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Full Length Research Paper

Direct and residual effect of rock phosphates on rice (*Oryza sativa* L.) productivity and soil phosphorus status in Alfisols of Eastern Plateau of India

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A study was conducted on rainfed rice to find out the efficiency of phosphate rocks (PRs) as P-fertilizer. Four sources of phosphatic (P) fertilizers namely, triple superphosphate (TSP), Morocco rock phosphate (MORP), partially acidulated phosphate rock (PAPR) and Mussoorie rock phosphate (MRP) were used. Both the direct and residual effect of different P-sources on rice yield, P-uptake, phosphorus availability in soil and balance of soil P in the direct-residual system of P application in rice were recorded. The result on yield showed significant best effect by direct application of water-soluble TSP (2.77 t ha^{-1}) followed by PARP (2.50 t ha^{-1}) in the first crop. The best residual effect on the yield of rice was obtained by insoluble and slowly available rock phosphates, MORP (3.87 t ha^{-1}) followed by PARP (3.81 t ha^{-1}) and MRP (3.74 t ha^{-1}). The yield also increased with the increase of phosphate dose at 40 or 80 kg P ha^{-1}, applied once in three years and residual effect was better than the direct one. TSP and PARP gave linear response whereas MORP and MRP showed quadratic response to P-application. MRP also depicted highest P-balance in soil, (29.53 kg P ha^{-1}) and better economic benefit was received in favour of PARP and MORP in the three-crop system.

Key words: Rock phosphates, rice, P-balance, response curve.

INTRODUCTION

P-uptake is reported to be highest in rice in India followed by millet and oilseed crop (Pathak et al., 2010). Thus, low phosphate availability in the Alfisols of Eastern Plateau of India, which is as a result of high phosphate fixation (60 to 70%) by hydroxides of iron and aluminium when water soluble P-fertilizer is applied, leads to poor yield of rice. This has been also accentuated with time recently in majority of the soils in India.

In tropical Oxic Rhodustalf – Alfisols, high rates of water soluble phosphatic fertilizers are required to increase crop production, which leads to the increase in manorial cost. Further, high analyzed water soluble P-fertilizers are not found sustainable too in the long run. Hence, the use of mineral fertilizers as means of maintaining soil fertility is gradually fading away (Adesanwo et al., 2009). Appropriate evaluation of phosphorus availability in soil is thus a prerequisite for ensuring productivity and long term sustainable

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Table 1. Solubility characteristics of the phosphatic fertilizers.

Sources	Percentage of phosphorus (P)			
	Water soluble	Citrate soluble	Insoluble	Total
Triple super phosphate	20.88	0.65	0.00	21.75
Morocco rock phosphate	0.14	1.28	13.50	14.87
Mussoorie rock phosphate	0.00	0.19	7.92	8.27
Partially acidulated rock Phosphate-30%	6.06	1.03	5.42	12.97

management of agro-ecosystem (Chien et al., 2003). Considering the situation, insoluble or slowly available phosphate rocks of proven grades may be an alternative for the management of acidic rice soils (Issak et al., 2010). Earlier, direct application of phosphate rocks to such soils has been advocated by Khasawneh et al. (1978), Rajan et al. (1996) and Qureshi et al. (2005). Kothandaraman et al. (1985) reported that in acid soil, application of some indigenous and imported phosphate rocks is as good as SSP or even better in rice. Thus, the agronomic effectiveness of phosphate rock and its solubility requires a time lag relative to monocalcium phosphate and hence its residual effect was found better and substantial (Hongqing et al., 2001). Alternatively, when phosphate rock was partially acidulated (50%) and pretreated, it even tended to be superior to triple super phosphate (Watkinson, 1994; Hammond et al., 1986). Rodriguez and Herrara (2002) also reported that relative agronomic effectiveness (RAE) of partially acidulated rock phosphate (PARP) was greater than unacidulated phosphate rocks.

Thus, although the use of phosphate rock has been well demonstrated in the management of acid soil, its effect in Alfisols of Jharkhand Plateau Region for growing rainfed rice for better phosphate availability and P-balance has never been tried and hence a study was undertaken.

MATERIALS AND METHODS

The experiment was conducted to study the direct and residual effect of Triple super phosphate (TSP-21.75% P), Morocco rock phosphate (MORP-14.87% P), Mussoorie rock phosphate (MRP-8.27%) and partially acidulated rock phosphate (PARP-12.97% P) on lateritic (Alfisol) acid soil of Chotanagpur Plateau Region of Giridih at the Agricultural Research Farm of Indian Statistical Institute. The solubility characteristics of the phosphatic fertilizers were analysed in the laboratory (Table 1).

The total phosphorous content of the fertilizers were estimated by digesting 1 g of the fertilizer sample with a mixture of concentrated hydrochloric acid and nitric acid at room temperature for about 24 h. Phosphorous content was then estimated colorimetrically, after diluting the mixture with water.

Water soluble phosphorous content was estimated by washing a gram of the fertilizer, placed on a funnel fitted with a filter paper, with successive volume of cold water and estimating phosphorous in the filtrate colorimetrically.

The residues left over after extracting the fertilizer with cold water were used for estimating the citrate soluble phosphorous in the fertilizers. It was treated with warm (65°C) ammonium citrate solution, and then filtered; the filtrate was treated with ammonium nitrate crystals maintaining the pH of the solution with 1:1 ammonium hydroxide and 1:1 nitric acid. This was then treated with a mixture of concentrated nitric acid and 20% ammonium molybdate to get a curdy white precipitate which was then dissolved in N/10 sodium hydroxide; and phosphorous was estimated volumetrically.

The soil was acidic (pH 5.3) with organic carbon (0.52%), total N (0.059%), available P (5.6 kg /ha) and available K (89.5 kg/ha), CEC (10.19 me/100 g) and Al oxide and Fe oxide (17.2 and 1.60%, respectively). Rice, Cv. Pankaj (150 days) was grown during the rainy season with different doses of P (10, 20, 30, 40 kg P ha^{-1} for TSP, MORP and PARP and 20, 40, 60, 80 kg P ha^{-1} for MRP) to study the direct effect of phosphatic fertilizers on its yield. The land was left fallow after the harvest of rice in the first year and then rice was grown again during the rainy seasons of the two consecutive years, in the same layout without any P-fertilizer to record the residual effects of P-treatments applied in initial year of the experiment. For each crop, nitrogen and potash were applied (80 and 60 kg ha^{-1} respectively) to all plots except the 'absolute control' treatment. The design of the experiment followed was Factorial Randomized Block Design augmented with two controls (absolute control - N_0 P_0 K_0 and P-control - N P_0 K), having 18 treatments altogether in four replications. All other package and practices for rice were followed as per recommendation under rainfed condition (Rainfall during the growing period, that is, June – November were 1796.7, 1062.1 and 1660.9 mm for the three consecutive years of experimentation, respectively). For the estimation of P-uptake by rice and available P in soil, plant including rice grain and surface soil samples (0 to 20 cm soil depth) were collected at harvest stage and analyzed for phosphorus (Jackson, 1972); the data were recorded following the standard procedure. The fertilizers used were also tested for their water soluble and citrate soluble P in the laboratory.

RESULTS AND DISCUSSION

Grain yield of rice-direct and residual effect

The grain yield of rice (Table 2) generally was lower (1.37 to 2.77 t ha^{-1}) in the first year (direct effect) than in the second and third years (3.24 to 4.23 t ha^{-1} Av.) of the experiment. This indicates that residual effect of phosphatic fertilizers particularly of rock phosphates is better than the direct effect. The sources of phosphates and their levels (10 to 40 and 20 to 80 kg P ha^{-1}) both produced significant effect and the yield of rice increased with the increase of the dose of P both by direct application in the first year and residual application during the second and third years of the experiment. The

Table 2. Grain yield of rice, P-uptake by rice, soil available phosphorus and benefit: cost ratio as affected by direct and residual phosphorus fro

Treatments-P(kg/ha)	Grain yield (t ha^{-1})				P-uptake (kg ha^{-1})				Soil available P	
	Direct	Residual			Direct	Residual			Direct	Re
	First year	Second year	Third year	Average	First year	Second year	Third year	Average	First year	Second year
Control-NoFertilizer	1.39	2.38	2.75	2.57	2.07	4.01	3.28	3.64	4.06	4.61
P-Control	1.43	3.07	3.09	3.08	2.24	5.25	4.53	4.89	5.22	5.54
TSP-10	1.78	3.20	3.27	3.24	3.27	7.83	8.26	8.04	10.53	13.29
TSP-20	2.15	3.31	3.43	3.37	4.42	8.82	9.33	9.07	11.50	13.95
TSP-30	2.32	3.69	3.84	3.77	5.45	10.44	10.97	10.70	12.08	15.62
TSP-40	2.77	3.88	4.07	3.98	7.25	11.68	12.51	12.09	13.30	17.70
Mean	2.26	3.52	3.65	3.59	5.10	9.69	10.27	9.98	11.85	15.14
MORP-10	1.59	3.48	3.67	3.58	2.70	8.84	9.37	9.10	9.29	13.80
MORP-20	1.98	3.57	3.89	3.73	3.92	9.80	10.52	10.16	9.71	14.46
MORP-30	2.06	3.91	4.06	3.99	4.52	10.84	11.97	11.40	10.18	16.03
MORP-40	2.15	4.05	4.26	4.16	5.85	12.44	13.51	12.97	11.12	17.74
Mean	1.95	3.75	3.97	3.87	4.25	10.48	11.34	10.91	10.07	15.51
MRP-20	1.37	3.38	3.59	3.49	2.41	8.41	9.41	8.91	6.27	10.82
MRP-40	1.75	3.55	3.72	3.64	3.32	9.37	10.25	9.81	6.79	11.74
MRP-60	2.09	3.72	3.87	3.80	4.49	11.45	12.18	11.81	7.37	11.57
MRP-80	2.26	3.98	4.06	4.02	5.52	12.83	14.48	13.65	7.68	12.41
Mean	1.88	3.66	3.81	3.74	3.93	10.51	11.58	11.04	7.03	11.64
PARP-10	1.69	3.25	3.50	3.38	3.05	8.87	10.47	9.67	7.54	14.69
PARP-20	1.86	3.53	3.74	3.64	3.85	10.56	11.63	11.09	7.68	14.96
PARP-30	2.02	3.91	4.09	4.00	4.69	12.75	13.14	12.94	8.48	15.17
PARP-40	2.50	4.18	4.27	4.23	6.66	14.02	15.00	14.51	9.26	15.98
Mean	2.02	3.72	3.90	3.81	4.56	11.55	12.56	12.05	8.24	15.20
Sources of P										
SEM±	0.039	0.06	0.07		0.24	0.50	0.30		0.37	0.69
$CD_{0.05}$	0.080	0.12	0.13		NS	0.99	0.60		0.75	1.37
Levels of P										
SEM±	0.039	0.06	0.07		0.24	0.50	0.30		0.37	0.69
$CD_{0.05}$	0.080	0.12	0.13		0.48	0.99	0.60		0.75	1.37
Interaction of SxL										
SEM±	0.079	0.12	0.13		0.48	0.99	0.61		0.74	1.38
$CD_{0.05}$	0.160	NS	NS		NS	NS	NS		NS	2.74

water-soluble TSP-40 produced significantly the highest yield (2.77 t ha^{-1}) followed by PARP-40, TSP-30, and MRP-80 on direct application of P-fertilizers. But, considering the residual effect, insoluble and slowly available MORP performed the best (Av. 3.87 t ha^{-1}) followed by PARP (3.81 t ha^{-1}) and MRP (3.74 t ha^{-1}). Further, irrespective of the dose of P, the performance of the two types of phosphate rock and the partially acidulated one was found almost at par. Although, the corresponding dose of MRP was double for its relatively low P-content and poor reactivity in soil. MORP and PARP also gave slightly higher cumulative yield for three years than TSP and MRP under direct-residual system of using P-fertilizers in rainfed rice. This might be due to lower P supply by TSP and MRP in the later years of the experiment compared to the phosphate rocks in the whole system, which is due to fixation of soluble P in soil in case of TSP and lower reactivity of MRP in soil.

Uptake of phosphorus by rice

The effect of different sources of phosphorus like, TSP, MORP, MRP and PARP on phosphorus uptake was statistically at par in direct application, although water soluble TSP resulted in higher uptake of P in rice (5.10 kg P ha^{-1}) followed by PARP (4.56 kg P ha^{-1}) and MORP (4.25 kg P ha^{-1}); MRP gave the least effect (3.93 kg P ha^{-1}) (Table 2). However, higher dose of P-application to rice registered significant progressive increase of P-uptake over control. On the other hand, the residual effect of phosphate application was found significantly better in the direct application of different sources and levels of phosphorus. Considering the average P-uptake in rice under residual application in the second and third years, the acid soluble PARP-40 gave the best effect (14.51 kg P ha^{-1}) followed by MRP-80 (13.65 kg P ha^{-1}) and MORP-40 (12.97 kg P ha^{-1}), while the control maintained poor and the least effect on the uptake of phosphorus by rice.

In the residual effect study, P-uptake in application of TSP markedly increased in the second and third years but was significantly low compared to P-uptake in application of the phosphate rocks. P-uptake in direct application of TSP was greater than that of the phosphatic rock sources. This might be due to increase in soil pH under submerged condition of rice, which leads to low fixation of P; thus water-soluble TSP released more phosphorus than forms of phosphate rock when P was directly applied to the first crop leading to better P-uptake. PRs are slow releasing fertilizers and they require time and water surrounding the particles in order to enable the dissolution products to diffuse away from the PR particle into the soil (FAO, 2004). Hence, the phosphate rocks and also their acidulated form released more P into the soil volume in the successive years of the experiment leading to greater uptake of P compared to its water soluble source in the residual effect.

Soil phosphorus – availability and balance

A significant variation on available soil-P was noticed due to direct application of different P-fertilizers in rice at increasing doses and also in their residual effect. TSP gave the highest soil available phosphate (11.85 kg P ha^{-1}) followed by MORP (10.07 kg P ha^{-1}); and the least by MRP (7.03 kg P ha^{-1}) in their direct application to rice which was also reflected by yield and crop uptake of P (Table 1). This is well attributed to the solubility characteristics of the P fertilizers (Table 3) which show that TSP has the highest water soluble P (20.88%) followed by PAPR (6.06%), MORP (0.14% and MRP (0.0%). Whereas, in the residual effect, MORP gave the highest available P in the soil (14.02 kg P ha^{-1}) followed by PARP (13.53 kg P ha^{-1}). FAO (2004), in their fertilizer and plant nutrition bulletin, reported that kinetics of PR dissolution is a two phase process.

The first phase is a fast dissolution process which could be related to short term efficiency and the second phase is a slow dissolution process representing a long term effect. This second phase might be responsible for increasing the residual P in the soil in the successive years. Residual contribution of available P from rock phosphatic sources was also reported by Akintokun et al. (2003). Mineral dissolution from phosphate rock for releasing of P in the available form into the soil solution is not an immediate process and depends on various factors; and hence has a better residual effect. Under same climatic and soil condition, particle size and chemical composition of PRs play an important role in their dissolution.

In this study, MRP is the least reactive PR and hence the residual effect of MRP was noted to be comparatively poor (11.28 kg P ha^{-1}) even at higher doses in comparison to imported MORP. Again, the residual soil available P was found higher in second year than in third year probably because of removal of available P from the soil solution due to plant uptake. The balance sheet (Table 3) of soil available P after three cropping seasons under direct-residual system showed a negative balance particularly under no-fertilizer and no-phosphate control treatments against a good reserve of soil phosphorus (Av. 29.53 kg P ha^{-1}) gained by application of high doses of Mussoorie rock phosphate once in three years. This can again be attributed to the low reactivity of MRP. In comparison to it, TSP, MORP and PARP showed poor but positive balance although at 40 and 80 kg doses; the balance of soil P was noted to be considerably higher (14.48, 13.51 and 52.99 kg P ha^{-1}) than the control. Panda (2007) also observed positive balance of fertilizer P in long term experiments in rice-rice systems in the treatment with N and P application where P fertilizer is to be applied at a higher dose. The overall result thus suggests that application of MRP, MORP or even TSP at high dose of 40 kg P ha^{-1} and about once in three years is conducive for good positive balance of soil phosphorus

Table 3. Relative balance sheet of soil phosphorus in direct – residual system.

Sources	Treatments: Inputs of P (kg/ha) First Year	Second year	Third year	*Initial soil P (kg/ha)	Total P in soil including added P (kg/ha) (For 3 years)	Total P-uptake by crop (kg/ha) (For 3 years)	Balance of P in soil (kg/ha)
No fertilizer	-	-	-	5.62	5.62	9.36	-3.74
P control	-	-	-	5.33	5.33	12.02	-6.69
Mean	-	-	-	5.47	5.47	10.69	-5.21
TSP	10	-	-	4.90	14.90	19.36	-4.46
TSP	20	-	-	5.21	25.21	22.57	2.64
TSP	30	-	-	5.11	35.11	26.86	8.25
TSP	40	-	-	5.92	45.92	31.44	14.48
Mean	25	-	-	5.28	30.28	25.06	5.23
MORP	10	-	-	5.71	15.71	20.91	-5.2
MORP	20	-	-	6.01	26.01	24.24	1.77
MORP	30	-	-	5.59	35.59	27.33	8.26
MORP	40	-	-	5.31	45.31	31.80	13.51
Mean	25	-	-	5.65	30.65	26.07	4.58
MRP	20	-	-	5.43	25.43	20.23	5.20
MRP	40	-	-	5.79	45.79	22.94	22.85
MRP	60	-	-	5.21	65.21	28.12	37.09
MRP	80	-	-	5.82	85.82	32.83	52.99
Mean	50	-	-	5.56	30.56	26.03	29.53
PARP	10	-	-	4.97	14.97	22.39	-7.42
PARP	20	-	-	5.72	25.72	26.04	-0.32
PARP	30	-	-	6.11	36.11	30.58	5.53
PARP	40	-	-	4.95	44.95	35.68	9.27
Mean	25	-	-	5.44	30.44	28.67	1.76

*Soil P before application of treatments in the first year.

which will satisfy the phosphate requirement of rainfed rice in acid soil.

Phosphorus response to rice

The yield response of rice to direct application of P-fertilizers was found linear in nature with water soluble TSP and also with partially soluble PARP (Figure 1). This is because both of them have more water soluble P in them for plant uptake and growth as compared to the PRs which are available to plant due to increase in soil pH in the submerged field. However, the different sources of phosphate rock, that is, MORP and MRP manifested quadratic nature of response to direct effect of P application in the first year, offering a maximum yield of 2.08 t ha^{-1} by MORP at 34.44 kg P ha^{-1} and 2.84 t ha^{-1} by MRP at 141.0 kg P ha^{-1}.

P-fertilizers in the first year

This is due to low dissolution rate of the PRs under submerged condition where pH of the soil tends to be neutral, thereby making the native soil phosphorus available to plants. The response pattern of residual phosphate rock in soil in second and third years (Figures 2 and 3) became similar to that of water-soluble and partially soluble P-sources in the first year (direct effect); this is again a linear response. This improvement in the effectiveness of PRs over time has been attributed to the continuation of PR dissolution process while a low concentration is maintained in the soil solution due to depletion of P because of plant uptake or conversion of soluble P to less available forms in the soil. The released P being entrapped as Fe-P and Al-P again becomes available in the subsequent years under submerged condition (De Datta, 1981).

Conclusion

Summarizing the various aspects of the study, it is revealed that while water soluble triple super phosphate gave the best performance by direct application in rainfed rice, insoluble but slowly available rock phosphate,

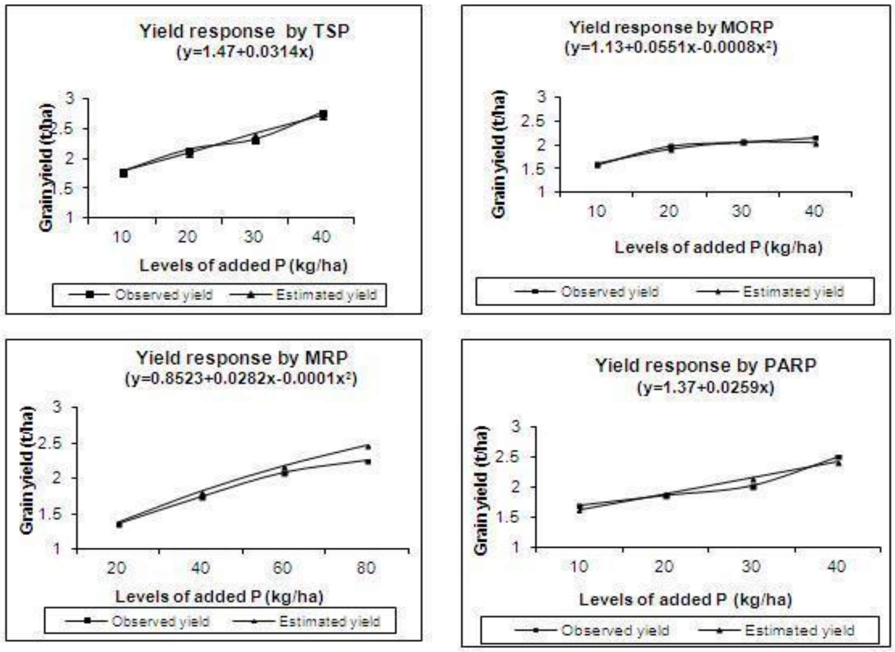

Figure 1. Yield-response curves as affected by direct application of different sources and levels of P-fertilizers in the first year.

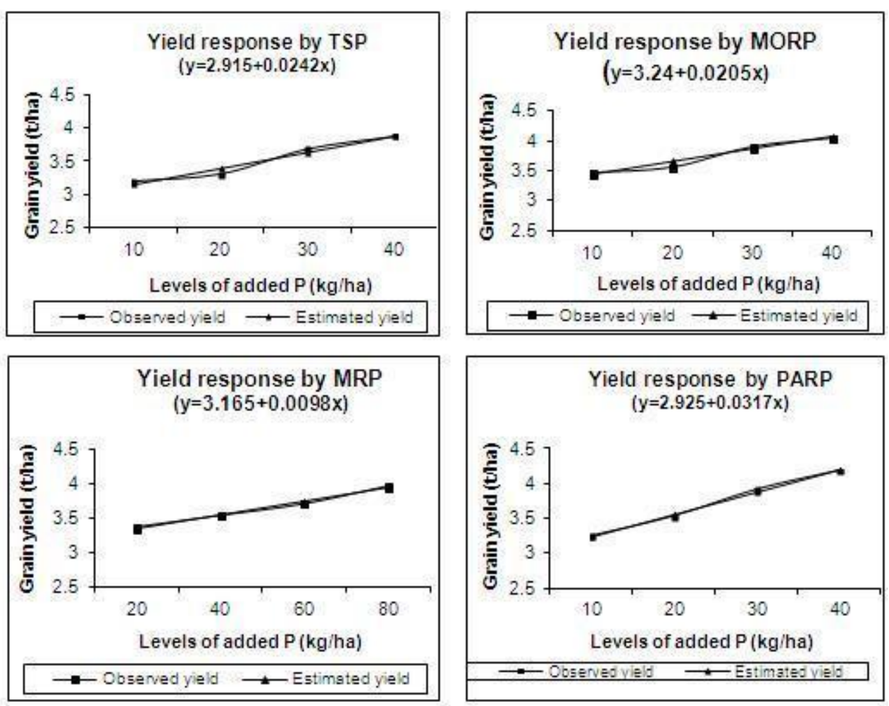

Figure 2. Yield-response curves as affected by direct application of different sources and levels of P-fertilizers in the second year.

particularly partially acidulated one and Morrocco rock phosphate showed good promise by their residual effects in the following seasons and was found even better than water soluble P-source. Rock phosphates (PARP and MORP) also left higher P- balance in soil applied once in three years under acid soil condition, along with higher

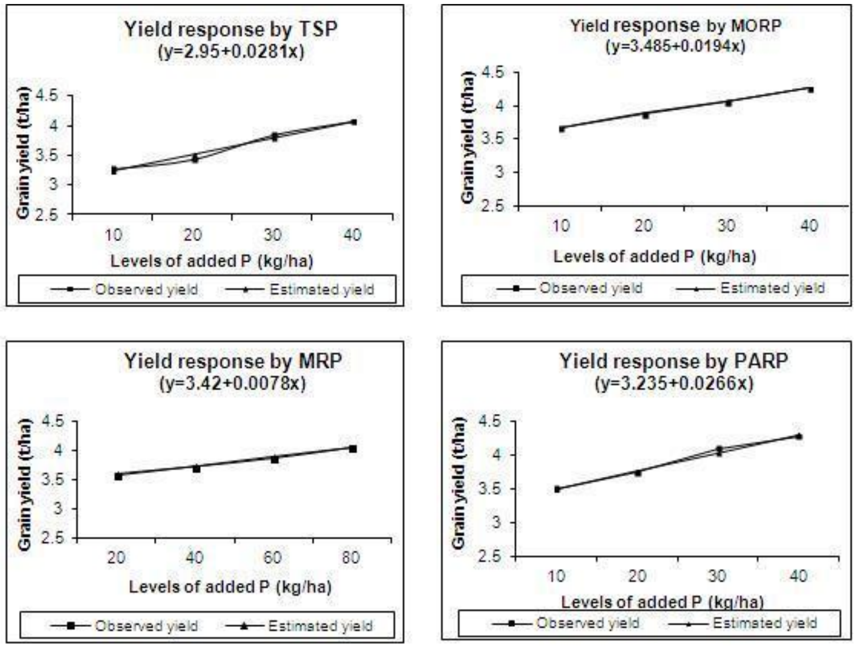

Figure 3. Yield- response curves as affected by direct application of different sources and levels of P-fertilizers in the year 1997.

benefit: cost ratio. This technology of direct-residual system of phosphate management in rainfed rice could fetch 40 to 50%. Higher grain yield than the average yield (1.5 t ha^{-1}) generally obtained by farmers under traditional system. Hongqing HU, Tan C, Cai C, Jizheng, HE Li X (2001). Availability and residual effects of phosphate rocks and inorganic P-fraction in a red soil of Central China. Nutr. Cycl. Agroecosys. 59:251-8.

REFERENCES

Adesanwo OO, Aditunji MT, Adesanwo JK, Osiname OA, Diatta S, Torimiro DO (2009). Evaluation of traditional soil fertility management practices for rice cultivation in southwestern Nigeria. Am-Eur. J. Agron. 2(2):45-49.

Akintokun OO, Adetunji MT, Akintokun PO (2003). Phosphorus availability to soyabean from an indigenous phosphate rock sample in soils from southwest Nigeria. Nutrient Cycling in Agroecosystems 65:35-41.

Chien CR, Sinaj S, Condron LM, Frossard E, Sherlock RR, Davis M.R (2003). Characterisation of phosphorus availability in selected New Zealand grassland soils. Nutr. Cycl. Agroecosys. 65:89-100. De Datta SK (1981). Principles and practices of rice production. Willey Publication P. 87. FAO Fertilizer and Plant Nutrition Bulletin 13, 2004. Use of phosphate rock for sustainable agriculture http://www.fao.org/docrep/007/y5053e/y5053e00.htm.

Hammond LL, Chien SH, Mokwunye AU (1986). Agronomic value of unacidulated and partially acidulated phosphate rocks indigenous to the tropics. Adv. Agron. 40:89-140.

Issak M, Sutradhar GNC, Rahman MM, Firdousi J, Hossain ATM, Sultana A (2010). Direct And Residual effect of phosphate rock on growth and yield of rice in acidic soil. Int. J. Agric. Environ. Biotechnol. 3(2):5-10. Jackson ML (1972). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd. New Delhi, pp 165-169 Khasawneh FE, Doll EC (1978). The use of phosphate rock for direct application to soils. Adv. Agron. 30:159-206.

Kothandaraman GV, Manickkam TS, Natrajan K (1985). In: Rock Phosphate in Agriculture. Tamilnadu Agricultural University, Coimbatore and Pyrites, Phosphates and Chemicals Ltd. (Government of India Undertaking).

Panda D, Samantaray RN, Mishra AK, Senapati HK (2007). Nutrient balance in rice. Indian J. Fert. 3:33-38. Pathak H, Mohanty S, Jain N, Bhatia A (2010). Nitrogen, phosphorus and potassium budgets in Indian Agriculture. Nutr. Cycl. Agroecosys. 86(3):287-299.

Qureshi AA, Narayanasamy G, Chhonkar PK, Balasundaram VR (2005). Direct and residual effects of phosphate rocks in presence of phosphate solubilizers and FYM on the available P, organic carbon and viable count of phosphate solubilizers in soil after soybean, mustard, and wheat crops. J. Indian Soc. Soil Sci. 53(1):97-100. Rajan SSS, Watkinson JH, Sinclair AG (1996). Phosphate rocks for direct application to soils. Adv. Agron. 57:77-159. Rodriguez R, Herrara J (2002). Field evaluation of partially acidulated phosphate rocks in a ferralsol from Cuba. Nutr. Cycl. Agroecosys. 63:21-26. Watkinson JH (1994). A test for phosphate rock reactivity in which solubility and size are combined in a dissolution rate function. Fert. Res. 39:205-211