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Research Paper

Effect of rock phosphate with different acidulates on growth and yield of different field crops

RAJEEW KUMAR[1], MAYA KRISHNA[2], AMIT BHATNAGAR[3], DEO SARAN PANDEY[4], VIJAY PAL SINGH[5] AND PRADEEP RAM[6]

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttrakhand 263 145

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ABSTRACT

A field experiment was conducted from 2009–10 to 2011–12 at the Norman E. Borlaug Crop Research Center at Pantnagar, Uttarakhand, to find out the efficiency of rock phosphate (RP) with different organic [farmyard manure (FYM), pressmud and phosphate-solubilizing bacteria (PSB)] and inorganic [single superphosphate (SSP) and gypsum]-acidulating materials. Rainy season (*kharif*) crops, namely rice (*Oryza sativa* L.), soybean [*Glycine max* (L.) Merr.], maize (*Zea mays* L.) and winter season (*rabi*) crops, namely Indian mustard [*Brassica juncea* (L.) Czernj & Cosson], *rabi* maize, chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.), were selected for the study. The experiment carried out in a randomized block design with 8 treatment combinations of different acidulates with rock phosphate and replicated 3 times. Treatments include control, SSP + RP, RP + gypsum, RP + PSB, RP + FYM, RP + PM, RP + FYM + PSB and RP + PM + PSB. The maximum grain yield (5.18 t/ha) and straw yield (10.87 t/ha) in rice were observed when press mud and gypsum was used for acidulation respectively. *Kharif* maize and *rabi* maize gave the maximum grain yield when rock phosphate was acidulated with SSP. However, treatment effects were non-significant. Soybean, Indian mustard and lentil gave the maximum grain yield in gypsum acidulation of rock phosphate, but the effect due to treatments was significant in Indian mustard only. In chickpea, significantly higher grain yield (2.38 t/ha) was recorded in FYM + PSB acidulation than the other treatments which was found on a par with FYM and PM + PSB acidulation treatment.

Key words: Acidulation, Field crops, Growth, Rock phosphate, Yield

Phosphorus is one of the important plant nutrients, often referred as 'energizer', because it involves in energy transformation and also a part of genetic material of all cells (Buddh, 2014). Phosphatic fertilizers like SSP, TSP, DAP etc. are added to the soil as fertilizer for phosphorus nutrition in Indian soils, but their cost and fixation causes burden on the farmers. Fixation of P in the soil may help enhance P status in the soil which needs to utilize by making it in available form (Buddh, 2014). Acidulates might be helpful to convert these insoluble P into soluble and available form. Rock phosphate is a sedimentary rock that contains P in water-insoluble apatite form and contains 25–39% of P_2O_5 and also a source of 33–36% of Ca. Quality rock phosphate is imported to manufacture phosphatic fertilizer in India, as the indigenous rock phosphate is poor in quality and cannot be utilized for manufacturing of P fertilizer. However, utilization of indigenous rock phosphate may help reduce economic burden on country. Rock phosphate is soluble in acid soils to some extent owing to the presence of hydrogen ions and, therefore, its use is common in these soils (Savini *et al*., 2006). However, Massey *et al*. (2009) reported that due to low solubility of rock phosphate in alkaline soils, the direct application of rock phosphate has not been effective as compared to the acidic soils. Studies show that rock phosphate solubility increases with the increase in organic matter content in surroundings (Alzoubi and Gaibore, 2012). The decomposed organic matter liberates organic acids such as humic acid, which lower soil *p*H and helps boost the availability of P from rock phosphate (Ali *et al.,* 2012). Therefore, methodology to improve efficacy of indigenous rock phosphate as a sources of plant available phosphorus needs to be investigated. Keeping above in view, this study was conducted to determine the effectiveness of rock phosphate in combination with organic and inorganic acidulates to make P more available from rock phosphate in different rainy (*kharif*) and winter (*rabi*) season crops.

[1]**Corresponding author's Email:** shuklarajeew@gmail.com
[1,3]Junior Research Officer, [2,6]Ph.D. Scholar, [4,5]Professor, Department of Agronomy, College of Agriculture

MATERIALS AND METHODS

A field experiment was executed at the Norman E. Borlaug Crop Research Center of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (29° N, 79.29° E, 243.84 m above the mean sea-level), lying in *tarai* belt of Shivalik range of Himalayan foothills. Soil of the experimental site was silty loam in texture with *p*H 7.9, having medium organic carbon (0.61 %) and low in available nitrogen (251 kg/ha) and potassium (107 kg/ha), medium in available phosphorus (22.5 kg/ha). Acidulates like gypsum, farmyard manure (FYM), pressmud (PM) and phosphorus-solubilizing bacteria (PSB, strain taken from the IARI, New Delhi) were used for the study. Seven crops, namely rice, *kharif* maize, soybean, Indian mustard, *rabi* maize, chickpea, and lentil, were selected as test crops. The experiment carried out in a randomized block design with 8 treatment combinations of different organic and inorganic acidulates with rock phosphate and replicated 3 times. Different treatments and their combinations were: T_1, control, where recommended dose of phosphorus was applied through Udaipur rock phosphate (RP) consisting 20% P_2O_5; T_2, single superphosphate (SSP) + RP (half of the recommended P was supplied through RP and remaining half through SSP); T_3, RP + gypsum (full dose of P through RP along with gypsum at 125 kg/ha); T_4, RP + phosphate-solubilizing bacteria (PSB) (full dose of P through RP + PSB @ 2 kg/ha); T_5, RP + FYM (full dose of P through RP + FYM in the amount equal to RP); T_6, RP + PM (full dose of P through RP + PM in the amount equal to RP); T_7, RP + FYM + PSB (full dose of P through RP + FYM in the amount equal to RP + PSB @ 2 kg/ha); and T_8, RP + PM + PSB (full dose of P through RP + PM in the amount equal to RP + PSB @ 2 kg/ha). The recommended doses of fertilizers were 120–60–40, 20–40–40, 20–40–40, 150–60–40, 120–60–40, 120–60–40 and 20–60–40 kg N-K_2O-P_2O_5/ha for Indian mustard, chickpea, lentil, wheat, maize, rice and soybean respectively. The P nutrient sources were applied as per the treatments for different crops and other nutrients were applied through conventional fertilizers over all the treatments. The standard package and practices were used to raise the crops. Observations were taken using standard procedures and data were subjected to statistical analysis for treatment comparison.

RESULTS AND DISCUSSION

Crop growth parameters of kharif *crops*

Plant height, tillers/m² and dry-matter accumulation in rice crop improved in gypsum acidulation than the other treatments while minimum plant height, tillers/m² and dry-matter accumulation was in SSP, pressmud and PSB acidulation respectively (Table 1). Although, the effect of the treatments was non-significant. In the presence of sufficient moisture condition, gypsum forms sulphuric acid which dissolves rock phosphate and makes phosphorus available to the plant. Phosphorus is responsible for establishment and proliferation of the plant roots, which leads to better absorption of nutrients. Phosphorus also, have metabolic role in photosynthesis, transformation of sugar to starch, transportation of genetic material and many other. All these might have resulted in the better growth and higher yield. In *kharif* maize also, the effect of treatments was non-significant on the plant height but maximum plant height was observed with RP + SSP and the minimum with RP + PM + PSB treatment. However, in soybean the maximum plant height was recorded when RP was acidulated with PM + PSB which was statistically at par with other treatments. In soybean although the plant height were the maximum in RP + PM + PSB treatment but the number of branches/plant and dry-matter accumu-

Table 1. Crop growth parameters of rice, rainy season maize and soybean (pooled data of 3 years)

Acidulates	Rice			Rainy season maize	Soybean		
	Plant height (cm)	Tillers/m²	Dry-matter (g/m²)	Plant height (cm)	Plant height (cm)	Branches/ plant (Nos.)	Dry-matter (g/plant)
Control (RP alone)	119	335	559	129	50	10	28
RP + SSP	116	347	583	138	52	11	38
RP + gypsum	127	389	670	135	51	11	36
RP + PSB	119	355	555	133	50	10	37
RP + FYM	118	381	590	133	51	11	41
RP + PM	118	335	640	125	54	11	31
RP + FYM + PSB	118	363	599	131	50	10	36
RP + PM + PSB	119	367	617	123	55	10	32
SEm±	2.9	15.0	29.9	6.6	1.6	0.6	3.7
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

RP, Rock phosphate; SSP, single superphosphate; PSB, phosphate-solubilizing bacteria; FYM, farmyard manure; PM, pressmud; NS, non-significant lation were the highest in FYM acidulation. The increase in the growth parameters might be owing to the increased release of phosphorus from the dissolution of rock phosphate mediated by organic acids produced from the FYM decomposition. Manjunath *et al*. (2006) in their study reported that, in Frenchbean total dry-matter accumulation was increased significantly when rock phosphate was treated with vermicompost (1:2) and PSB. The results also supported the findings of Mashori *et al.* (2013).

Crop growth parameters of rabi *crops*

Plant growth parameters of different *rabi* crops were found non-significant except dry-matter accumulation in *rabi* maize (Table 2). There was no significant effect on growth parameters of Indian mustard, though maximum plant height was recorded in FYM-acidulated rock phosphate and minimum in PSB-treated rock phosphate. Maximum number of branches/plant was found in FYM and PM + PSB acidulated rock phosphate along with the control treatment. Dry-matter accumulation was the maximum in SSP-acidulated rock phosphate and the minimum in the control treatment, where no acidulation was done. Effect of treatment over plant height of *rabi* maize was non-significant, though it was the maximum in SSP and FYM + PSB-acidulated rock phosphate. Dry-matter accumulation was the maximum in FYM + PSB-acidulation of rock phosphate, which was at par with gypsum, SSP and PM + PSB-acidulated rock phosphate, but significantly higher than the rest of the treatments. The PSB acidulated rock phosphate might have improved supply of phosphorus at the later stages of crop growth, thus resulting in better growth (Munda *et al*., 2013). Similar results were reported by Mahanta and Rai (2008).

In case of chickpea all the growth parameters were non-significant due to the treatments. The maximum plant height was in PM + PSB and PM-acidulated rock phosphate. Dry-matter accumulation was the maximum in FYM and SSP-acidulated rock phosphate. In a similar study, Patil *et al.* (2011) reported that, compost 5 t/ha along with rock phosphate at 200 kg/ha with PSB recorded significantly higher plant height, number of branches, leaf-area index (LAI) and total dry-matter production (TDMP) over compost and FYM applied with 50 kg/ha rock phosphate and absolute control. This might be owing to the application of crop residues and organic manures with PSB as organic acids and CO_2 released from crop residue facilitates dissolution of rock phosphate (Prasad, 2009). Saravanan and Panneerselvam (2014) also reported that, application of rockphosphate with compost and PSB increased plant height, number of branches, LAI and TDMP of gram. Higher dose of rock phosphate with PSB applied along with compost might have resulted in higher availability of phosphorus owing to better mineralization of nutrients. In lentil crop data showed that there was no significant effect on growth parameters owing to the rock phosphate acidulation treatments. However, plant height, branches/plant and dry-matter accumulation observed maximum in gypsum acidulation as compared to the other treatments.

Yield attributes and yield of kharif *crops*

In rice there was no significant effect of treatment on yield and yield-attributing characters (Table 3). The maximum number of panicles/m^2 was recorded in the control treatment. The 1,000-grain weight was the maximum in PM-acidulated rock phosphate. The maximum grain yield (5.18 t/ha) and straw yield (10.87 t/ha) were recorded with PM-acidulated rock phosphate and gypsum acidulated

Table 2. Crop-growth parameters of Indian mustard, winter *rabi* maize, chickpea and lentil (pooled data of 3 years)

Acidulates	Indian mustard			Winter maize		Chickpea		Lentil		
	Plant height (cm)	Branches/ plant (Nos.)	Dry-matter (g/plant)	Plant height (cm)	Dry-matter (g/plant)	Plant height (cm)	Dry-matter (g/plant)	Plant height (cm)	Branches/ plant (Nos.)	Dry-matter (g/plant)
Control (RP alone)	150	11	32	150	62	43	24	41	9	3.2
RP + SSP	151	10	38	160	71	43	27	43	10	3.5
RP + gypsum	151	9	37	156	73	44	25	44	11	3.6
RP + PSB	149	10	33	148	68	44	24	43	10	3.1
RP + FYM	155	11	39	153	64	43	27	43	10	3.5
RP + PM	151	10	37	153	66	45	23	43	11	3.5
RP + FYM + PSB	151	10	37	160	77	44	25	43	10	3.4
RP + PM + PSB	151	11	34	153	69	45	25	43	10	3.5
SEm±	2.8	0.7	1.9	3.5	2.8	1.1	1.2	1.3	0.6	0.2
CD (P=0.05)	NS	NS	NS	NS	8.4	NS	NS	NS	NS	NS

RP, Rock phosphate; SSP, single superphosphate; PSB, phosphate-solubilizing bacteria; FYM, farmyard manure; PM, pressmud, NS, non-significant rock phosphate respectively. Similar results were reported by Khalil *et al*. (2002) where FYM and gypsum with rock phosphate resulted in higher yield than the other under untreated Biophos inoculation and was statistically similar to that of yields obtained from FYM, green manure and rock phosphate alone-treated pots under Biophos inoculation. Similar conclusions have also been reported by Ghosal *et al*. (1998). In case of *kharif* maize, yield-attributing characters and yield were not affected significantly due to the treatments. However, SSP-acidulated rock phosphate observed the maximum of the both cob girth and cob length. The 100-grain weight of the *kharif* maize was maximum with the pressmud-acidulated rock phosphate. Treatments were failed to produce significant difference in the yield. Maximum grain yield was recorded in SSP-acidulated rock phosphate, while the minimum grain yield in PSB-acidulated rock phosphate. The reason might be that during the initial phase of crop growth SSP has supplied phosphorus to the plant followed by phosphorus supply from rock phosphate mineralization during later stages of crop which resulted in increased yield.

Number of pods/plant of soybean was maximum in gypsum and FYM-acidulated rock phosphate and the control treatments, which do not differ significantly from the other treatments. Grain weight/plant was significantly higher in the PSB-acidulated rock phosphate. However, 1,000-grain weight was the maximum in RP + FYM + PSB treatment which was significantly higher than the control and PM-acidulation treatment and at par with rest of the treatments. Grain yield of soybean was non-significant due to the treatment. It was maximum in gypsum- and PSB-acidulated rock phosphate and the minimum yield was achieved in SSP and PM + PSB-acidulated rock phosphate. Gypsum facilitates dissolution of rock phosphate, thus increases yield by enhancing phosphorus nutrition. Along with P solubilization activity, PSB liberates phytohormone (IAA) that might have a positive influence on yield attributes and yield (Yadav *et al*., 2015).

Yield attributes and yield of rabi *crops*

There was no significant effect of treatments on 1,000-grain weight of Indian mustard, though it was the maximum in SSP-acidulated rock phosphate (Table 4). Grain yield was found significantly higher in gypsum the acidulated rock phosphate as compared to the other treatments. Stover yield was also highest in gypsum-acidulated rock phosphate which was at par with SSP, PM + PSB, PM and FYM + PSB-acidulated rock phosphate and significantly higher than rest of the treatments. Shaktawat *et al.* (2006) observed the maximum seed yield of Indian mustard with RP + PSB + FYM at 90 kg P_2O_5/ha, which was at par with the same treatment combination at 60 kg P_2O_5/ha and superior to the absolute control treatment and they concluded that, application of higher phosphorus doses through rock phosphate alone or in combination with acidulates were better than the lower doses. The low-grade rock phosphate such as Mussoorie rock phosphate (MRP) can be advantageously utilized when applied with PSB inoculation along with rice and wheat residue incorporation (Sharma and Prasad, 2003).

The treatments failed to bring significant effect on yield-attributing characters and yield of *rabi* maize. Length of cob and girth of cob was higher in FYM + PSB-acidulated rock phosphate while 100-grain weight and grain yield were higher in PM + PSB and SSP-acidulated rock phosphate, respectively. In case of chickpea, all the

Table 3. Yield attributes and yield of rice, rainy season maize and soybean (pooled data of 3 years)

Acidulates	Rice				Rainy season maize				Soybean			
	Panicles/ m^2 (Nos.)	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Cob length (cm)	Cob girth (cm)	100-grain weight (g)	Grain yield (t/ha)	Number of pods/ plant	Grain weight/ plant (g)	1,000-grain weight (g)	Grain yield (t/ha)
Control (RP alone)	207	25.4	4.81	9.79	16	13	26.8	4.62	35	16.8	203	2.00
RP + SSP	199	25.3	4.94	10.29	17	14	26.9	4.77	33	17.4	214	1.92
RP + gypsum	199	26.7	5.15	10.87	17	13	27	4.59	35	17.8	209	2.09
RP + PSB	198	25.9	5.08	9.70	16	13	24.2	4.58	33	23.8	213	2.04
RP + FYM	204	26.2	4.95	9.94	16	14	26.7	4.60	35	19.5	213	2.02
RP + PM	201	26.9	5.18	10.56	17	14	27.9	4.64	33	16.9	198	2.00
RP + FYM + PSB	192	25.7	5.00	9.78	17	13	27.4	4.68	33	20.3	220	1.96
RP + PM + PSB	189	26.6	5.12	10.43	17	14	27.7	4.64	32	15.4	204	1.92
SEm±	19.1	0.5	0.24	0.42	0.4	0.3	0.7	0.09	0.8	0.4	5.9	0.04
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.2	17.6	NS

RP, Rock phosphate; SSP, single superphosphate; PSB, phosphate-solubilizing bacteria; FYM, farmyard manure; PM, pressmud; NS, non-significant

Table 4. Yield attributes and yield of Indian mustard, winter maize, chickpea and lentil (pooled data of 3 years)

Acidulates	Indian mustard			*Rabi* maize				Chickpea				Lentil			
	1,000-grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Cob length (cm)	Cob girth (cm)	100-grain weight (g)	Grain yield (t/ha)	Pods/ plant (Nos.)	Seeds/ pod (Nos.)	1,000-grain weight (g)	Grain yield (t/ha)	Pods/ plant (Nos.)	Seeds/ pod (Nos.)	1,000-grain weight (g)	Grain yield (t/ha)
Control (RP alone)	4.9	1.27	4.53	15	13	26.9	5.50	20	1.5	157	1.83	30	1.6	19.8	1.55
RP + SSP	5.4	1.42	4.72	15	13	28.3	5.55	27	1.1	166	1.96	35	2.0	20.5	1.68
RP + gypsum	5.2	1.64	4.74	14	13	27.5	5.34	27	1.5	166	2.02	41	2.0	21.1	1.78
RP + PSB	4.4	1.22	4.56	15	13	26.2	5.13	26	1.1	163	1.93	31	1.6	20.2	1.65
RP + FYM	4.4	1.25	4.58	15	13	28.2	4.94	28	1.4	163	2.23	33	1.3	20.5	1.58
RP + PM	4.2	1.25	4.66	15	13	28.0	5.52	26	1.2	157	2.06	34	2.0	20.6	1.58
RP + FYM + PSB	4.8	1.28	4.64	16	14	27.7	5.16	31	1.9	167	2.38	33	2.0	21.3	1.69
RP + PM + PSB	4.5	1.41	4.72	15	13	28.6	5.22	26	1.4	167	2.15	40	2.0	20.4	1.72
SEm±	0.3	0.06	0.03	0.3	0.2	0.9	0.19	2.3	0.2	3.3	0.9	2.3	2.0	0.4	0.05
CD P=0.05)	NS	0.19	0.12	NS	NS	NS	NS	NS	NS	NS	0.26	6.9	NS	NS	NS

RP, Rock phosphate; SSP, single superphosphate; PSB, phosphate-solubilizing bacteria; FYM, farmyard manure; PM, pressmud; NS, non-significant

yield-contributing parameters were non-significant due to the treatments but when rock phosphate was applied in combination with FYM and PSB resulted in the maximum number of pods/plant, number of seeds/pods and 1,000-grain weight as compared to the other treatments. Grain yield was the highest in FYM + PSB acidulation of rock phosphate, being at par with FYM and PM + PSB-acidulated rock phosphate and significantly higher than the rest of the treatments. According to Savini *et al*. (2006) when there is addition of organic manure in the soil there is release of various organic acids during the decomposition. These organic acids chelate calcium and magnesium ions and increase the availability of phosphorus from the rock phosphate. These results also support the findings of Saravanan and Panneerselvam (2014). This increase in yield and yield-contributing characters may be owing to more absorption of phosphorus in the presence of PSB because of its increased mineralization, and also owing to positive correlation with symbiotic nitrogen fixation due more root growth supported by increases absorption of phosphorus (Kushwaha, 2007).

For lentil crop, number of pods/plant was significantly higher in gypsum acidulation of rock phosphate which was at par with RP + PM + PSB and RP + SSP treatments and significantly superior to the rest of the treatments. Number of seeds/pod was almost unaffected due to the treatments. The maximum 1,000-grain weight was recorded when rock phosphate was acidulated with FYM + PSB and the minimum in control treatment. However, grain yield was the highest in gypsum-acidulated rock phosphate, being statistically at par with the other treatments. In the similar study, Mona (2015) recorded higher pod and straw yields of green pea in acidulated RP than the super phosphate. It was because of the conversion of unavailable form of phosphorus to available form which positively affected the root growth at initial plant-developmental stages. Along with phosphorus there was also increase in uptake of N and K uptake. These findings are also supported by Govere *et al*. (2003).

Economics

In case of the rice crop when rock phosphate was acidulated with PM, the maximum net returns and benefit: cost (B:C) ratio were observed (Table 5). It is due to low input cost of the treatment and higher gross returns though the yield was maximum in gypsum acidulation. In *kharif* maize and *rabi* maize, economic parameters, viz. net returns and B : C ratio were higher in SSP acidulated rock phosphate treatment. Gypsum resuted in the maximum net return and B:C ratio in soybean, Indian mustard and lentil. It was owing to less cost of inputs and higher grain yield. Rock phosphate when acidulated with FYM + PSB

Table 5. Economics of different rainy and winter season crops (pooled data of 3 years)

Acidulates	Rainy season						Winter season							
	Rice		Rainy season maize		Soybean		Indian mustard		Winter maize		Chickpea		Lentil	
	Net returns (×10³ ₹/ha)	B:C	Net returns (×10³ ₹/ha)	Benefit: cost rao	Net returns (×10³ ₹/ha)	B:C	Net returns (×10³ ₹/ha)	B:C	Net returns (×10³ ₹/ha)	B:C	Net returns (×10³ ₹/ha)	B:C	Net returns (×10³ ₹/ha)	B:C
Control (RP alone)	48.8	2.13	32.3	1.84	12.0	0.57	1.9	0.12	36.7	2.12	14.9	0.85	15.6	1.17
RP + SSP	51.4	2.27	32.8	1.88	10.9	0.52	2.5	0.16	37.8	2.18	17.2	1.00	18.1	1.36
RP + gypsum	54.3	2.33	30.2	1.68	13.2	0.62	5.6	0.34	35.6	2.02	18.0	1.03	19.7	1.45
RP + PSB	51.3	2.23	31.5	1.77	12.5	0.59	3.3	0.20	33.7	1.91	16.4	0.93	17.3	1.28
RP + FYM	50.5	2.20	29.1	1.64	12.3	0.58	2.1	0.13	31.6	1.84	21.7	1.22	15.9	1.2
RP + PM	54.2	2.37	30.8	1.74	11.9	0.56	1.4	0.09	37.3	2.13	18.8	1.06	16.0	1.16
RP + FYM + PSB	50.6	2.17	29.1	1.62	11.0	0.51	2.7	0.16	34.2	1.94	24.2	1.34	17.9	1.30
RP + PM + PSB	53.1	2.30	31.3	1.75	10.4	0.49	3.5	0.21	34.1	1.93	20.2	1.11	18.3	1.33

RP, Rock phosphate; SSP, single superphosphate; PSB, phosphate-solubilizing bacteria; FYM, farmyard manure; PM, pressmud; NS, non-significant; B:C, benefit:cost ratio

resulted in the maximum net return and B : C ratio for chickpea crop production.

It can be concluded that application of rock phosphate alone as a source of phosphorus fertilizer is not too effective as application with acidulents. Since solublization of the rockphosphate is limited and a slow process. Therefore to realize the results in the form of growth and yield of the crop acidulation the rock phosphate becomes necessary practice. The experimental results indicate that acidulation of rock phosphate with SSP, gypsum, FYM, pressmud and PSB enhances its efficacy along with increase in growth and yield of the crops.

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