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Title:	IMPROVING SOLUBILITY OF ROCK PHOSPHATES BY NANOFORMULATION ALONG WITH ORGANIC ACIDS AND PHOSPHATE SOLUBILIZER

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Abstract: Phosphorus (P) is the second most limiting nutrient element next only to nitrogen. Thus, application of P-fertilizers to sustain agricultural production and productivity become essential. But in recent times the towering prices of the P-fertilizers have led to decline in the application of P which in turn widened the NPK ratio. The resource of high-grade rock phosphate (RP) which is the backbone of the P-fertilizer industry is very limited in India and usually imported from other countries that led to further increase in cost of fertilizers. The high-grade RP is a finite, non-renewable resource which is going to be exhausted in near future. Therefore, there is an urgent need to develop an alternative source to the costly P-fertilizer. In this regard, India is fortunate to have about 260 million tonnes of RP reserve, most of which is predominated by low-grade containing <20% P2O5. These indigenous lowgrade RP can be used as a source of P-fertilizer with some technological intervention. In the present study three independent approaches were attempted to utilize two indigenous low-grade RP from Purulia and Udaipur along with a high-grade RP from Gafsa. In the first approach, nanoformulation of RPs were prepared by sedimentation and centrifugation methods, followed by preparation of organic acid loaded nanoclay polymer composites (NCPC) products. These products were analyzed for chemical and morphological characteristics using different modern techniques. In the second approach, an incubation experiment was conducted under laboratory condition to study the release of P in an Alfisol from Jharkhand amended with various RPs treated with organic acid loaded NCPC at different levels of acid and applied at three levels of P in soil for 90 days. In the third approach, a pot culture experiment was conducted in the greenhouse to see the effectiveness of different RPs treated with organic acid loaded NCPC with and without phosphate solubilizing bacteria (PSB) viz., Pseudomonas striata and their impacts on changes in available and different fractions of P and biological properties in two contrasting soils (Alfisol from Jharkhand and Inceptisol from Haryana) under wheat-rice cropping system. In the first attempt, it was not possible to prepare nanoformulation of RP (nano RP) from commercially available 100-mesh size RP using mechanical separation and centrifugation technique. The total P content in the nano RP declined substantially from that of 100-mesh size RP indicating that these nano RP particles do not correspond to the P-mineral present in the apatite and most probably be the clay particles. Even the size of the nano RP isolated by this technique do not correspond the usual nano size of < 100 nm. However, SEM images and FTIR spectra of nano RP showed significant deviations from that of the original 100 mesh size RP. The incubation experiment showed a positive impact of the organic acids in their ability to release P from all the RP sources, and oxalic acid was found to perform better over citric acid in 190 solubilizing P from RPs. The Gafsa RP maintained highest content of available P in soil, followed by DAP. The two indigenous RPs maintained almost comparable available P in soil throughout the period of incubation. With increase in levels of P application, there was an increase in amount of release of P from all the RPs, but with the increase in levels of organic acid both Udaipur and Purulia RPs showed increase in the available P but Gafsa RP showed maximum P release at organic acid level of 20 mg kg-1 soil. Data emanated from greenhouse experiments on the performance of RP treatments along with the organic acid loaded NCPC and PSB inoculation showed significant improvement in all the parameters over the absolute control. The yield of wheat grain was higher (6.03 g pot-1) when oxalic acid loaded NCPC (OA-NCPC) was applied to soil compared to citric acid loaded NCPC (CA-NCPC) (5.89 g pot-1) in Alfisol. In Inceptisol also the OA-NCPC proved to be better over CA-NCPC. Significant improvements in yield, P uptake and available P status in both the experimental soils for both the crops were observed with PSB inoculation over uninoculated ones. When direct impact of DAP was compared with that of RP in case of wheat crop, the performance of DAP was observed to be slightly better over the RP treatment. But when the residual impacts were considered in rice crop, the performance of RP was better over DAP. Among the various inorganic P fractions, the calcium P (Ca-P) fraction was most influenced by the RP application and it increased from 114 mg P kg-1 (LP0) to 200 mg P kg-1 (LP100) in Inceptisol, while in Alfisol where Ca-P was the least dominating fraction it increased from 14.6 mg P kg-1 (LP0) to 110 mg P kg-1 (LP100). In general, the iron P (Fe-P) fraction was dominant in case of Alfisol, followed by the reductant soluble P (RS-P) and then the aluminium P (Al-P). In case of Inceptisol, the Ca-P was the major fraction followed by RS-P and Al-P. All the treatments combinations helped to maintain higher saloid-P than that of absolute control and thus would be able to supply P to crop plants and sustain the growth and yield. Among the biological properties the PSB inoculation had strong positive impact on the enzyme activities as well as the microbial biomass P. The higher enzyme activity in the PSB inoculated pots were accompanied by a reduction in the organic P content in the soil. The acid phosphatase activity was higher in Alfisol due to the acidic (pH 5.14) while the alkaline phosphatase activity was higher in Inceptisol due to the neutral pH (7.52). The indigenous RP sources along with organic acid loaded nanoclay polymer composites and inoculation with phosphate solubilizing microorganism acted as a promising P source to crops and could be used as an alternative to the costly P-fertilizers like DAP.

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