Research Article

Improving effectiveness of rock Phosphate through mixing with Farmyard manure, Humic acid and Effective microbes to enhance yield and Phosphorus uptake by wheat

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Abstract

The cheaper rock phosphate (RP) could replace the commercial phosphatic fertilizer with pronounced advantages provided if the solubility and release of P from RP is enhanced through addition of some organic amendments. Combined application of RP with organic materials to soil reduces the dependence on chemical fertilizers and maintains higher levels of P in soil solution for a longer period than the fertilizer alone. Thus the present field study was conducted to investigate the effect of RP treated with farmyard manure (FYM), humic acid (HA) and effective microbes (EM) on the yield and uptake of P by wheat in marginal P calcareous alkaline soil during rabi 2011-12. The treatments were control (T1), 90 kg P_2O_5 ha⁻¹ as single super phosphate (T2), 90 kg P_2O_5 ha⁻¹ as RP (T3), RP+ 10 t FYM ha⁻¹ (T4), RP+ 5 kg HA ha⁻¹ (T5), RP+EM (T6), RP+HA+EM (T7), RP+FYM+EM (T8) and RP+FYM+HA+EM (T9) were arranged in a Randomized Complete Block (RCB) design with three replications. The SSP, RP and FYM was applied on soil surface; humic acid was first mixed with the sand and then applied whereas EM was first activated and then applied through spray on the soil surface at 200 L ha⁻¹. After thorough mixing of treatments with soil, the wheat seeds cv. Atta Habib were sown in lines spacing 25 cm apart through seed drill with seed rate of 120 kg ha⁻¹. The results showed that the application of RP alone significantly increased the grain yield from 3.74 in control to 4.42 t ha⁻¹. This effect of RP was further enhanced when combined with FYM, HA, or EM and produced 4.98, 4.6 and 4.8 t grain yield ha⁻¹, respectively suggesting improvement in P solubility. Among the amendments, FYM was superior to HA or EM but combining HA or EM with mixture of RP+FYM further enhanced the beneficial effect of RP. When RP was applied with FYM+HA+EM the grain yield jumped to the maximum (5.2 t ha⁻¹) which was statistically

similar to SSP. This combination resulted in net return of Rs. 36251 ha⁻¹ with VCR of 4.02 which was almost double of SSP fertilizer. The tissue leaf N and grain N and P also significantly improved with application of RP in combination with the said amendments. Similarly the soil N and AB-DTPA extractable P also showed significant improvement with combined application of RP with FYM, HA and EM. The combination of RP+FYM+HA+EM which had the maximum yield with 2 times higher VCR than SSP and had higher tissue P at anthesis and in soil at boot and after harvesting of crop stages of the crop could be the optimum choice under the prevailing soil and climatic conditions.

Keywords: Grain yield; Rock phosphate; farmyard manure; Humic acid; Effective microbes; Wheat.

Introduction

Wheat (*Triticum aestivum* L.) belongs to family Poaceae which is self-pollinated and long day rabi crop. GoP, [1] reported that wheat is the main staple food and largest grain crop of Pakistan. It contributes 14.4 % to agriculture sector and 3 % to GDP. Satar Satar, [2] investigated that about 90% soils in Pakistan are deficient in phosphorus from low to severely low due to its widespread calcareous nature. Ahmad et al., [3] that in calcareous soil the recovery of phosphatic fertilizer is low, 5 – 9 % remains as water soluble, 15 % to 25 % is recovered by plant while the remaining part from 49 to 59 % is converted to unavailable calcium and magnesium phosphate. Sharif, [4] reported that plant tissue could recover only 11 to 19% of applied phosphatic fertilizer. Alam et al., [5] suggested that the variable recovery of applied P fertilizer and its recovery by plant may depend on crop species and yield potential, type of fertilizers, application methods and soil conditions. So the use of phosphatic fertilizers in recommended proportion at proper time and by a suitable method has a great effect on the wheat yield.

Khasawneh and Doll, [6] reported that the rock phosphate, the natural P mineral rock, is a raw material for the phosphatic fertilizer, animal feed supplements and industrial chemicals. NFDC, [7] reported that approximately 90% of RP production is used for fertilizer, animal feed supplements and balance for industrial chemicals. Reddy

et al., [8] suggested that rock phosphate is the natural source of phosphorus and its direct application to soil may replace the chemical phosphatic fertilizer. Geonadi et al., [9] found that rock phosphate contains a high quantity of phosphate minerals but slowly release P limits its widespread application as direct source of P. Gyaneshwar et al., [10] investigated that due to its slow release, the direct application of RP is often ineffective that could be made effective when applied with P solubilizing microbes that enhances the solubilization of RP. Chabot et al., [11] reported that phosphorus solubilizing microorganism consisting bacteria fungi and actinomycetes produces various types of acids in their metabolic reaction that facilitate P release from RP and other sources.

Organic materials, such as farm yard manure and Humic acid are useful for plant growth and development, because they provide all essential elements and improve physico-chemical properties of soil. Khattak and Muhammd, [12] reported that application of 1.0 to 5.0 Kg HA ha⁻¹ to the soil can bring appreciable increase (up to 20%) in yields of maize and improvement in soil physico-chemical conditions. Brams, [13] found that Humic acid added to soils generally reduce fixation and solubilize insoluble phosphorus in soils. Similarly, Misra and Hesse, [14] investigated that the farm yard manure (FYM) contains 0.5% N, 0.2% P₂O₅ and 0.5% K₂O on average basis. Also Guar, [15] found that FYM improves the properties of

soil which influencing the behaviors of plant growth and crop production and thus reduce dependence on chemical fertilizer.

The combine use of RP with HA, FYM and EM is rightly expected to increase the release of P from the RP. The present study was conducted to evaluate and compare the performances of these organic sources on the release of P from RP and check the possibility of direct application of RP in the prevailing calcareous alkaline conditions of the soil.

Materials and Methods

The experiment was conducted at The University of Agriculture Peshawar, Pakistan during 2011-12. There were nine treatments (as shown below) in the study including seven RP treatments applied alone and in combination with FYM, EM, and HA, one control and one SSP fertilizer for comparison. The treatments combinations were Control, Single Super Phosphate (SSP) (90 kg P_2O_5 ha⁻¹), Rock Phosphate (RP) (90 kg P_2O_5 ha⁻¹), RP+Humic Acid (HA) (5 kg ha⁻¹), RP+ Farm Yard Manure(FYM) (10 t ha⁻¹), RP+ Effective Microbes (EM), RP+HA+EM, RP+FYM+EM and RP+FYM+HA+EM. These treatments were arranged in Randomized Complete Block (RCB) design with three replications. The treatment plot size was 4x5 m² consisting of 16 rows 4 meter long. Irrespective of P source and combination, all the treatments excluding control received similar dose of P as 90 kg P_2O_5 ha⁻¹ while N at the rate of 120 kg ha⁻¹ in the form of urea was applied to all plots including control. The RP, SSP and urea fertilizers to designated plots were applied through broad cast after seed bed preparation followed by thorough mixing with soil. The FYM was broad cast on the surface of soil at the rate of 10 t ha⁻¹; Humic acid at the rate of 5 Kg ha⁻¹ was first mixed with the sand and then broad cast whereas EM was first activated and then applied through spray on the soil surface. After

treatment application, the wheat seeds cv. Atta Habib were sown in lines spacing 25 cm apart through seed drill with seed rate of 120 kg ha⁻¹.

Statistical analysis

Statistical analysis of data regarding various plant parameters such as plant height, spike length, thousand grain weight, grain sipke⁻¹ biological yield, grain yield, soil nutrients concentration and their accumulation by plant leaves at anthesis stage and grains was evaluated through ANOVA techniques as suggested by Steel and Torrie [16] according to Randomized Complete Block design. The means were compared with Least Significant Difference (LSD) test was used for any significant difference among the treatments.

Results and Discussion

The pre-sowing soil analysis of the plot showed that the soil under study was silty clay loam in texture, strongly calcareous (16.5 % $CaCO_3$) and alkaline in reaction (pH 7.8) but had no sign of salinity (EC 0.15 dS m⁻¹). The soil under study was low in organic matter (0.79 %) deficient in nitrogen (0.08 %), marginal in P (5.75 mg kg⁻¹) but adequate in K (125 mg kg⁻¹). These values were compared with the standard values given by [17].

Yield and yield components of wheat

The analysis of variance showed that the plant height exhibited statistically non-significant results due to small changes in plant height. The plant height ranged from 88.7 cm in control to only 90.3 cm in the treatments receiving RP in combination with HA+EM+FYM (Table 2). The spike length of wheat was non-significantly affected by SSP and RP applied alone or in combination. However, as compared to control the treatments showed increasing trends in spike length and increased from 9.3 cm in control to 9.6 cm in SSP treated plot and to 9.7 cm in plots receiving RP in combination with FYM+HA+EM. The non-

significant effect of RP in combination with organic sources was in accordance to the [18] who observed non-significant response in spike length with application of RP treated with PSM alone or with FYM. Statistical analysis of the number of grains spike⁻¹ data indicated that the effect of SSP and different combination of RP with FYM, EM and HA was significant at $p \leq 0.05$. The maximum numbers of grains spike⁻¹ (59.8) was recorded in the plot receiving RP in combination with HA+ FYM +EM followed by 58.4 which was obtained in the treatment received RP+HA+EM. The results for the rice crop which showed that grains per spike were increased by combined treatments of PSB inoculation with rock phosphate or TSP are in conformity with the findings of [19]. These results are also sported by [20] who applied humic acid on the millet and found significant increase in grain number per bunch. The maximum 1000-grain weight of 49.1 g was obtained from RP+FYM+HA+EM treatment followed by (47.5 g) and (47.3 g) in treatments receiving SSP and RP+FYM respectively while the minimum 1000-grain weight of 42.2 g was recorded in control. These results are sported by [20] who applied humic acid to the millet and found profound increases in 1000-gain weight. Statistical analysis of the grain yield (t ha⁻¹) indicated that the effect of SSP and different combination of RP with FYM, EM and HA was significant ($P \leq 0.05$) as shown in Table 2. This effect of RP was further enhanced when combined with HA or FYM or EM which yielded 4.6, 4.98 and 4.8 t grain yield ha⁻¹, respectively. This steady increase in the grain yield indicated that P solubilization was enhanced with combine application of RP with FYM, HA or EM. Among the mentioned combination, the RP + FYM was superior that could be associated to the fact that FYM is a good soil conditioner and provides about all plant nutrients. Similarity the combination of EM

or HA with mixture of RP+FYM further enhanced the beneficial effect of RP. When RP was applied with FYM+HA+EM the grain yield jumped to the maximum of all treatments i.e. 5.2 t ha⁻¹ which was similar to SSP plot. The comparable yield in SSP and RP+HA+EM, RP+FYM+EM and RP+FYM+HA+EM suggested that costly commercial fertilizer could be replaced with RP if applied in combination with FYM, HA or EM to enhance the release of P to meet the crop requirement. The maximum grain yield (5.3 t ha⁻¹) was recorded from the treatment received RP in combination with FYM+HA+EM which was 43.25 % higher than control (table 2). These results are in consonance with the [12, 21, 22].

The application of alone RP induced significantly higher biological yield of 10.3 tone ha⁻¹ than control (8.9 t ha⁻¹) indicating that RP could help in supplying P to crop. This release of P from RP could be enhance when combined with HA or EM or FYM. The combination of RP and FYM produced 11.2 ton ha⁻¹ of biological yield which was even better than SSP alone (10.6 ton ha⁻¹). Similarly RP + HA and RP+EM produced 11.2 and 11.0 ton ha⁻¹ of biological yield which was higher than SSP alone. The superior effect of RP with HA, EM and FYM could be associated to higher release of P from RP as well as to other individual beneficial effect. [23] got the maximum biological yields cowpea and ragi crops were obtained receiving bio-activated rock phosphate with *A. awamori*. The combination of RP with HA+EM or EM+FYM or HA+EM+FYM could further enhanced the biological yields with a range from 12.2 to 12.5 ton ha⁻¹ significantly higher over SSP plot but statistically similar with each other. Maximum biological yield of maize obtained from rock phosphate (RP) fed dung through composting with RP are also reported by [24]. The highest harvest index (48.5 %) was recorded in plots

fertilized with SSP, while the crop fertilized with RP +FYM and RP+EM produced harvest index of 44.4 and 43.5 %, respectively (table 2). The control plots where no phosphorus fertilizer was applied produced lowest harvest index value of 41.5 % which was similar to treatments receiving RP+EM+HA and RP+EM+FYM. As

compared to SSP, the lower Harvest index in treatments receiving RP in different combination with FYM, EM and HA suggested that along with grain yield the application of these amendments with RP also increased the biological yields. These results are same with the findings of [25].

Table 1. Physiochemical properties of experimental soil before sowing

S.No.	Property	Unit	Value
1	Organic matter	%	0.79
2	pH (1:5)	...	7.8
3	EC (1:5) dS m ⁻¹	...	0.15
4	Lime (CaCO ₃)	%	16.5
5	Total Nitrogen	mg kg ⁻¹	0.08
6	AB-DTPA ext. P	mg kg ⁻¹	5.75
7	Silt	%	54.4
8	Clay	%	30.9
9	Sand	%	15.7
10	Texture	...	Silty clay loam

Table 2. Plant height, spike length, grain spike⁻¹, thousand grain weight, grain yield, biological yield and harvest index as effected by SSP and different combination of RP with FYM, EM and HA

Treatment	Plant height	Spike length	Grain spike ⁻¹	1000 grain wt	Grain yield	Biological yield	Harvest Index
	--cm--	--cm--	-	---g---	----- t ha ⁻¹ -----		----%---
Control	88.7	9.2	52.6 e	42.2 e	3.7 f	8.9 d	41.6 b
SSP	90.2	9.6	58.3 b	47.5 ab	5.2 ab	10.7 bc	48.5 a
Rock Phosphate	88.9	9.3	56.4 cd	44.1 de	4.4 e	10.3 c	42.9 b
RP+HA	89.4	9.5	56.8 bcd	45.2 bcd	4.6 de	10.9 bc	42.4 b
RP+FYM	90.2	9.4	57.8 bc	47.3 ab	4.9 bc	11.2 b	44.4 b
RP+EM	89.3	9.4	56.1 d	43.7 de	4.8 cd	11.0 b	43.5 b
RP+HA+EM	89.1	9.5	58.4 b	44.7 cd	5.1 b	12.3 a	41.5 b
RP+EM+FYM	89.9	9.5	57.8 bc	46.8 abc	5.2 ab	12.5 a	41.6 b
RP+HA+EM+FYM	90.3	9.7	60.8 a	49.1 a	5.3 a	12.6 a	42.5 b
LSD (5%)	NS	NS	1.6	2.47	0.23	0.614	3.239

*mean followed by same letter(s) in the column do not significantly different at P (0.05)

Soil Analysis

The maximum total soil N content at boot stage was recorded in the plot receiving RP+HA+EM+FYM closely followed by the

treatment of RP+EM+FYM and RP+FYM with the values 0.11 and 0.09% respectively (table 3). The minimum value was recorded in plots receiving RP alone, RP+HA and

RP+EM suggesting that those plots that did not receive FYM had comparatively lower soil N. The total N after harvesting though did not change statistically with treatments but closely followed the similar trend as shown at boot stage. At harvest stage the control all those plots receiving FYM in combination had comparatively higher N. Application of organic manures and NPK improved the soil nitrogen content were also observed by [26]. The results were also similar to [27] who found the highest N availability in soil with application of farm yard manure (FYM) with 12.5% rock phosphate. The maximum AB-DTPA extractable P concentrations (17.68 mg kg^{-1}) was observed in treatments receiving SSP fertilizer followed by treatment of RP applied with HA+EM+FYM and EM+FYM with the values 8.72 and $8.72 \text{ mg P kg}^{-1}$ respectively (table3). Higher AB-DTPA extractable P in RP treated plots suggested that addition of these amendments i.e. FYM, HA and EM substantially increased the release of P from RP as compared to RP alone. At post-harvest the AB-DTPA still showed significant response to treatments but on overall basis these AB-DTPA were decreased as compared to boot stage. This decrease in [P] could be due to plant uptake

and conversion of P into insoluble fraction or losses. However at this stage as well the SSP surpassed all other treatment with the value of 10.52 and followed by RP treated with HA+FYM+EM (7.24 mg kg^{-1}) suggested that it maintained the same pattern (table 3). The use of RP alone and in combination with organic manures significantly increased the total organic P content in soils was showed by [28]. Similarly [29] also reported the solubilization of P was high from the treatment receiving RP with compost or cow dung as compare to alone RP treatment.

The AB-DTPA extractable K concentrations in soil were non-significantly affected by SSP and RP applied alone or in different combination with FYM, HA and EM (Table 3). The difference between the treatments is very less and statistically non-significant are due to the only presence of nature K in the soil because no K fertilizer was applied. The highest concentrations of K were found in those treatments which had received FYM, because FYM is a good source of all plant nutrient including K. The same results for the canola crop who observed the maximum concentrations of the total K in the plot which received RP combine with FYM and PSB were obtained by [30].

Table 3. Comparing the effect of the SSP and RP applied alone or in combination with FYM, HA and EM on soil NPK level at boot stage and after harvesting of wheat

Treatment	Nitrogen concentration (%)		AB-DTPA extractable Phosphorus (mg/Kg)		AB-DTPA extractable potassium (mg/kg)	
	boot stage	After harvest	boot stage	After harvest	boot stage	After harvest
Control	0.09 cd	0.013	2.04 f	1.52 e	106.1	88.7
SSP	0.08 cd	0.012	17.68 a	10.52 a	105.8	89.7
RP	0.07 d	0.016	3.68 ef	2.72 e	107	86.7
RP+HA	0.07 cd	0.014	5.12 de	4.788 cd	104.7	88.3
RP+FYM	0.09 bc	0.018	7.64 be	5.68 bc	108.8	84.5
RP+EM	0.07 d	0.014	5.36 de	3.28 de	102.9	89.5
RP+HA+EM	0.08 cd	0.015	6.28 cd	5.84 bc	108.1	89.3
RP+EM+FYM	0.11 ab	0.018	8.72 b	5.88 bc	110.43	92.8
RP+HA+EM+FYM	0.12 a	0.02	8.56 b	7.24 b	112.1	87.9

LSD (5%) 0.02 NS 1.06 1.12 NS NS

*means followed by same letter(s) in the column do not significantly different at P (0.05)

Leaf Analysis

Statistical analysis of the data showed that total N concentrations in wheat leaf at anthesis stage were significantly affected by treatment combinations (Table 4). The highest N concentration with RP+FYM+HA+EM was strongly supported by [30] who obtain the same results for the canola crop. The P content of leaf was non-significantly affected by different treatments. The highest mean of phosphorus concentration (0.25 %) was recorded from the treatment which was fertilized with SSP. This treatment was followed by treatment fertilized by RP along with HA, FYM and EM with the value of 0.23 % while the lowest concentrations of 0.19 % was recorded from the control treatment (Table

4). The maximum uptake of P in soybean crop from the treatments receiving RP with combination of PSM and FYM was reported by [22, 31]. The potassium concentration of leaf was non-significantly affected by different treatments. The highest concentration of Potassium (4.45 %) in the leaf was recorded from the treatment fertilized with RP along with HA, FYM and EM. This treatment is nearly followed by treatment fertilized with SSP with the value of 4.4 % while the lowest concentration of potassium was recorded from the plot receiving RP only. The highest K concentration in the treatment received RP+FYM+HA+EM was strongly supported by These results are in agreement with the findings of [30, 32, 33].

Table 4. Comparing the effect of the SSP and RP with the different combination of EM, HA, FYM on leaf NPK concentration at anthesis stage

Treatments	Concentration in plant leaf (%)		
	Nitrogen	Phosphorus	Potassium
Control	0.81 c	0.191	4.36
SSP	0.96 ab	0.248	4.4
RP alone	0.86 c	0.208	4.11
RP+HA	0.93 b	0.207	4.2
RP+FYM	0.95 ab	0.235	4.33
RP+EM	0.85 c	0.201	4.19
RP+HA+EM	0.96 ab	0.223	4.42
RP+EM+FYM	0.96 ab	0.228	4.2
RP+HA+EM+FYM	0.99 a	0.233	4.45
LSD (5%)	0.055	NS	NS

*mean followed by same letter(s) in the column do not significantly different at P (0.05)

NS: Non Significant

N and P concentrations in wheat grains

The total nitrogen concentrations of grain were significantly affected by the SSP and RP applied alone or in different

combinations with FYM, HA or EM (Table 4.6). The highest concentrations of total nitrogen were recorded from the treatments fertilized with RP along with HA, FYM and

EM (1.7 %). This treatment was closely followed by treatment fertilized with RP+EM+FYM with the value 1.53 % statistically similarly to treatment of RP+HA+EM and SSP treated plot with values of 1.46 % and 1.43 % respectively. The highest N in RP+FYM+HA+EM was strongly sported by [30] who obtain the same results for the canola crop where t the maximum concentrations of the total nitrogen was obtain from the plot which received RP combine with FYM and PSB. The highest concentration of Phosphorus concentration was recorded from the treatments fertilized with RP along with HA+FYM+EM (0.16 %). This treatment was closely followed by treatment of

RP+EM+FYM and RP+FYM with similar value of 0.15 %, while the lowest concentration was recorded from the control treatment (0.10 %). These results were supported by [18] who applied PSM with RP alone or along with organic matter. The superior effect of RP+FYM+HA+EM in terms of producing the highest grain P concentration was also supported by [30] who obtained the same results for the canola crop where the maximum concentrations of phosphorus was obtained from the plot that received RP combined with FYM and PSB. The maximum uptake of P by soybean from the treatment which receiving RP with combination PSM and FYM was also reported by [22].

Table 5. Wheat Grain N and P concentration (%) in grain as affected by application of SSP and RP alone or in different combination of FYM, HA and EM

Treatment	% N	% P
Control	0.69 d	0.10 f
SSP	1.41 ab	0.14 bc
RP	0.78 cd	0.13 d
RP+HA	1.08 bcd	0.11 ef
RP+FYM	1.16 bc	0.15 ab
RP+EM	1.09 bcd	0.12 e
RP+HA+EM	1.46 ab	0.14 c
RP+EM+FYM	1.53 ab	0.15 ab
RP+HA+EM+FYM	1.7 a	0.16 a

*mean followed by same letter(s) in the column do not significantly different at P (0.05)

Economic Analysis of SSP and RP application

The economical analysis of SSP and RP with different combination with HA, EM, and FYM are shown in Table 4.5. The maximum net return of Rs. 36251 ha⁻¹ was obtained by the treatment receiving RP along with FYM+HA+EM followed by treatment by combining RP with HA+EM with Rs. 33551 ha⁻¹, while the commercial fertilizer (SSP) has net return of Rs. 29124 ha⁻¹. However being cheaper the RP and RP+HA and RP+EM had higher VCR values with range from 7.28 to 8.79 in

comparison to 2.65 observed for SSP fertilizer. When the RP was added with FYM which was comparatively more costly than HA or EM the VCR dropped down to 3.95 and 3.77. However the treatment of RP+HA+EM+FYM which the maximum grain yield, maximum net return of Rs. 36251 ha⁻¹ having VCR value of 4.02 which was almost double of SSP fertilizer could be recommended on economical basis. This was supported by [34] who recommended the RP for the increasing of agricultural production instead of the commercial fertilizer (SSP, DAP etc) because of the high

cost. Similar results were also given by [35] stated that the RP can increase the agricultural production as the commercial fertilizer can do, but it is totally dependant on soil, crop, climatic condition and mineral composition of RP.

Table 6. Comparative economical analysis of SSP and RP applied alone or in combination with FYM, HA and EM to wheat crop in calcareous soil

Treatments	Yield	Yield Increase	Increase Yield Value	Cost of Fertilizer	Net Return	VCR
	Kg ha ⁻¹		-----	Rs. ha ⁻¹ -----		
Control	3735	-	-	-	-	-
SSP	5168	1433	40124	11000	29124	2.65
RP	4420	685	19180	2025	17155	8.47
RP+HA	4618	883	24724	2525	22199	8.79
RP+FYM	4978	1243	34804	7025	27779	3.95
RP+EM	4778	1043	29204	3525	25679	7.28
RP+HA+EM	5077	1342	37576	4025	33551	8.34
RP+EM+FYM	5187	1452	40656	8525	32131	3.77
RP+HA+EM+FYM	5352	1617	45276	9025	36251	4.02

Wheat Price @ Rs.28 kg⁻¹, FYM @ Rs.500 tone⁻¹, RP @ Rs.4.5 kg⁻¹, SSP @ Rs.20 kg⁻¹, HA @ Rs.100 kg⁻¹, EM @ 150 liter⁻¹.

Net return = value of increase yield - cost of fertilizer

VCR = value of increase yield / cost of fertilizer

Conclusions

Alone application of RP increased the grain yield of wheat from 3.73 in control to 4.42 t ha⁻¹ indicating that direct application of RP is workable but it is not as efficient as SSP fertilizer which produced the grain yield of 5.17 t ha⁻¹. The comparatively higher yield in RP treatment suggested P releases from RP during the crop growth. The superior effect of RP+FYM as compared to RP+EM or RP+HA could be associated to lower level of native organic content of soil (0.78%) and application of FYM would have drastically altered many soil properties. The combination of HA or EM with mixture of RP+FYM further improved its yielding potential and gave statistically more yields than SSP treated plots. Similarly the combination of RP with all (FYM+EM+HA) was superior than combination with any two or one and produced the highest 1000-grain weight and grain and straw yields with higher leaf tissue N, P and K. The RP applied alone or in combination with FYM, HA and EM was more economical than

commercially available SSP. The SSP had VCR value of 2.65 where the RP produced VCR values from 3.77 to 8.79 in different combination with HA, EM and FYM. The combine application of RP with HA, EM and FYM increased the N, P and K concentrations in wheat leaves at anthesis stage and N and P in wheat grains suggesting improving in crop quality. The treatment of RP+HA+EM+FYM which produced the maximum grain yield and maximum net return of Rs. 36251 ha⁻¹ with VCR value of 4.02 which was almost double of SSP fertilizer suggested that it was more economical than commercial phosphatic fertilizer. So The RP is economical and cheaper than commercial phosphatic fertilizer but it should be applied in combination with FYM, HA or EM to ensure the higher yield of the crop. Based on the research conducted, application of RP at 450 kg ha⁻¹ along with 10 t FYM, 5 kg HA and 10 L EM ha⁻¹ is recommended for economical crop yields.

Authors' contributions

Conceived and designed the experiments: D Muhammad, M Waheed & M Mussarat,
Performed the experiments:

M Waheed, MA Khan & T Naseem, Analyzed the data: M Waheed & MA Khan, Contributed reagents/materials/analysis tools: D Muhammad & M Mussarat, Wrote the paper: MA Khan.

References

- GoP (2008). Federal Bureau of Statistics. Statistics Division, Ministry of Finance and Economic Affairs, Government of Pakistan.
- Satar S (2011). Phosphorous requirement of maize genotype on a calcareous soil, critical internal and external phosphorous concentration. LAP Lambert Acad. Pub. ISBN 978-3-8433-5963-4.
- Ahmad N, Saleem MT and Twyford IT (1992). Phosphorus Research in Pakistan a Review, Symposium on the role of phosphorus in crop production, Government of Pakistan Planning and Development Division, NDFC, Islamabad: 59-92.
- Sharif M (1885). Improvement of P fertilizer efficiency. Proc. Inter. Seminar on fertilizer use efficiency. 106-116.
- Alam SM, Shah SA, Akhter M (2003). Varietals differences in wheat yield and phosphorus use efficiency as influenced by method of phosphorus application. *Songklanakarian J. Sci. Technol.* 25(2): 175-185.
- Khasawneh FE and Doll EC (1978). The use of phosphate rock for direct application to soils. *Ad. Agron.* 30: 159-206.
- NFDC (1989). Crop response to fertilizer. NFDC Publication 4/89. Islamabad.
- Reddy MS, Kumar S and Babita K. 2002. Bio-solubilization of poorly soluble rock phosphates by *Aspergillus tubingensis* and *Aspergillus niger*. *Bioresource Technol.* 84: 187-189.
- Geonadi DH, Siswanto and Sugiarto Y (2000). Bioactivation of poorly soluble rock phosphate with a phosphorous solubilizing fungus. *Soil Sci. Soc. Am. J.* 64:927-932.
- Gyaneshwar P, Kumar GN, Parekh LJ and Poole PS. 2002. Role of soil micro-organisms in improving P nutrition of plants. *Plant Soil.* 245:83-93.
- Chabot RH, Antoun and Cescas MP (1993). Stimulation of growth of maize and lettuce by inorganic P solubilizing micro-organisms. *Canadian J. Microbiol.* 39: 941-947.
- Khattak RA and Muhammd D (2008). Increasing crop production through humic acid in rained and salt effected soil in kohat. Final technical progress report. Agriculture Linkages Program, PARC, Islamabad.
- Brams E (1973). Effect of Humic acid on P fixation. *Plant Sci.* 39: 465.
- Misra RV and Hesse PR (2004). Comparative analysis of organic maure, FAO/UNDP Regional Project. RAS/75, Field document 24. FAO, Rome.
- Guar AC (1994). Bulky organic manures and crop residues. In: Tandon, H.L.S. (ed), Fertilizers, Organic manures, Recyclable wastes and Bio-fertilizers, Fertilizers Development and Consultation Organization, New Delhi, India. 36-51.
- Steel RGD and Torrie JH (1980). Principal and Procedures of Statistic. A biometrical approach. McGraw-Hill, New York.
- Rashid A (1996). Secondary and micro-nutrients (chapter #12) Elena Bashir and Robyn Bantel (eds) Soil Science. National Book Foundation Islamabad. 341-385.
- Afzal A, Sharif M, Asad A and Farooq M (2005). Response of wheat to phosphate solubilizing micro-organisms. *Int. J. Agri. Biol.* 7(2):207-209.
- Akhbari GA, Eftekhari G and Allahdad I (2010). Evaluation of rock and super phosphates effects on yield and yield components of Rice (*Oriza sativa* L.) with and without Phosphate Solubilizing Bacteria. *American-Eurasian J. Agron.* 3(3): 51-58.
- Saruhan V, Kusvuran A and Babat S (2011). The effect of different humic acid

- fertilization on yield and yield component of common millet (*panicum miliaceum*). *Scientific Research and Assays*. 6(3): 663-669.
21. Aery NC (2001). Phosphate Rock with Farmyard Manure as Phosphorous Fertilizer in Neutral and weakly Alkaline Soils. *Current Sci*. 80(9): 1113-1115.
 22. Noor A (2011). Improvement of Soil Chemistry Characteristics of Upland with Rock Phosphate, Phosphate-Solubilizing bacteria and Farmyard Manure for increase in Soybean Yield. *Journal of Tropical Soils*. 13(1): 852-875.
 23. Swamy CA, Raghunandan BL, Chandrashekhara M and Brahma Prakash GP (2010). Bio-activation of Rock Phosphate via seed treatment with P solubilizing microbes (PSM) in enhancing P nutrition in cowpea and ragi. *Indian J. Sci. Technol*. 3(7): 689-692.
 24. Sharif M, Matiullah K, Tanvir B, Shah AH and Wahid F (2011). Response of fed dung composted with rock phosphate on yield and phosphorus and nitrogen uptake of maize crop. *African J. of Biotechnol*. 10(59):12595-12601.
 25. White EM and Wilson FEA (2006). Response of grain yield, biological yield and harvest index and their rate of genetic progress to N availability in ten winter wheat varieties. *Iresh J. Agric. and Food Research*. 45: 85-101.
 26. Esilab AO, Reda F, Ransom JK, Bayu W, Woidehahid G and Zemichael B (2000). Integrated nutrient management strategies for soil fertility improvement and *Striga* control in northern Ethiopia. *Afr. Crop Sci. J*. 8(4): 403-410.
 27. Gaiind S, Pandey AK and Lata (2006). Microbial biomass, P nutrition and enzymatic activities of wheat grown soil in response to P enriched organic and inorganic manures. *J. Environ. Sci. Health*. 41(2): 177-187.
 28. Laskar BK, Debnathnad NC and Basak RK (1990). Phosphorus availability and transformation from Massoorie rock phosphate in acid soils. *Environment and Ecology*. 8:612-616.
 29. Pramanik P, Bhattacharya S, Bhattacharya P and Banik P (2009). Phosphorous solubilization from rock phosphate in presence of vermicomposts in Aqualfs. Dept. of Renewable Resources, University of Wyoming, Laramie. 152(2): 16-22.
 30. Awaad MS, Rashid AA and Bayoumi MA (2009). Effect of farmyard manure combined with some phosphate sources on the productivity of canola plants grown on a sandy soil. *Research J. of Agric. And Biol. Sci*. 5:1176-1181.
 31. Rodriguez D, Kelti-Jons WG and Goudriaa J (1995). Leaf area expansion and assimilate production in wheat (*Triticum aestivum* L.) growing under low P condition. *Plant and Soil*. 200: 227-240.
 32. Gaj R (2010). Influence of different potassium fertilization levels on nutritional status of winter wheat and yield during critical growth stage. *J. of Elementol*. 15(4): 629-637.
 33. Bergmann W (1992). Nutritional Disorder of Plants. Gustar Fisher, Jena, Stuttgart. 117-131.
 34. Van K (1991). Overview of Phosphorous deposits in East and Southern Africa. View Record in Scopus (19). *Pert. Res*. 30127-30150.
 35. Rajan SSS, Watkinson JH and Sinclair AG (1996). Phosphatic rock for direct application to soils. Omega Scientific Publishers, New Delhi. Adv. Agron. 57: 78-159.