International Research Journal of Pure & Applied Chemistry

21(19): 33-39, 2020; Article no.IRJPAC.61926
ISSN: 2231-3443, NLM ID: 101647669

Root Architecture, Yield and Phosphorus Uptake by Rice: Response to Rock Phosphate Enriched Compost and Microbial Inoculants

Kasturikasen Beura[1], Amit Kumar Pradhan[1*], G. K. Ghosh[2], Anshuman Kohli[1] and Mahendra Singh[1]

[1]Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India.
[2]Palli Siksha Bhavana, Visva Bharti, Shantiniketan, West Bengal, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author KB conducted the field study and performed the laboratory analysis. Author AKP conducted statistical analysis and wrote the first draft of the manuscript. Author GKG supervised the entire study and gave technical inputs. Author AK reviewed the scientific literature during formation of the research hypothesis and helped in experimental layout. Author MS coordinated the preparation of enriched compost and provided microbial inoculants for the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2020/v21i1930275
Editor(s):
(1) Dr. Richard Sawadogo, Research Institute for Health Sciences Ouagadougou, Burkina Faso.
Reviewers:
(1) Monier Morad Wahba, National Research Centre, Egypt.
(2) Anil Kumar, Guru Angad Dev Veterinary & Animal Sciences University, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61926

Short Research Article

Received 02 August 2020
Accepted 08 October 2020
Published 30 October 2020

ABSTRACT

There is relatively little information about root architecture response under various cropping systems. This research concerns the influence of rock phosphate enriched compost and microbial inoculants on root morphology and root colonization through Arbuscular Mychorrhizal fungi under rice crop. In this study, we estimated the root length (RL), root biomass (RB), mychorrizal root infection, crop yield and phosphorus uptake in grain and straw. Root samples were collected after harvesting of crop located at Instructional farm of Bihar. Root parameters including root length (18.14 cm) and dry root biomass (0.93 g) were observed to be significantly higher in the treatments inoculated with Arbuscular mycorrhizal fungi over control (statistically at par but numerically higher than 100% RDF) because of the hyphal extensions leading to increased reach and surface area of

---

**Corresponding author: E-mail: amyth_bhu88@rediffmail.com;*

roots in rice crop. Highest uptake of P by the grain and straw of rice (13.78 and 11.03 $kgha^{-1}$) was recorded with the combined application of chemical fertilizers with rock phosphate enriched compost in the presence of microbial inoculants like PSB and AMF.

Keywords: AM fungi; microbial inoculants; root growth; P uptake; yield.

1. INTRODUCTION

Cereals, predominantly rice and wheat, are the primary sources of carbohydrates (energy) for humans in India. Hence, rice-wheat cropping system plays a dominant role in the total agricultural production of the country. Phosphorus (P), an essential plant nutrient required for storage and transfer of energy in the plants, is critical for cereal production systems. The fact that P utilization efficiency is quite low and most of the P fertilisers are imported, calls for identifying alternate sources of phosphorus for crop production. Hence, this study was conducted to prepare and characterize rock phosphate enriched compost as an alternate indigenous source of phosphorus, evaluate the effects of its application in combination with P solubilizers and mobilizers on fractionation of total P in soils, soil microbial activities and P uptake.

P nutrition to the crops can be enhanced by the inclusion of microbial inoculants like plant-growth-promoting rhizobacteria (PGPR) and arbuscular mycorrhizal fungi (AMF). AMF have been widely reported to be able to improve the soil nutritional status along with the growth and development of plants [1]. They also protect the plants against root pathogens and impart drought resistance to crops [1]. AMF characteristically colonize the roots of host plants and facilitate the promotion the plant growth, which may be attributed to the increased uptake of nutrients particularly P thus improving the P nutrition to plants [2,3]. AMF are potentially capable of increasing the plant growth and can be alternatively used to substitute for the functions of some fertilizers mainly due to its role in enhancing nutrient uptake, particularly in low fertility soils [4]. Root colonization with the AMF significantly improves the nutrition of P in the plants grown on soils with majority of P in sparingly soluble forms [5]. AMF synthesize organic compounds like siderophores which help in the desorption of P into labile pools in soil. By producing organic acids, AMF can also solubilize the partially soluble or insoluble sources of P which are a part of the crystalline mineral structure in the soil. Organic exudates like citrates when released into the rhizosphere are effective in increasing the P availability to plants by mobilizing the less soluble Fe and Al phosphates or P fixed in form of insoluble Calcium phosphates [6].

PGPR in soil tend to secrete organic acids having low molecular weight (*esp*. Gluconic acid, fumaric acid and keto-gluconic acid, etc.) which dissolve phosphatic minerals [7] and bring the otherwise insoluble P into the labile pool which in turn contribute to the crop uptake. Certain P solubilizing bacteria like *Pseudomonas striata* can help in solubilizing the native P in soil for availability to the plants. Besides providing P for plant uptake, the phosphate solubilizing microbes also to some extent facilitate the plant growth by enhancing the efficiency of nitrogen fixation, improving the accessibility of other trace essential elements and by synthesizing important growth promoting compounds [8].

A significant progress in evaluating root morphology and distribution has been advocated in recent years. Despite, root research as a whole in response to application of rock phosphate enriched compost and microbial inoculants are limited and still challenging.

Keeping in view the above facts in mind, the investigation was carried out to determine the effects of combined application of rock phosphate enriched compost and microbial inoculants on root morphology and crop yield and uptake in sandy loam (Typic Haplustept) soils of Bihar under rice crop.

2. MATERIALS AND METHODS

Rock phosphate procured from Udaipur, Rajasthan was processed and used for preparation of enriched compost by mixing rice straw, cow dung and rock phosphate with *PSB*. The compost thus prepared was characterized for total macronutrients and cationic micronutrients. The effects of application of enriched compost at rates contributing to the application of phosphorus at the recommended dose of phosphorus *vis-a-vis* that contributing to half of the recommended dose of phosphorus and remaining half through chemical fertilizers, full dose of phosphorus through chemical fertilizers, and through rock phosphate along with an absolute control on P fractionation was studied in an incubation study. Inocula for mycorrhizal species *i.e. Glomus mosseae* and rhizobacteria *viz*., *Burkholderia cepacia* and *Azospirillum brasilense* were procured from biolab of BAU, Sabour.

A field experiment was formulated for the crop rice with 10 treatments (replicated thrice) under Randomized Block Design. The site of study was located at 25º 23' N and 87º 07' E, at an altitude of 37.19 m above MSL in the agricultural research farm of Bihar Agricultural University. The experimental area is prevailed by sub-tropical climatic conditions with hot desiccating summer, cold winter and an annual rainfall of about 1300 mm experienced mostly during mid June-mid October. The month of May is generally the hottest with a maximum temperature of 35-39ºC on an average. The coldest month of the year has been recorded to be January with a minimum temperature between 5-10ºC.

2.1 Root Biomass

To determine the root biomass, three quadrants of 1 × 1 ft were laid down randomly in each plot during the grain filling stage. Metallic cores (10 cm internal diameter and 15 cm height) were used for taking samples for root studies from each treatment. The sample cores were kept in water overnight and then soil was removed from the roots by washing them with a fine jet of water. The roots were collected on fine sieves for fin al washing with a micro jet tap and were dried in oven at 60 ± 5ºC for 48 hours and subsequently their weight was taken to determine the root biomass.

2.2 Root Length

Roots were separated from soil particles carefully by the process of washing and through sieves. After removal of foreign material, the roots were preserved in ethanol (20%). Root length (RL) was measured subsequently by using the line interception method outlined by [9] using the formula:

$$RL = (11/14) \times I \times D$$

Where, I is total numbers of root intercepts with vertical and horizontal grid lines and D is grid square dimensions in cm.

2.3 Root Colonization (%)

Root infection by VAM was estimated in root samples representative of each plot at the time of crop harvest. 15 cm roots were taken from plants uniformly from each plot. Mycorrhizal infection for each plant was estimated in the portion of root segments colonised with mycorrhiza using the method outlined by [10].

$$\%\ \text{Root colonization} = \frac{\text{Number of root segments colonized with AM}}{\text{Total number of root segments taken}} \times 100$$

Table 1. Treatment structure for field experiment

Sl. no.	Treatment details	Notation
1.	Control	Control
2.	100 % RDF	RDF
3.	RPC @ 100% of the RDP dose	R100
4.	RPC @ 100% of the RDP dose + PSB	R100+PSB
5.	RPC @ 100 % of the RDP dose + VAM	R100+VAM
6.	RPC @ 100% of the RDP dose + PSB + VAM	R100+PSB+VAM
7.	50 % RDP + RPC @ 50 % of the RDP dose	RDP50+R50
8.	50 % RDP + RPC @ 50 % of the RDP dose + PSB	RDP50+R50+PSB
9.	50 % RDP + RPC @ 50 % of the RDP dose + VAM	RDP50+R50+VAM
10.	50 % RDP + RPC @ 50 % of the RDP dose + PSB + VAM	RDP50+R50+PSB+VAM

RDF- Recommended dose of fertilizers (N:P:K=120:60:40) through Urea, Diammonium Phosphate and Muriate of Potash; RPC- Rock Phosphate enriched compost (Composition: 1.27% N; 2.65% P and 1.18% K); RDP- Recommended dose of Phosphorus; PSB- Phosphorus solubilizing bacteria (@ 20.0 g kg^{-1} seed); VAM- Vescicular Arbuscular Mycorrhiza (@10 kg/ha inoculums/ha)

2.4 Nutrient Uptake

Calculation of nutrient uptake was done by multiplying the concentration of a particular nutrient with grain and straw yields.

Straw uptake (kg ha^{-1}) = (Straw nutrient content (%) x Straw yield (q ha^{-1})).

Grain uptake (kg ha^{-1}) = (Grain nutrient content (%) x Grain yield (q ha^{-1})).

2.5 Statistical Analysis

The data obtained after conduction of incubation study and field experimentation were subject to analysis for ANOVA by using SPSS 16.0 statistical software (SPSS Inc.) to determine the effects of various treatments. The difference in the effect of various treatments is also explained using the multiple comparisons of means as per Duncan's Multiple Range Test. Critical difference at 5% level of significance was used to differentiate among treatment means. Pearson correlation coefficients and P-values were calculated for all possible variable pairs by appropriate statistical computations to judge the relationship of various treatments and fractions with the productivity of the crops and their nutrient uptake. The asterisks * and ** indicate significance at $p<0.05$ and 0.01, respectively.

3. RESULTS AND DISCUSSION

3.1 Root Colonization by VAM

Mycorrhiza is formed by the development of a symbiotic relationship between certain groups of soil fungi and root systems of most of the plants [11]. Mychorrhizal root colonization changed significantly ($P < 0.05$) under the application of various P sources and microbial inoculants. The maximum root colonization of 54.95% was recorded under RDP50+R50+PSB+VAM which was 18.96% and 13.86% higher compared to control (45.57%) and 100% RDF (45.24%) treatment respectively after rice harvest. AM root colonization was increased numerically at harvesting stage when compared with application of 100% RDF and control. At harvesting stage the root colonization did not differ significantly among all the treatments. Mycorrhizal fungi differ in their ability to infect and colonize roots [12]. The higher mycorrhizal colonization in absolute control could be due to the competitive ability of the mycorrhiza even in nutrient stress condition by host plant roots. Mychorrizal infection was also found to be higher under treatments containing VAM as a constituent. Similar findings were also observed in the study conducted by [12].

3.2 Root Length and Biomass

Root biomass (dry) of rice was observed to be significantly affected by the combined application of chemical fertilizer, rock phosphate enriched compost along with microbial inoculants. The maximum root biomass (dry) of 0.93 g was recorded under RDP50+R50+PSB+VAM treatment, which was significantly higher than control (0.58 g) and statistically at par with all other treatments although numerical increments were observed in comparison to 100% RDF and RPC @100% RDP. The root biomass was 60.34% and 14.8% higher in RDP50+R50+PSB+VAM treatment compared to control and RDF treatment, respectively. Significant variation in root length was observed within the treatment structure where T10 *i.e.* RDP50+R50+PSB+VAM showed 18.14 cm of root length closely followed by T9 (RDP50+R50+VAM) with value of 17.95 cm. Root length of plants under all other treatments were significantly lower with control treatment having the lowest (8.72 cm).

Significant variation in root length was observed within the treatment structure where T10 *i.e.* RDP50+R50+PSB+VAM showed 19.85 cm of root length closely followed by T9 (RDP50+R50+VAM) with value of 19.18 cm. Root length of plants under all other treatments were significantly lower with control treatment having the lowest (9.12 cm).

3.3 Yield and P Uptake

The increase in yield of rice may be linked with the increased solubilization and mobilization of P owing to the co-inoculation of PSB and mycorrhiza. The increased solubility of P in soil also enhanced P uptake and its subsequent translocation in the plant. Inoculation of mycorrhiza increased the mobilization of otherwise unavailable P by increasing the absorbing surface of the roots thus leading to a vigorous growth of plants.

Data presented in Table 2 depicts the effect of combined application of rock phosphate enriched compost and a chemical fertilizer which was found to have led to a higher straw and grain yield over 100% RDF in rice. The treatment

Table 2. Initial chemical status of experimental soil

Parameter	pH	Electrical conductivity (dSm^{-1})	Oxidisable organic carbon (%)	Mineralizable N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	DTPA-Fe (mg kg^{-1})	DTPA-Mn (mg kg^{-1})	DTPA-Cu (mg kg^{-1})	DTPA-Zn (mg kg^{-1})
Value	7.69	0.118	0.56	171.92	15.97	218.71	11.24	8.36	0.56	0.64

Table 3. Effect of different treatment combinations including fertilizers, enriched compost, phosphate mobilizers and solubilizers on the root characteristics of rice

Treatment	VAM infection (%)	Root length (cm)	Root biomass
Control	45.57c	8.72e	0.58b
RDF	45.24c	14.21d	0.81a
R100	47.82bc	15.02c	0.89a
R100+PSB	48.40bc	15.21bcd	0.89a
R100+VAM	51.87ab	17.39abc	0.90a
R100+PSB+VAM	51.97ab	17.53b	0.90a
RDP50+R50	45.79c	15.45bcd	0.92a
RDP50+R50+PSB	49.54abc	15.69abcd	0.92a
RDP50+R50+VAM	54.31a	17.95a	0.93a
RDP50+R50+PSB+VAM	54.95a	18.14a	0.93a
SE_m(±)	1.89	3.49	0.087
C.D. (p=0.05)	5.66	10.44	NS

**Values followed by the same letter represent the absence of any statistically significant difference*

Table 4. Effect of treatments on the yield and P uptake in rice

Treatment	Grain yield (q/ha)	Grain P uptake (kgha^{-1})	Straw yield (q/ha)	Straw P uptake(kgha^{-1})
Control	28.03b	5.64c	39.25b	4.88c
RDF	42.00a	11.27ab	58.80a	9.26ab
R100	39.33a	10.13b	55.07a	6.73bc
R100+PSB	42.67a	10.56b	59.73a	7.88abc
R100+VAM	43.00a	10.56b	60.20a	8.03abc
R100+PSB+VAM	44.00a	10.75b	61.60a	8.34abc
RDP50+R50	43.33a	11.28ab	60.67a	8.56abc
RDP50+R50+PSB	45.00a	11.83ab	63.00a	9.56ab
RDP50+R50+VAM	45.00a	11.85ab	63.00a	9.46ab
RDP50+R50+PSB+VAM	48.67a	13.78a	68.13a	11.03a
$SE_m(\pm)$	3.048	0.811	4.27	0.91
C.D. (p=0.05)	9.126	2.43	12.78	2.74

**Values followed by the same letter represent the absence of any statistically significant difference*

containing integrated use of chemical fertilizers, RPC and microbial inoculants registered highest grain and straw yield (48.67 and 68.13 q/ha) which was statistically significant over control (28.03 q/ha) but was numerically higher from that of 100% RDF treatment (42.00 and 58.80 q/ha).

Similar results were reported by [13] who observed the highest grain and straw yield when rock phosphate was combined with the inoculation of PSB. Increased amount of P uptake resulted in characteristic improvement in leaf photosynthetic rate, biomass production and grain formation which in turn increases the grain yield of the crops.

Data pertaining to phosphorus uptake by grain and straw of rice are also presented in Table 2. The highest phosphorus uptake (13.78 and 11.03 kg ha^{-1}) was noticed with combined application of rock phosphate enriched compost and chemical fertilizers which was statistically at par with 100% RDF treatment (11.27 and 9.26 kg ha^{-1}) after rice harvest. Both are statistically superior over absolute control. The uptake of phosphorus by rice grain was higher than straw. This might be due to the enhanced mobilization of phosphorus from plant parts to grain.

These results were in accordance with the results obtained by [14] who found that combined application of PSB with chemical sources of P increased plant P uptake resulting in higher plant biomass, grain and straw yield.

Roy et al. [15] also reported that organic fertilizers are helpful for the soil health and the application of P with phosphate solubilizing microbes produce crop yields which were statistically at par to that of inorganic fertilizers. The results of this study were in accordance with the results of previous studies conducted by [16,17].

With the application of RPC and PSB, greater P contents were observed in straw and grain samples which may be attributed to the pronounced activity of PSB, improved root growth and/or better solubilization of P in rock phosphate during the composting process. [18] also found that the addition of organic inputs increases the dissolution of rock phosphate by complexing Ca^{2+} ions in the soil solution and finally increases the available P for the crop plants grown in calcareous soils.

4. CONCLUSION

After perusal of the results obtained from the above study it can be concluded that in combination with co-inoculated mycorrhiza and potential phosphorus solubilizing rhizobacteria proved to be an effective alternative for chemical fertilizers due to the beneficial effects obtained for positive impact on the root characteristics leading to a statistically significant improvement in root length and biomass due to higher colonization and root surface expansion. The grain yield, P uptake and P use efficiency was significantly enhanced by the integrated use of chemical fertilizers with RPC in the presence of AM fungi and P solubilizing bacteria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kumar A, Choudhary AK, Suri VK. Influence of AM–fungi and applied phosphorus on growth indices, production efficiency, phosphorus–use efficiency and fruit–succulence in okra (*Abelmoschus esculentus*)–pea (*Pisum sativum*) cropping system in an acid Alfisol. Indian J. Agric. Sci. 2015;85(8):1030-1037.
2. Hirata H, Masunaga T, Koiwa H. Response of chickpea grown on ando-soil to vesicular-arbuscular mycorrhizal infection in relation to the level of phosphorus application. Soil Science and Plant Nutrition. 1988;34:441–449.
3. Smith SE, Read DJ. Mycorrhizal symbiosis. 3rd Edition. Academic Press Ltd., London; 2008.
4. Cooper K, Grandison GS. Interaction of vesicular-arbuscular mycorrhizal fungi and root knot nematode on cultivars of tomato and white clover susceptible to *Meloidogyne hapla*. Annals of Applied Biology. 1986;108:555–565.
5. Shenoy VV, Kalagudi GM. Enhancing plant phosphorus use efficiency for sustainable cropping. Biotechnol. Adv. 2005;23:501–513.
6. Hinsinger P. Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: A review. Plant and Soil. 2001;237:173-195.
7. He ZL, Bian W, Zhu J. Screening and identification of microorganisms capable of utilizing phosphate adsorbed by goethite. Commun. Soil Sci. Plant Anal. 2002;33:647-663.
8. Mittal V, Singh O, Nayyar H, Kaur J, Tewari R. Stimulatory effect of phosphate-solubilizing fungal strains (*Aspergillus awamori* and *Penicillium citrinum*) on the yield of chickpea (*Cicer arietinum* L. cv. GPF2). Soil Biol. Biochem. 2008;40:718–727.
9. Tennant D. A test of modified line intersects method of estimating root length. Journal of Ecology. 1975;63:995-1101.
10. Biermann B, Linderman RG. Quantifying vesicular-arbuscular mycorrhizae: A proposed method towards standardization. New Phytologist. 1981;87:63-67.
11. Hata S, Kobae Y, Banba M. Interactions between plants and arbuscular mycorrhizal fungi. Int Rev. Cell Mol. Biol. 2010;281:1–48.
12. Singh M, Rakshit R, Beura K, Lal M. Field evaluation of arbuscular mycorrhizal fungi (AMF) for microbial activities and yield of maize under alluvial. J. Appl. Nat. Sci. 2016;8(4):2055-2059.
13. Sharma S, Prasad R, Shivay Y, Dwivedi M, Kumar S, Kumar D. Effect of rates and sources of phosphorus on productivity and economics of rice (*Oryza sativa*) as influenced by crop-residue incorporation. Indian J. of Agron. 2009;54:42-46.
14. Panhwar Q, Othman RA, Rahman Z, Meon S, Razi I, Naher U. Contribution of phosphate-solubilizing bacteria in phosphorus bioavailability and growth enhancement of aerobic rice. Spanish J. Agric. Res. 2011;9:810-820.
15. Roy SK, Sharma RC, Trehan SP. Integrated nutrient management by using farmyard manure and fertilizers in potato-sunflower–paddy rice rotation in the Punjab. J. Agric. Sci. 2001;37:271-278.
16. Nevens F, Reheul D. The application of vegetable, fruit and garden waste (VFG) compost in addition to cattle slurry in a silage maize monoculture: Nitrogen availability and use. Eur. J. Agron. 2003;19:189–203.
17. Verma P, Yadav AN, Kazy SK, Saxena AK, Suman A. Elucidating the diversity and plant growth promoting attributes of wheat (*Triticum aestivum*) associated acido-tolerant bacteria from Southern Hills Zone of India. Natl. J. Life Sci. 2013;10:219-226.
18. Sanyal SK, De Datta SK. Chemistry of phosphorus transformations in soil. Adv. Soil Sci. 1991;16:1-12.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/61926