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Effect of di-ammonium phosphate and rockphosphate enriched biogas slurry on yield and uptake of phosphorus by mustard

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Abstract*:* A greenhouse pot-culture experiment was conducted in a Typic Haplustept with mustard as a test crop to evaluate the response of different levels of phosphorus applied though rockphosphate enriched biogas slurry (RPEBGS), di-ammonium phosphate and rockphosphate on dry matter yield and P-use efficiency. The results indicated that P supplied through di- ammonium phosphate produced the highest dry matter yield (13.5 g pot $^{-1}$), P content (2.63 mg P g^{-1}) in plants and total P uptake (34.70 mg P pot^{-1}) followed by RPEBGS and rockphosphate . The relative agronomic effectiveness of RPEBGS in terms of dry matter yield and total P uptake was higher to the tune of 67.75 and 69.95 per cent, respectively. The data on uptake and per cent P utilization clearly indicated the superiority of RPEGS than other sources.

Additional key words: *Rockphosphate enriched biogass slurry; P-use efficiency, Agronomic effectiveness*

Introduction

With the increased use of nutrients in exploitive agriculture, the proportion of phosphatic fertilizer has also increased which is expected to reach 14 million tonnes by 2030 from the current level of consumption *i.e.,* 38.3 kg P_2O_5 ha^{-1} to 7.2 million tonnes in 2009-2010 (FAO 2011). India depends heavily on import for phosphatic fertilizers either in the form of finished product or intermediate form as orthophosphoric acid or rockphosphate as raw material for indigenous processing. The prices of commercial fertilizer are escalating and that limit its use by farmers. As country has large deposits (≈260 million tonnes) of rockphosphate (FAI 2011) having 18-20% P_2O_5 as insoluble form. However the crop recovery of P from applied phosphate seldom exceeds 15-20% with water-soluble sources and is much lower with insoluble rock phosphate.

This urgently calls for an improvement in the effectiveness of rock phosphate and to increase efficiency of P utilization by crops in nearly neutral soils. The combined use of low grade rockphosphate and organic manures has been reported to be beneficial in augmenting yield and P-use efficiency in oilseed crops (Singh *et. al*. 1994). Keeping this in view, present investigation was carried out to evaluate the efficiency of rock-phosphate enriched biogas slurry *vis-a-vis* di-ammonium phosphate and rockphosphate on yield and P efficiency for mustard crop.

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Materials and Methods

Treatment details and materials used

A greenhouse pot-culture experiment was conducted to evaluate the relative efficiency of rockphosphate enriched biogas slurry (RPEBGS), rockphosphate (RP) and di-ammonium phosphate (DAP) as a source of P, on agronomic efficiency, contribution of P from P sources and P-use efficiency in mustard. Rockphosphate enriched biogas slurry was prepared by using a slurry mixture of powdered rockphosphate procured from Rajasthan State Mines and Minerals Limited, Udaipur, and fresh cattle dung in 1:40 ratio was used as a feedstock for digestion in biogas plant model. The model of biogas plant was assembled by using a cylindrical stone pot (depth 22.5 cm and diameter 23.5 cm) as digester tank and a cylindrical plastic container (height 23 cm and diameter 20 cm) erected in inverted position in the stone pot to serve the purpose of gas holder. The biogas plant model was run for 90 days using slurry mixture of rockphosphate and cattle dung. The dried slurry was analysed for extractable P.

Bulk surface soil (0-15 cm) was collected from Todapur area of IARI Farm, processed and passed through 2 mm sieve. The soil (Typic Haplustept) had a pH (7.5), EC (0.62 dsm^{-1}), CEC (10.8 c mol (p^{+}) kg^{-1}) and OC (0.34 %), the available N (215.3 kg ha^{-1}), available P (8.8 kg ha^{-1}) and available K (237.6 kg ha^{-1}), respectively. The P fixing capacity of soil was 35.6 per cent. The processed soil of 7 kg was filled in wide mouth glazed pots of 8 kg capacity. The experiment was laid out in factorial CRD with four levels of P (0, 8, 16 and 24 mg P kg^{-1} soil) and three sources of P (RP, RPEBGS and DAP). The fertilizer materials were analyzed following standard procedures.

The DAP and Biogas slurry (BGS) had 21 per cent and 1.1 per cent N, respectively. RP had traces of water soluble, 2% citrate soluble (3.22%) and 2% formic acid soluble (4.10 %) of P_2O_5, respectively. Similarly, the P_2O_5 (%) content in RPEBGS was 0.41 , 2.12 and 2.43 per cent of water soluble, 2 % citrate soluble and 2 % formic acid soluble, respectively. Biogas slurry (BGS) had water soluble P (0.12 %), 2 % citrate soluble (0.32 %) and 2 % formic acid (0.38%) P_2O_5. The di-ammonium phosphate contained about 54 % water soluble P_2O_5.

Treatment imposition, sowing and after care

The required amount of rockphosphate enriched biogas slurry (RPEBGS) and di- ammonium phosphate (DAP) were added separately to each pot as per treatment details and mixed thoroughly. The entire dose of potash (40 kg ha^{-1}), phosphorus and half dose of N (40 kg ha^{-1}) was applied basally through urea and potassium chloride and the rest of N (40 kg ha^{-1}) was top-dressed 30 days after sowing. Water was added in pots by gradual sprinkling to have the sufficient moisture at the time of sowing. Fifteen good quality seeds of mustard (*var.* Pusa Jaikisan) were sown in holes at 1.5 cm depth and then holes were loosely covered with soil. After germination, all the fifteen seedlings were allowed to grow for ten days which were finally thinned to four in each pot. Recommended agro-management practices were followed.

Harvesting, processing and analysis of plant samples

At flowering (75 days after sowing), above ground portion of the plants were harvested, washed and air-dried. Later, plant material was dried in hot air oven at 70°C till constant weight was obtained. Dry weight of the plant material from each pot was recorded and was grounded. From each treatment, two gram powdered plant materials was taken in 150 ml conical flasks and digested with 15 ml of di-acid mixture of HNO_3 and $HClO_4$ in the ratio of 5:1 (by volume) on a hot plate. The digested extracts of plant samples were made up to 100 ml. Phosphorus determination in the di-acid digested plant material was carried out by phosphorus-molybdate yellow colour method in HNO_3 medium (Koenig and Johnson 1942). The relative agronomic effectiveness (RAE) of rockphosphate enriched biogas slurry, rockphosphate and di-ammonium phosphate was computed from crop response data on dry matter yield and P uptake as given below:

$$\text{RAE : (Dry matter yield) : } \frac{\text{Dry matter yield with RPEBGS/RP – Dry matter yield in control pot}}{\text{Dry matter yield with standard P fertilizer (DAP) – Dry matter yield in control}} \times 100$$

$$\text{RAE : (P uptake) : } \frac{\text{P uptake with RPEBGS/RP – P uptake in control pot}}{\text{Puptake with standard P fertilizer (DAP) – P uptake in control pot}} \times 100$$

Statistical analysis

The data were statistically analyzed and the standard error of mean (S.Em ±) and critical differences were calculated for main treatment and their interactions and are reported at 5 per cent level of probability to test the significance (Gomez and Gomez 1984).

Results and Discussion

Dry matter yield: Data on dry matter yield (Table 1) indicated that treatments significantly increased the mean dry matter yield over control. The per cent (mean) increase of the mean dry matter yield over control was 54.2, 72.3 and 85.5 per cent at 8, 16 and 24 mg P kg^{-1} levels of P sources, respectively. Among P sources maximum mean dry matter production (13.05 g pot $^{-1}$) was observed with DAP, followed by RPEBGS (10.88 g pot $^{-1}$) and rockphosphate (8.48 g pot^{-1}). There was significant difference between the levels with respect to dry matter production. Mean maximum dry matter production (11.74 g pot $^{-1}$) was recorded at 24 mg P kg^{-1} levels. The relative agronomic effectiveness of RP and RPEBGS was 32.0 and 67.71 per cent, respectively (Fig.1). The interaction effect of levels and sources of P was significant towards biomass yield. Maximum dry matter yield of 14.55 g pot $^{-1}$ was recorded with DAP applied at 24 mg P kg^{-1}. Application of RPEBGS at 8 mg P kg^{-1} produced 9.65 g pot^{-1} dry matter, which was significantly higher than RP applied at 24 mg P kg$^{-1.}$ Similar results were also observed by Singh and Kamath (1988) and Shekhawat *et al.* (2012). The positive response to P application may be ascribed to available P status and medium P fixing capapcity of the soil (Rans and Angiras 1955). The favourable effect of phosphorus fertilization on dry matter yield of mustard might be due to its key role in energy transformation in various metabolic processes (Tomar *et al.* 1992).

P content and uptake: Treatments significantly increased the mean P concentration in plant over control (Table 1). Among P sources, DAP (2.63 mg g^{-1}) exhibited highest mean values for P content in plants followed by RPEBGS (2.49 mg g^{-1}) and RP (1.92 mg g^{-1}). The interaction between levels and sources of P was significant towards P content. Maximum P concentration (2.81 mg g^{-1}) in plants was found with the application of DAP at 24mg P kg^{-1}. It was further observed that fertilization of mustard crop with DAP at 16 mg P kg^{-1} level and RPEBGS at 24 mg P kg^{-1} level was comparable on P content. It was evident that phosphorus concentration in plants showed an increasing trend with increasing levels of P_2O_5 upto 24 mg kg^{-1}. These results are in agreement with the earlier reports (Sharma and Kamath 1990). The increase in P uptake with increasing levels of P may be due to increased availability and absorption of P by mustard (Reddy *et al.* 1988). Burauel *et al.* (1990) stated that plants' exhibit a high demand for phosphate during the vegetative growth and are able to accumulate in cell vacuole.

Table 1. Effect of sources and levels of P on dry matter yield, P content and P uptake in mustard

Treatments/sources	Drymatter Yield (g pot $^{-1}$)	P content (mg P kg^{-1})	P Uptake (mg P pot^{-1})
Control	-	-	-
P1 (RPEGS)	9.65	2.37	22.29
P2 (RPEGS)	11.10	2.50	27.14
P3 (RPEGS)	11.90	2.62	31.57
Mean	10.88	2.49	27.00
Control	-	-	-
P1 (RP)	8.13	1.89	15.54
P2 (RP)	8.54	1.91	16.52
P3 (RP)	8.77	1.96	17.36
Mean	8.48	1.92	16.47
Control	-	-	-
P1 (DAP)	11.50	2.43	28.06
P2 (DAP)	13.11	2.67	35.09
P3 (DAP)	14.55	2.81	40.95
Mean	13.05	2.63	34.70
Cumulative mean of different values			
Control	6.33	1.78	11.27
P1 (from all sources)	9.76	2.23	21.96
P2 (from all sources)	10.91	2.36	26.34
P3 (from all sources)	11.74	2.46	29.96
Mean	10.80	2.35	26.06

	Dry Matter		P content		P uptake	
	SEm±	CD (5%)	SEm±	CD (5%)	SEm±	CD (5%)
Source	0.09	0.26	0.008	0.020	0.26	0.75
Level	0.10	0.27	0.008	0.020	0.28	0.79
Source X Level	0.17	0.37	0.010	0.004	0.58	1.52

P1- 8 mg P kg $^{-1}$: P2- 16 mg P kg $^{-1}$: P3- 24 mg P kg $^{-1}$:

The P uptake increased with increasing P rate as compared to control (Table 1). The difference in P uptake (mean) among different levels of P was significant. Highest mean P uptake (34.70 mg pot^{-1}) was noticed with DAP followed by RPEBGS (27.00 mg g^{-1}) and RP (16.47 mg pot^{-1}). The interaction between levels and sources was significant for total P uptake. Maximum P-uptake was observed with DAP applied @ 24 mg P kg^{-1} (40.95 mg P pot^{-1}). It was observed that P uptake @ 16 mg P kg^{-1} applied through DAP was significantly higher than the RPEBGS applied at 24 mg P kg^{-1} level (31.57 mg P pot^{-1}). The agronomic effectiveness of RPEBGS in terms of total P uptake was 69.95 per cent as against the 22.19 per cent with direct application of RP (Fig. 1).

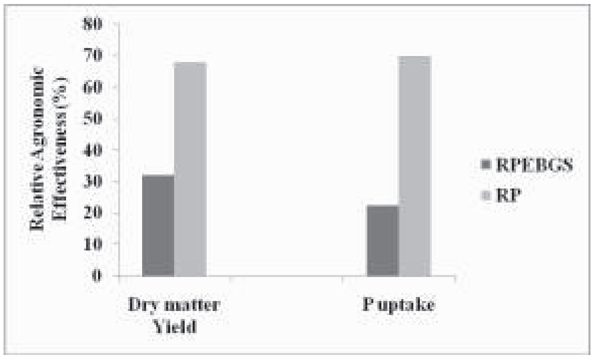

Fig. 1. Relative agronomic effectiveness of RP and RPEBGS with respect to dry matter yield and P uptake as compared to standard P fertilizer (DAP)

Among the P sources, DAP produced maximum dry matter yield and total P uptake followed by RPEBGS and RP, respectively. These results are in agreement with those reported by Singh *et al.* (1994). Agronomic effectiveness of RPEBGS in terms of dry matter yield and P uptake was much higher than that of direct application of RP owing to higher plant assimilable P_2O_5 in RPEBGS. Moreover, RPEBGS contained substantial amount of fairly digested dung biomass which upon decomposition in soil produced various organic acid and dissolved the part of the rock phosphate component of RPEBGS which in turn resulted in higher dry matter yield and P uptake in plants via higher availability of P.

P uptake from fertilizer and P utilization

Sources of P resulted in large variation in fertilizer P uptakes. The mean value was as high as 23.43 mg P pot^{-1} with DAP, and as low as 5.20 mg P pot^{-1} with RP. The increasing levels of P_2O_5 irrespective of sources increased the P uptake. The interaction between the sources and levels was found significant for P uptake. Maximum fertilizer P uptake (29.68 mg P pot^{-1}) was noticed with the highest level (24 mg P kg^{-1}) of DAP application. Data further indicated that DAP at 16mg P kg^{-1} level with P uptake of 23.82 mg P pot^{-1} was significantly higher than the RPEBGS applied at 24 mg P kg^{-1} level . However, P uptake at 8 mg P kg^{-1} applied through RPEGS was at par with 24 mg P kg^{-1}levels of RP

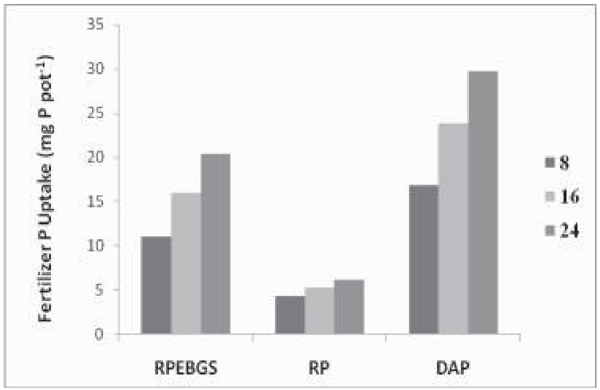

Fig. 2. Effect of Levels and Sources of P on fertilizer P uptake by Mustard crop

DAP followed by RPEBGS and RP was highest with the per cent P utilization. The per cent P (mean) utilization from applied P were 19.10, 13.38 and 11.13 at 8, 16 and 24 mg P kg^{-1} levels, respectively (Figure 3). The reduction in P utilization at higher level of P was ascribed to the fact that plant absorbed more amount of P but it was not in proportion to the added dose. The higher utilization at lower dose may be due to the greater competition of plants for the nutrients where the available P content was less.

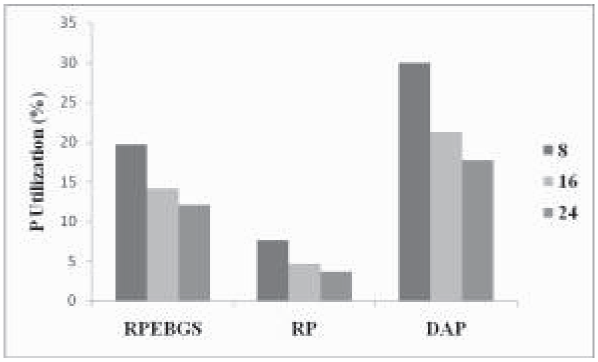

Fig. 3. Effect of Levels and Sources of P on per cent P utilization by Mustard crop

The data on P uptake and per cent P utilization in mustard clearly indicated the superiority of DAP over RPEBGS and RP. The content P_2O_5 in fertilizer materials as well as soil reaction were not suited to the direct application of RP in mustard and that resulted in lowest P uptake and utilization from the RP in mustard. In contrast to RP, RPEBGS is the modified form prepared from the anaerobic digestion of dung and RP as feedstock in biogas plant contained an appreciable amount of semi-decomposed humus forming material, around 17.5 per cent water soluble P_2O_5 , 59 to 67.7 per cent acid soluble P_2O_5 (citric and formic acid) and 29 per cent Olsen P_2O_5 and release of organic acids further dissolved P from RPEBGS and resulted in increased availability of P to plants.

Conclusion

The mustard crop responded to phosphorus application upto 24 mg P kg^{-1}. Among the three P sources, DAP emerged as the most efficient with respect to dry matter yield, P uptake and P use efficiency in mustard. However, the relative agronomic effectiveness of rock phosphate enriched biogas slurry (RPEBGS) in terms of dry matter yield and total P uptake was much higher than that of direct application of RP. Therefore, RPEBGS proved a better option over direct application of rock phosphate as a phosphate source in neutral soils of alkaline Inceptisol for increased dry matter yield, P uptake and P-use efficiency in mustard crop.

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