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Introduction of Rock Phosphate Tailing and Single Super Phosphate Inoculated with PSB Enhance Phosphorus use Efficiency, Growth and Yield of Wheat (*Triticum aestivum* L.)

Sarita Choudhary, Ram Hari Meena, S.C. Meena, Seema Pooniyan and Santosh Yadav

Department of Soil Science and Agricultural Chemistry, Maharana Pratap University of Agriculture and Technology, Udaipur 313 001, Rajasthan, India

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ABSTRACT

Continuous rise in the price of phosphatic fertilizers is causing a burden on the farmers. This experiment was undertaken with the purpose of developing a strategy to utilize and solubilize rock phosphate tailing from Jhamarkotra mines Udaipur District, Rajasthan, India through different combinations with SSP inoculated with phosphate solubilizing bacteria and observed their effectiveness as P source against commercial single super phosphate (SSP) using wheat as the test crop. Control (without P application) and P application through RPT and SSP inoculation through PSB in different combination were also included for comparison. Results shows that application of 50% RDP through SSP and 50% RDP through RPT along with PSB significantly better performed than other treatments in terms of P use efficiency of soil and yield of wheat. This study could help to utilize Jhamarkotra rock phosphate tailing as a P source for wheat, with combination with SSP and seed inoculation with PSB and reduce the dependence on commercial fertilizers like SSP.

***Key words**: Rock phosphate tailing, Wheat, SSP, PSB*

Introduction

Phosphorus is one of the second important essential nutrients required by plants and its bioavailability is associated with increases in plant growth (Fonseca *et al.,* 2020). It plays an important role in virtually all major metabolic processes in plant including photosynthesis, energy transfer, signal transduction, macromolecular biosynthesis and respiration (Khan *et al.,* 2010). Although P is abundant in soils in both inorganic and organic forms, it is a major limiting factor for the plant growth as it is an unavailable form for root uptake. Indiscriminate consumption of phosphate fertilizers, in addition to high costs of importing fertilizers from abroad, also has harmful effects such as phosphorus poisoning caused by excessive absorption, increasing its concentration in plant tissues and disrupting the balance of nutritional elements, accumulation of boron in the plant to the extent of toxicity, reducing the absorption of copper, immobilizing iron in the soil and preventing its absorption by the root, disrupting the metabolism of zinc in the plant, reducing mycorrhization of the root, soil contamination with cadmium; decreasing the yield and quality of the product, increasing the negative charge of soil and water pollution to phosphorus and occurrence of the eutrophication phenomenon etc. (Cordell *et al.*, 2011; Renneson *et al.*, 2016; Jupp *et al.*, 2021). Furthermore, in this regard, use rock phosphate as substrates in P solubilization by microorganisms is also a promising strategy (Soumare *et al.*, 2020). This strategy aims to reduce P adsorption and precipitation by promoting P sources with a low solubility instead of soluble P sources (Soltangheisi *et al.*, 2019). In fact, insoluble RP could be more efficient than soluble fertilizers in terms of recovery of phosphate by plants especially in sandy soils subjected to heavy leaching (Chen *et al.*, 2006).

Rock phosphate is a natural, abundant and cheap source of phosphate. However, due to the low absorbability of phosphorus in this source as well as several reasons such as the calcareous nature of most soils, the presence of high pH, drought stress, the presence of a lot of bicarbonate in irrigation water and the lack of organic matter in agricultural soils, the direct use of this source is not common in soils especially in calcareous soils (Walan *et al.*, 2014; Sarikhani *et al.*, 2019). Rock. It is being mined by opencast mining that handles nearly 20 million tonnes of rock annually and beneficiates ~3000 tones of ore per day. The more than 30% P_2O_5 ore ground and marketed as such to the fertilizer industry, but bulk of the low grade ore-18-20 % P_2O_5, is upgraded by forth floatation method to 32-34% P_2O_5 and marketed as beneficiated RP. A substantial amount of ~14 % P_2O_5 ore is stacked at mines as waste (Ranawat *et al.*, 2010).

A large number of phosphate tailings are produced in the process of phosphate ore dressing, and its output accounts for 20%–30% of the raw ore (Chen *et al.*, 2017). Part of the phosphate ore is mainly processed by ore washing, resulting in tailings containing phosphate and clay (Zhang, 2014). Traditionally, most of the phosphate tailings are mainly stored in tailings dams, which occupy a large amount of land with high disposal costs and resulting environmental hazards (Zheng *et al.*, 2015; Chen *et al.*, 2018). These dolomitic tailing along with rock phosphate can be potentially useful in agriculture (Babel *et al.*, 2016). Mao and Zhang (2021) studied the mineralogical composition of a phosphate tailing. The results show that the main minerals in the phosphate tailing are cellophane. According to analysis of mineralogical characteristics, the physical and chemical properties of phosphate tailings provided the basis for comprehensive utilization of phosphorus resources. The nutrients content as P_2O_5 of phosphate tailing is 8.23 %, the SiO_2 is 20.49 %, the MgO is 3.42%, the CaO is 34.68% and the content of sesquioxide (Al_2O_3+Fe_2O_3) is 2.28%.

Materials and Methods

Soil sampling and Analysis

Surface soil (0-15 cm) samples were collected from all the plots after the harvest of wheat during *rabi* season 2021-2022 and 2022-2023 from Agronomy farm, Rajasthan College of Agriculture, Udaipur, Rajasthan. The sample was air –dried, passed through 2 mm sieve, and analyzed phosphorus use efficiency (Huang *et al.* 2018). The observation on number of effective tillers, plant height, ear length, 1000 grain weight, grain, straw and biological yield were recorded at the time of harvest.Plant height was recorded at the time of harvest from 1-meter row length; ten plants were randomly selected for recorded number of effective tillers. Grain, straw and biological yield at maturity were determined from an area of 10 m^2.

$$\text{APUE(\%)} = \frac{\text{Grain yield of nutrient applied plot–Grain yield of control plot}}{\text{Amount of applied fertilizer}}$$

Statistical analysis

The various data collected in the experiment were subjected to analysis of variance using through the procedure suitable to the experiment carried out in randomized block design described by Panse and Sukhatme (1985). The comparison between means was calculated by critical difference (CD) at 5 percent level of significance.

Results and Discussion

Phosphorus use efficiency

The P use efficiency in soil showed a significant increase over control due to application of T_5. The highest P use efficiency wererecorded under plotreceivedT_5 (20.47%) and followed byin treatment T_4 (18.02%), 25% RDP through SSP and 75% RDP through RPT along with PSB (13.08 %) over control on pooled basis. (Figure 1). However, it is known that the use of PSB and P sources can reduce the negative impacts of these fertilizers and enhance PUE in an efficient and environment friendly manner (Etesami, 2019).

Growth attributes

Plant height was significantly affected by application of SSP, RPT and PSB in different combination. It was significantly increased by application of T_5. On average, application of T_5 increased the plant height about 18.50 per cent on pooled basis. The number of effective tillers was significantly influenced by T_5 (Table 1). The higher response of PSB to plant growthmight be due to the mobilization of available P by the native soil microflora or increased PSB activity in the rhizosphere following PSB application and consequently by enhanced P solubilization which enhanced the growth and yield of plants (Ekin, 2010; Nadia *et al.*, 2023).

Yield attributes

The maximum number of effective tillers 112.21 reported in treatment received T_5 followed by T_4 over control. The similar trend was reported in ear length and test weight (Table 1) the PSB have the ability to convert insoluble low-grade RP into soluble forms that affect the growth and development of a plant. These findings of the present investigation are in the close agreement with the research findings of Biswas (2011), Devi *et al.* (2011), Abbasi *et al*. (2013).

Grain yield

Results revealed the maximum grain yield (Figure 2) of wheat (5053 kg ha^{-1}) was recorded from plot

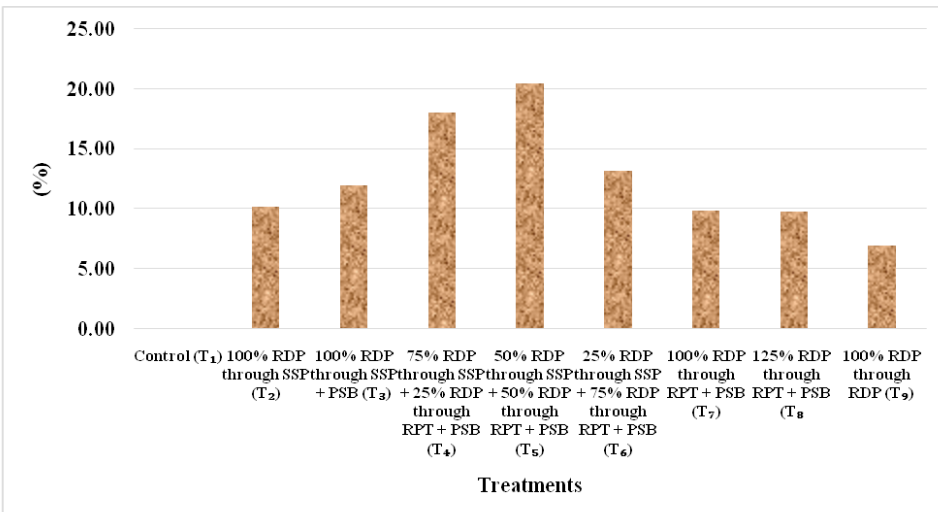

Fig. 1. Effect of SSP, rock phosphate tailing and phosphate solubilizing bacteria on phosphorus use efficiency

Table 1. Effect of SSP, rock phosphate tailing and phosphate solubilizing bacteria on phosphorus use efficiency on pooled basis

Treatments			Plant height (cm)	No. of effective tillers (m^{-1} row length)	Ear length (cm)	Test weight (g)
T_1	:	Control	81.87	96.63	11.55	40.07
T_2	:	100% RDP through SSP	91.69	107.59	12.85	42.18
T_3	:	100% RDP through SSP + PSB	92.76	107.97	12.91	42.81
T_4	:	75% RDP through SSP + 25% RDP through RPT + PSB	95.55	110.80	13.25	45.18
T_5	:	50% RDP through SSP + 50% RDP through RPT + PSB	97.01	112.21	13.35	46.30
T_6	:	25% RDP through SSP+ 75% RDP through RPT + PSB	93.14	108.80	12.98	43.26
T_7	:	100% RDP through RPT+PSB	91.45	107.35	12.80	42.58
T_8	:	125% RDP through RPT + PSB	91.25	107.15	12.77	42.45
T_9	:	100% RDP through RPT	89.94	105.79	12.59	42.09
		SEm ±	0.54	0.85	0.07	0.40
		CD (P=0.05)	1.56	2.44	0.21	1.15

receiving T_5. The lowest grain yield was observed in case of control (3825 kg ha^{-1}) which was due to absence of any external source of phosphorus to the plots. This is also due to low availability of Pat initial stage of root development as well as letter stage. When 75 % RDP through SSP + 25% RDP through RPT along with PSB applied as the source of P to plants, the yield obtained was 4907 kg ha^{-1}which was not significantly different from the treatments receiving P through 50% RDP through SSP + 50% RDP through RPT + PSB. However, the yield was higher side with rock phosphate tailing along with SSP and PSB as the P source, which might be due to the combined positive impact of the both source. The P solubilizing capacity of PSB like *Basillus megatherium*is well known fact, which helps in increasing the release P from rock phosphate tailing. The crop production affected due to applied P from fertilizer gets fixed to plant unavailable forms. On the other hand, inoculation of PSB resulted in continuous solubilization of P from RP tailing and soil-fixed-P, simultaneously PSB also inhibited P-fixation. Thus, P availability increased to the crops compared to alone SSP. Similar results was reported by Ghosal *et al*. (2013) and Roy *et al.* (2018). The positive effect of PSB inoculation could be attributed to relatively less precipitation of the applied soluble P due to solubilization of indigenous insoluble P fraction (Saleem *et al.* 2013 and Mali *et al.* 2017).

The straw yield (Figure 2) of wheat varied from a minimum of 5005 kg ha^{-1} in the plot receiving control to a maximum of 6285kg ha^{-1} in the plot receiving treatment T_5. The straw yield significantly higher when combined application of SSP along with RPT and PSB inoculation. The total biomass yield also showed similar trend as the grain and straw yield of wheat. The effect of SSP, rock phosphate tailing and

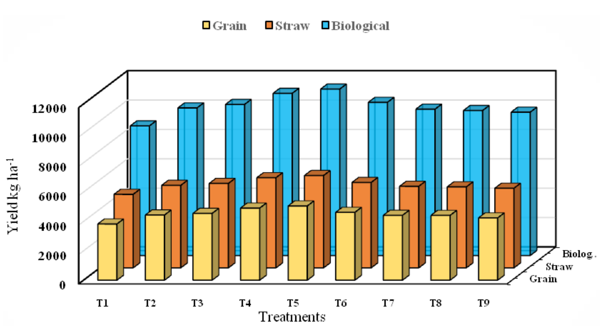

Fig. 2. Effect of SSP, rock phosphate tailing and phosphate solubilizing bacteria on grain, straw and biological yield

inoculation with PSB (*p<0.05*) were all statically significant in enhancing to biological yield of wheat. It is observed that combined application of SSP, RPT and inoculation with PSB have significant effect on biomass. Its might be due to 50% P apply through SSP fulfill the initial P requirement of plants and 50% P applied through RPT and PSB was provided P for optimum growth and development stage of plant. The inoculation throughPSB was mobilized unavailable P. PSB might have further enhanced P uptake by more exploration of soil volume thereby making 'positionally unavailable' nutrients to 'available'. This might have been achieved by reducing the diffusion distance of phosphate ions and by increasing the surface area for absorption of P through the increasing diameter of root hairs. Similar finding were also reported by Mahanta *et al*. (2017), Trabelsi *et al*. (2017), Cheng*et al*. (2017). The interrelationship between various yields attributes of the crop and its grain, straw and biological yield had also been observed by Biswas (2011), Mali *et al.* (2017), Trabelsi *et al.*, (2017), Sarkar *et al*. (2018) and Kharche *et al*. (2020).

Conclusion

This study investigated the effectiveness of SSP, rock phosphate tailing and PSB which is low grade RP as a direct source of P for short duration crop like wheat. The performance of jhamrakotra rock phosphate tailing in combination with SSP and inoculation with PSB equally effective as that of conventional water soluble P-fertilizer like SSP in improving the yield and P use efficiency. The seed inoculation with PSB enhanced the P utilization as compare to control. The limited RP reserves and the increasing cost of commercial P-fertilizers, known as alternative source of Phosphorus.

Conflict of Interest: None

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