomic efficiency values (0.894 and 0.972 for 16 kg N/ha and 32 kg N/ha respectively) very close to 1, indicating that the mixed fertilizers were almost as effective as di-ammonium phosphate. These values were significantly higher than those obtained for treatments using low grade RP along with ammonium nitrate. This was presumably due to the additional nutrient sulphur present in ammonium sulphate, which favours plant growth in terms of the biomass of plant. In addition, ammonium sulphate is about 2 to 3 times more acidifying than ammonium nitrate. The relative agronomic efficiency obtained for RP along with ammonium nitrate at 16 kg N/ha was fairly close to that of RP along with ammonium sulphate treatments, but the relative agronomic efficiency for ammonium nitrate applied at 32 kg N/ha was only 0.7045. Among the tests conducted ammonium sulphate at 16 kg N/ha in presence of RP proved to be generally more effective as a mixed fertilizer than other combinations. With reference to all treatments, the plants subjected to the treatment of absolute control had the least values for all the growth parameters.Table 4 clearly indicates that the addition of inorganic nitrogen fertilizers to low grade RP had a noteworthy effect on the height as well as on the dried biomass of the plant. The height and dried biomass values of plant, for both the RP with ammonium sulphate treatments as well as RP with ammonium nitrate applied at 16 kg N/ha treatment, werecomparable to that of di-ammonium phosphate. The trend followed was the same for both, proof of concept as well as residual effect test. This showed that the addition of ammonium sulphate or ammonium nitrate to low grade RP enhanced its performance in terms of height and biomass.

In the test for residual effects of the fertilizers, an increase in electrical conductivity of soil was observed, for all the treatments, due to the nitrogen fixation properties of *Cicerarietinum*. This increase in nitrogen content of soil resulted in an increase in the biomass of the plant in all the treatments. Since the biomass obtained from absolute control treatment increased from 1.249 g (proof of concept) to 1.587 g (residual effect test), there was a reduction in the percentage biomass increase for all treatments. The values of percentage biomass increase and relative agronomic efficiencies, for various treatments, project the similarity in the trend of results obtained for the proof of concept and residual effect tests. The biomass of plants study showed that low grade RP, applied along with inorganic nitrogen fertilizers, works almost as efficiently as DAP and could be used as a viable substitute for the same.The study for yield of crop was conducted to confirm the above mentioned claim.

Discussion

Studies for the yield of crop

As proof of concept and residual effect tests for biomass of plant proved that 16 kg N/ha is the more favorable rate at which inorganic nitrogen fertilizer should be added to the soil, ammonium sulphate and ammonium nitrate were applied at 16 kg N/ha for the yield of crop study.

Yield studies in absence of Farmyard Manure

First cropping

The addition of inorganic nitrogen fertilizers to low grade RP had a pronounced effect on the yield of plant as compared to low grade RP. The yields obtained from both the treatments of low grade RP applied along with nitrogen fertilizers, was comparable to that of the yield obtained from di-ammonium phosphate (Table 5). These observations clearly projected the similarity in the trend followed by the results of biomass of plant and yield of plant tests.

Table 5: Direct application of Rock Phosphate along with N containing inorganic fertilizers: Study with *Vignamungo and Vignaradiate*, Soil pH = 8.0, E.C. of soil measured after cropping during proof of concept and residual effect tests

Ttm. No.	Treatment	Biomass per plant (grams)		% Biomass increase		Relative agronomic efficiency	
		Proof of concept	Residual Effect	Proof of concept	Residual Effect	Proof of concept	Residual Effect
1	Farmyard manure at 4 ton/ ha.	2.67	3.12	--	--	--	--
2	Di-ammonium phosphate at 60 kg P_2O_5/ ha + farmyard manure at 4 ton/ ha.	4.45	5.09	66.67	63.14	--	--
3	Rock phosphate. RP (20.04/14.74) at 60 kg P_2O_5/ ha + farmyard manure at 4 ton/ ha.	3.31	3.78	23.97	21.15	0.359	0.334
4	Rock phosphate, RP (20.04/14.74) at 60 kg P_2O_5/ ha + ammonium sulphate at 16 kg/ ha of N + farmyard manure at 4 ton/ ha.	4.26	4.95	59.55	58.85	0.893	0.932
5	Rock phosphate, RP (20.04/14.74) at 60 kg P_2O_5/ ha + ammonium nitrate at 16 kg/ ha of N + farmyard manure at 4 ton/ ha.	3.95	4.76	47.9	53.52	0.718	0.847

Soil Analysis

The analysis of soil at regular intervals was useful in projecting the acidification of soil caused by nitrifying bacteria.In all the treatments pertaining to RP along with inorganic nitrogen fertilizers, a gradual decrease in the pH value of the soil was observed.The soil used for the study was alkaline in nature (pH 7.8 to 8.1). Nitrifying bacteria, responsible for the acidification of soil, prefer an alkaline environment (pH ranging from 7.5 to 8.2) for their proper functioning as suggested by James et al.,[20]. This acidification helps in phosphate solubilisation which enhances the performance of RP in terms of the biomass and the yield of plant. Hence, it was observed that the agronomic efficiency of low grade fine size RP applied along with nitrogen fertilizers was comparable to that of di-ammonium phosphate, in alkaline soil (Fig. 1).

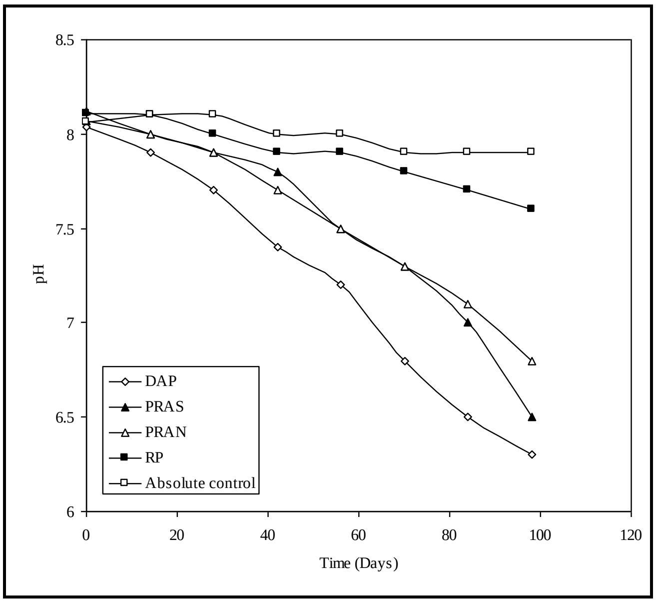

Figure 1: pH values for treatments pertaining to RP with inorganic nitrogen fertilizers

Second cropping

*Vignaradiata*was used as the test crop for residual effect studies after the *Vignamungo* crop was harvested. No further fertilizers were applied to these trays. The yield obtained using *Vignamungo* was more than that of *Vignaradiata*. Conversely, the percentage biomass increase in all the treatments declined notably due to the increase in the yield of absolute control (from 1.43 to 2.17), as seen in the case of biomass of plant test. However an increment in the relative agronomic efficiencies or low grade RP with nitrogen fertilizers treatments was observed. This proves that the effect of low grade RP applied along with ammonium sulphate or ammonium nitrate is sustained for a considerable period of time.

Yield studies in presence of Farmyard Manure

First cropping

A remarkable increase in crop yield was observed, in all the treatments, on addition of FYM. The yield obtained from the absolute control treatment increased from 1.43 g to 2.67 g when FYM was applied (Table 6). A similar increase (from 2.28 g to 3.31 g) was observed in the case of low grade RP when FYM was applied along with it. However the yield was not comparable to that of di-ammonium phosphate. This is because of the presence of carbonate gangue in low grade RP which neutralizes the acidification caused by the decomposition of FYM. However, a remarkable increase in yield was observed when FYM was applied to low grade RP along with ammonium sulphate or ammonium nitrate. The nitrogen fertilizers speed up the decomposition of FYM which increases nutrient availability and nutrient uptake of plant. The yield obtained from treatments RP + ammonium sulphate + FYM and RP + ammonium nitrate + FYM were comparable to that of di-ammonium phosphate + FYM. However, the treatments of RP + ammonium sulphate + FYM and RP + ammonium nitrate + FYM were more effective than di-ammonium phosphate alone.

Second cropping

In the second cropping, the relative agronomic efficiencies obtained (with respect to di-ammonium phosphate + FYM) for the treatments RP + ammonium sulphate + FYM and RP + ammonium nitrate + FYM were 0.932 and 0.8476. These results illustrate that low grade RP with inorganic nitrogen fertilizers works as efficiently as di-ammonium phosphate even when FYM is applied along with it.

Table 6: Direct application of Rock Phosphate along with N containing inorganic fertilizers and Farmyard Manure: Study with *Vignamungo and Vignaradiate*, Soil pH = 8.0, E.C. of soil measured after cropping during proof of concept and residual effect tests.

Ttm. No.	Treatment	Biomass per plant (grams)		% Biomass increase		Relative agronomic efficiency	
		Proof of concept	Residual Effect	Proof of concept	Residual Effect	Proof of concept	Residual Effect
1	Farmyard manure at 4 ton/ ha.	2.67	3.12	--	--	--	--
2	Di-ammonium phosphate at 60 kg P_2O_5/ ha + farmyard manure at 4 ton/ ha.	4.45	5.09	66.67	63.14	--	--
3	Rock phosphate. RP (20.04/14.74) at 60 kg P_2O_5/ ha + farmyard manure at 4 ton/ ha.	3.31	3.78	23.97	21.15	0.359	0.334
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5	Rock phosphate, RP (20.04/14.74) at 60 kg P_2O_5/ ha + ammonium nitrate at 16 kg/ ha of N + farmyard manure at 4 ton/ ha.	3.95	4.76	47.9	53.52	0.718	0.847

Conclusions

The study revealed that, in alkaline soils, low-grade RP in fine size when applied along with ammonium sulphate or ammonium nitrate at 16 kg N/ha results in an agronomic efficiency, in terms of biomass and yield of plant, comparable to that of di-ammonium phosphate. This may be due to the enhancement of phosphate solubilisation of low grade RP by inorganic nitrogen fertilizers. Thus, this mixed fertilizer of low grade RP along with inorganic nitrogen fertilizers could be used successfully as a cheaper source of P-fertilizer in the place of costly water soluble phosphate fertilizers like di-ammonium phosphate in crop production and as an alternative and viable technology to utilize low-grade RP. However, more information on the optimum amounts of the mixed fertilizersisrequired for improved crop production. This would aid the poor resourced farmers, especially those working with alkaline soil.

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