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YIELD, NPK CONTENT AND NUTRIENT UPTAKE OF WHEAT AS INFLUENCED BY THE APPLICATION OF ACIDULATED ROCK PHOSPHATE

SK CHAUDHARY*, MOHAMMAD HASHIM[1], MOHAMMAD SAQUIB[2] AND CB SINGH[3]

G. B. Pant University of Agriculture and Technology,
Pant Nagar-263145,Uttarakhand, India

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Abstract

Field experiments were conducted to study the performance of wheat crop under acidulated rock phosphate (RP) during *rabi* season of 2009 - 2010 and 2010 - 2011. Pooled data indicated that RP + gypsum produced maximum shoot population, yield attributes, grain yield (49.2 q/ha), biological yield (120 q/ha), over other treatments and recorded highest benefit: cost ratio. Maximum nitrogen content in grain was recorded in SSP alone followed by RP + PM + PSB treatment. However, maximum total nitrogen uptake was recorded in RP + PM + PSB treatment. Maximum phosphorous content in grain was found in RP + gypsum and in straw in RP + SSP treatment. Maximum potassium content in grain was found in RP + pyrites and in straw in RP + FYM + PSB treatment, while maximum total phosphorus and potassium uptake was found in RP + gypsum treatment. RP + PSB recorded maximum available nitrogen after crop harvested while maximum available phosphorus and potassium was found in RP + gypsum. Rock phosphate acidulated with gypsum each 300 kg/ha found best in terms of recording grain yield, biological yield and benefit: cost ratio, and can be used as alternate source of phosphatic fertilizers.

Introduction

Wheat (*Triticum aestivum* L.) is the India's second most important staple food crop after rice. It is cultivated on 31.2 million hectare area with a production of 95.9 million tones and the productivity of 3.075 t/ha (Anon. 2014 - 2015). Nutrient management plays key role in wheat production. In all primary and secondary nutrients involved in crop production, phosphorus (P) is of key importance. It has wide spread influence on plant growth and development and plays a series of functions in the plant metabolism from cell division to root development, energy storage, transfer and uniform ripening of crops (Singh and Rai 2003). Phosphorus is an essential plant nutrient and its deficiency restricts crop yields severely. Tropical and subtropical soils are predominantly acidic, and often extremely P deficient with high P-sorption (fixation) capacities. Therefore, substantial P inputs are required for optimum plant growth and adequate food and fibre production. Manufactured water-soluble P fertilizers such as superphosphates are commonly recommended to correct P deficiencies, but most developing countries import these fertilizers, which are often in limited supply and represent a major outlay for resource-poor farmers. In addition, intensification of agricultural production in these countries necessitates the addition of P not only to increase crop production but also to improve soil P status in order to avoid further soil degradation. Hence, it is imperative to explore alternative P sources. Under certain soil and climate conditions, the direct application of PR, especially where available locally, has proved to be an agronomically and economically sound alternative to the more expensive superphosphates (Zapata 2004). Indian soils are generally poor in available phosphorous. Intensive agriculture, however, has resulted further depletion of available phosphorous to a great extent. Among major

*Author for correspondence: <chaudhary7002@gmail.com>. Nalanda College of Horticulture, Noorsarai, Nalanda-803113 (Bihar) India. [1,3]ICAR-Indian Agricultural Research Institute, Regional Station Pusa, Samastipur, Bihar, India-848125. [2]CS Azad University of Agriculture and Technology, Kanpur, India.

nutrients used in crop production, phosphorous use efficiency is minimum due to fixation and slow mobility of applied phosphorous, which results in low crop recovery (20-25%). Diammonium phosphate (DAP), SSP, TSP and nitrophosphates are known chemical fertilizers used for phosphorous nutrition. However, their fixation into soil to insoluble form is relatively more (Sekhar *et al.* 2002). Therefore, there is need to search ways and means to develop phosphorous management system which can make best use of applied and residual phosphorous in soils and thereby increasing phosphorous use efficiency. Rock phosphate is an alternate source of phosphorous for direct application because loosely consolidated aggregate of microcrystals with a relatively large specific surface area with greater proportion of isomorphic substitution (Zapata 2003). It contains about 50% of its total P_2O_5 as tri-calcium phosphate, which is neither water soluble nor citrate soluble. But its solubility can be increased by adding acids or acid forming substances which increases phosphorous supplying power of rock phosphate in the presence of decaying organic matters. These organic matters while decomposing release CO_2, citric acid, malonic acid, fulvic acid and other organic acids which in turn attack insoluble tri-calcium phosphate in rock phosphate to convert them into water and citric acid soluble form. Some microorganism like *Bacillus megatherium* var. *phosphaticum* and cellulose decomposing fungi *Phanerochaet chrysosporium* also enhances the phosphorous availability (Sekhar *et al.* 2002). The soluble P released from soil constituents by the activity of PO_4 solubilizing microorganisms (PSM) is actively taken up by mycorrhizal plants. Combined inoculation with VAM fungi and PSM has been shown to result in better uptake of native soil P as well as P from rock phosphates (Azcon *et al.* 1976, Kucey 1987). Microbial solubilization of rock phosphates and use of acidulating materials like farmyard manure, crop residue and pressmud are receiving greater attention these days. This process not only compensates the higher cost of manufacturing of fertilizers in industries but, also increases nutrient mobility in soil. Increase in demand and cost of chemical phosphatic fertilizers necessitated investigation to utilize the large reserve of low grade rock phosphates which may be an alternative of chemical phosphatic fertilizers.

Materials and Methods

Field experiment was conducted during *rabi* season of 2009-2010 and 2011-12 at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Soil of the experimental site was silty loam in texture with slightly alkaline in reaction (pH 7.9) having medium organic carbon (0.61%), low in available nitrogen (251 kg/ha) and potassium (107 kg/ha) and medium in available phosphorous (22.5 kg/ha). Experiment was laid in randomized block design with 10 treatments replicated in thrice. The wheat crop var. PBW-550 was sown as experimental material. A total of ten treatments were selected *viz.*, single super phosphate (SSP) alone, rock phosphate (RP) alone, RP + gypsum, RP + SSP, RP + PSB, RP + FYM, RP + FYM + PSB, RP + pressmud (PM), RP + PM + PSB and RP + pyrites. 150 kg nitrogen, 60 kg P_2O_5 and 40 kg K_2O/ha were applied to all treatments. One-third of nitrogen, half dose of phosphorous (through SSP and RP as per treatment) and full dose of potassium were applied as basal. One-third of nitrogen and remaining half dose of phosphorous were top dressed just after first irrigation and remaining nitrogen was top dressed at first node formation stage. Rock phosphate treated with the acid causing materials like gypsum, SSP, PSB, FYM, pressmud and pyrites is called acidulating rock phosphate. Rock phosphate and their acidulating materials were mixed manually just before application to the field and were applied as per treatments. Economics of different treatment was worked out as per the standard procedure. Plant samples were analyzed for NPK content in per cent in both grain and straw and calculated total uptake by crop (kg/ha). Soil sample were analyzed before sowing and just after harvesting of crop. The data was statistically analysed with the help of analysis of variance (ANOVA) technique as suggested by Gomez and Gomez (1984) for a randomized block design. The results are presented at 5% level of significance (p = 0.05) for making comparison between treatments.

Results and Discussion

Rock phosphate with gypsum recorded significantly higher grain yield 49.2 q/ha (Table. 1). This is might be due to the more number of spikes per square meter and more number of fertile spikelets per spike. Gypsum made the phosphorous available to the plant by creating acidic condition through the formation of sulphuric acid in the presence of sufficient soil moisture. Acidulation of rock phosphate with pressmud, FYM, pyrites and SSP alone also yielded 47.0, 46.4, 44.9 and 48.2 q/ha respectively, which was 8.5, 7.3, 4.23 and 10.78% higher over RP alone. It is because of acidulating materials, which reduces the phosphorous fixation capacity of soil and make them available to plants (Mclean and Ssali 1977). Application of phosphorous solubilizing bacteria alone and along with FYM and pressmud recorded 0.7, 5.5 and 5.5% higher grain yield over rock phosphate alone. This is mainly attributed to the microorganism, caused excretion of organic acid like glutanic acid, succinic acid, lactic acid, oxalic acid, glyoxalic acid, maleic acid, fumaric acid, tartaric acid, α-ketobutyric acid, propionic acid and formic acid. These acids solubilize the phosphorous and make them available to the plant. Since this reaction take place in the rhizosphere and because of microorganism render more phosphorous into soil solution than is required for their own growth and metabolism. This surplus amount of phosphorous becomes available to plant (Singh and Kapoor 1999). Straw yield did not show significant differences. However, the application of rock phosphate with different acidulating materials recorded more straw yield over rock phosphate alone (Table 1). This could be probably due to more growth and development of plants that had become possible due to more phosphorous availability.

Grain yield of wheat is contributed by the number of spike, spike length, number of grains per spike and 1000 grain weight. The highest number of spike ($441/m^2$) was recorded in rock phosphate with gypsum (Table 1). However, RP with other acidulating materials also recorded higher number of spike over rock phosphate alone. This might be due to more number of plant population with more number of effective tiller/m^2. Significantly longest spike and number of fertile spikelets per spike was recorded in rock phosphate with gypsum and SSP alone. This may be due to assured moisture supply caused more nutrient availability. Rock phosphate acidulated with pressmud, FYM and pyrites also recorded more spike length over rock phosphate alone. Since the acidulated rock phosphate has been considered to be a possible means of minimizing the phosphorous fixing capacity of the soil and make them available to plants, resulted better growth and development. Number of sterile spikelets per spike, number of grains per spike and 1000-grain weight showed non-significant difference. However, the highest number of grains per spike was recorded in rock phosphate with gypsum. This might be due to more dry matter accumulation, more photosynthesis, and proper translocation of photosynthates from source to sink. Significantly higher shoot population was recorded in rock phosphate with gypsum as compare to RP alone. Shoot population increased with increasing crop age upto 60 days after sowing and after that started declining due to tillers mortality (Fig. 1). The lowest shoot population was recorded in RP alone that was due to less emergence count.

The maximum nitrogen content in grain was found in SSP alone and in straw in RP with PM plus PSB (Table 2). It would be probably due to more translocation and accumulation of photpsynthates in grains. The maximum total nitrogen uptake was recorded in RP with PM plus PSB (Table 3). It may be due to acidity generated by pressmud neutralized the soil reaction and made the nitrogen available to plant. These results are in close conformity of Singh and Kapoor (1999). He also reported that nitrogen and phosphorous uptake were enhanced following inoculation with PSB. Significantly maximum phosphorous content was found in RP with gypsum in grain and in RP plus SSP in straw (Table 2). It might be due to more uptake of phosphorous. The maximum total phosphorous uptake was found in RP with gypsum (Table 3). It may be due to more available phosphorous. Maximum potassium content was found in RP with pyrites in grain and in RP plus FYM plus PSB in straw (Table 2), while the maximum total potassium uptake was found in RP with gypsum (Table 3). It might be due to acidulation that converted non exchangeable potassium to exchangeable form (Richter 1994). The lowest total uptake was recorded in RP with SSP. It would be probably due to potassium fixation. Much of the inorganic fertilizers applied to the soil fixed the potassium into insoluble form and rendered unavailable to plant (Sanyal and Datta 1991).

Table 1. Effect of rock phosphate on grain yield, straw yield and biological yield (pooled mean of two years data).

Treatment	No. of spike/ m^2	Spike length (cm)	No. of grains/ spike	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	1000-grain weight (g)
SSP alone	441	9.3	37	48.2	67.6	115.8	41.3
RP alone	347	8.3	33	43.0	66.1	109.1	37.3
RP + gypsum (1 : 1)	441	9.4	38	49.2	70.8	120.0	42.0
RP + SSP (50 : 50)	403	8.5	34	43.9	64.2	108.2	38.4
RP + PSB	398	8.5	34	43.3	65.8	109.1	38.4
RP + FYM (1 : 1)	431	9.0	37	46.4	69.7	116.1	40.0
RP + FYM + PSB	432	8.9	36	45.5	65.2	110.6	39.2
RP + press mud (1 : 1)	438	9.1	37	47.0	70.9	117.9	40.1
RP + press mud + PSB	423	8.8	35	45.5	65.8	111.2	39.1
RP + pyrites (1 : 1)	412	8.7	35	44.9	67.9	112.7	38.7
SEm ±	14	0.3	2	1.7	3.5	3.5	1.6
CD at 5%	43	0.9	NS	5.1	NS	10.2	NS

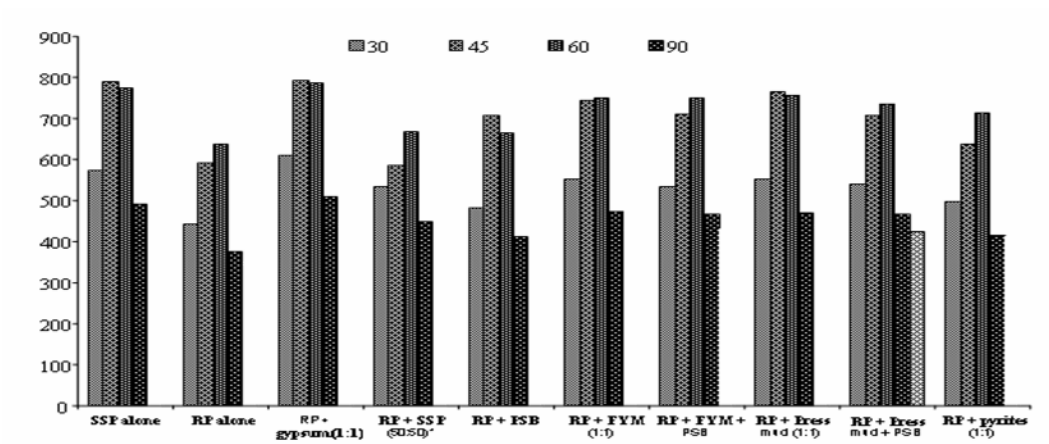

Fig. 1. Number of shoot/m^2 of wheat crop at different growth stages (30, 45, 60 and 90 DAS) as influenced by the application of rock phosphate.

There was highly significant and positive correlation existed between grain yield and yield attributes of wheat**.**

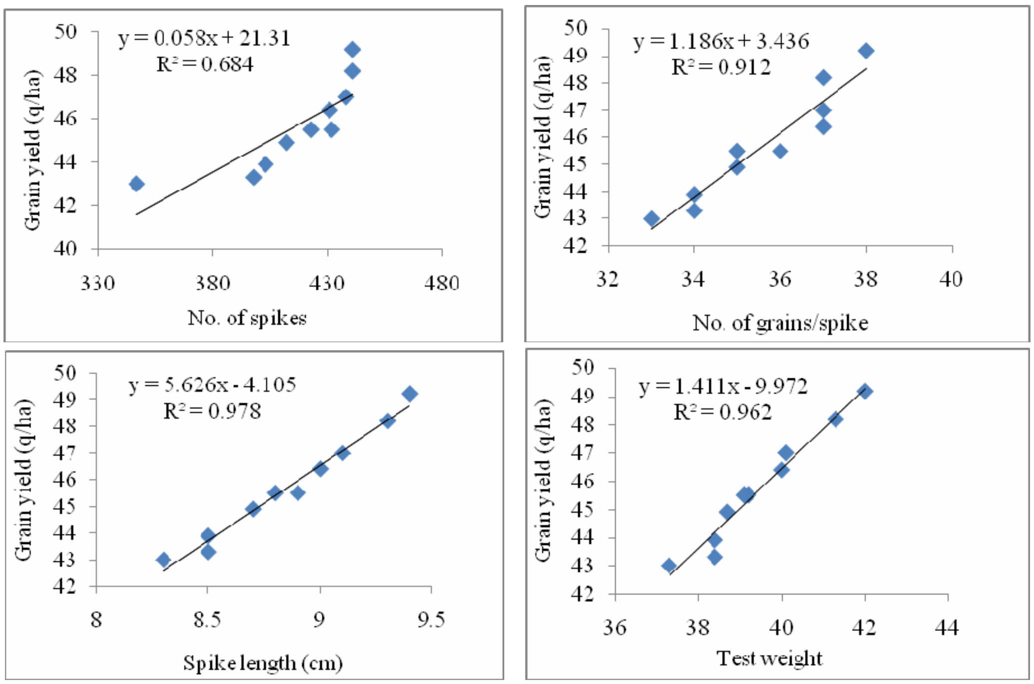

Fig. 2. Regression equation and trend lines of wheat grain yield and major yield attributes.

After crop harvest higher organic carbon per cent was recorded in RP with gypsum (Table 3). This might be due to dissolution of carbonate in neutral to alkaline soils results consumption of carbon dioxide gas and formation of carbonic acids, while precipitation of carbonates results release of carbon dioxide. This effect of soil carbonates dissolution or precipitation at proper soil moisture results net carbon sink. Significantly higher electrical conductivity was recorded in RP with PM and PSB followed by rock phosphate alone which is mainly attributed to the more salt content. The pH of the soil showed non-significant difference due to treatments, it may be due to buffering capacity of soil.

Available nitrogen content in soil after crop harvest had not affected due to different treatments and was irrespective of different rock phosphate acidulation. Higher available phosphorous in soil after crop harvest was found in RP with SSP. It might be due to the SSP which is soluble in water. Maximum available potassium in soil after crop harvest was recorded in rock phosphate with SSP. Most probably it may be due to water soluble SSP in presence of assured moisture supply.

Table 2. NPK content in grain and straw at harvest, and their uptake influenced by the application of rock phosphate (pooled mean of two years data).

Treatments	Nitrogen (%)		Phosphorous (%)		Potassium (%)		N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
SSP alone	1.79	0.37	0.287	0.122	0.99	1.40	86.4	25.0	13.8	8.2	47.6	94.8
RP alone	1.64	0.36	0.273	0.123	1.16	1.37	70.6	24.1	11.8	8.1	50.2	90.8
RP + gypsum (1 : 1)	1.65	0.37	0.295	0.124	1.11	1.37	81.4	26.3	14.5	8.8	54.6	97.2
RP + SSP (50 : 50)	1.76	0.34	0.292	0.141	1.01	1.27	77.4	21.7	12.9	9.1	44.1	81.6
RP + PSB	1.50	0.38	0.276	0.111	1.17	1.31	64.9	25.1	12.0	7.3	50.8	85.8
RP + FYM (1 : 1)	1.61	0.34	0.287	0.129	1.08	1.32	74.4	23.7	13.3	9.0	49.9	91.7
RP + FYM + PSB	1.58	0.41	0.279	0.116	1.07	1.45	71.7	26.5	12.7	7.5	48.7	94.3
RP + press mud (1 : 1)	1.76	0.31	0.243	0.133	0.96	1.25	82.5	22.1	11.4	9.4	45.2	88.3
RP + press mud + PSB	1.78	0.46	0.282	0.125	1.05	1.37	81.0	30.5	12.8	8.2	47.9	89.9
RP + pyrites (1 : 1)	1.67	0.35	0.281	0.136	1.18	1.25	74.8	23.7	12.6	9.2	52.9	85.1
SEm ±	0.01	0.00	0.002	0.001	0.01	0.01	3	1.6	0.5	0.5	1.9	5.0
CD at 5%	0.04	0.02	0.006	0.005	0.05	0.04	9	4.72	1.5	1.4	5.6	14.9

Table 3. Effect of rock phosphate on total nutrient uptake (kg/ha), soil organic carbon (%), EC (ds/m), pH, available nitrogen, phosphorous and potassium (kg/ha) and economics (Rs./ha) of wheat (pooled mean of 2 years data).

Treatments	Total N uptake	Total P uptake	Total K uptake	OC	EC	pH	Avail. N	Avail. P	Avail. K	Cost of culti. (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B : C ratio
SSP alone	111.4	22.1	142.4	0.63	0.25	7.88	155.5	27.3	101.4	21205	69893	48688	2.30
RP alone	94.7	19.9	140.9	0.59	0.35	7.98	154.3	26.8	102.2	21100	63848	42748	2.03
RP + gypsum (1 : 1)	107.8	23.3	151.8	0.64	0.30	7.77	153.5	25.6	105.1	21175	71856.	50556	2.38
RP + SSP (50 : 50)*	99.1	21.9	125.7	0.62	0.26	7.83	153.0	27.6	126.0	21152	64393	43241	2.04
RP + PSB	90.1	19.2	136.6	0.60	0.18	7.88	161.8	25.6	104.0	21300	64106	42956	2.01
RP + FYM (1 : 1)	98.2	22.3	141.6	0.62	0.26	7.81	153.9	27.1	112.3	21250	68424	47174	2.22
RP + FYM + PSB	98.3	20.2	143.0	0.61	0.21	7.82	153.9	27.5	99.6	21450	66287	44987	2.09
RP + press mud (1 : 1)	104.7	20.9	133.5	0.61	0.31	7.96	156.0	25.4	103.5	21250	69393	47406	2.23
RP + press mud + PSB	111.6	21.0	137.8	0.59	0.37	7.85	153.9	25.3	112.0	21450	66439	44889	2.09
RP + pyrites (1 : 1)	98.6	21.8	137.9	0.60	0.23	7.94	159.7	25.4	110.6	22258	66303	44045	1.98
SEm ±	3.1	0.7	5.2	0.00	0.00	0.10	2.9	0.2	3.2				
CD at 5%	9.4	2.0	15.5	0.02	0.02	0.29	8.7	0.7	9.7				

RP with gypsum recorded highest gross return (Rs. 71856.06), net return (Rs. 50556.060) and benefit: cost ratio (2.38), while the lowest was found in RP alone (Table 3). This higher gross and net return is due to more grain and straw yield which fetched more income from the market, and more benefit: cost ratio is due to less input cost. The highest cost of cultivation was recorded in RP with FYM plus PSB and RP with PM plus PSB. This maximum cost is due to the additional cost of PSB.

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