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Effect of Phosphorus Management on Yield of Direct Sown Rice

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ABSTRACT

An experiment was conducted to study the "Phosphorus management in direct sown rice in sandy clay soil" at Agricultural College Farm, Bapatla during *kharif*, 2018. The experimental soil was sandy clay in texture, neutral in reaction and non-saline. There was a significant improvement in the yield attributes, grain and straw yield of direct sown rice with application of 100% RDP + Vesicular Arbuscular Mycorrhiza (T_4). Application of phosphorus along with bio fertilizers showed significant influence on microbial population. Enzymatic activities like dehydrogenase and urease activity at tillering, panicle initiation and at harvest was not significantly influenced by the treatments while acid and alkaline phosphatase activity at tillering, panicle initiation and at harvest was significantly influenced by treatment which received 100% RDP + Vesicular Arbuscular Mycorrhiza (T_4) and it was on par with T_3.The increased activity of phosphates enzyme in soil might be due to increased solubilization and mobilization of soil through the activity of phosphatase enzyme which was increased when PSB and AMF were used.

Key words:*Phosphorus, PSB, VAM, Yield*

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Rice (*Oryza sativa* L.) is the principal food crop for the world billions of people. It plays a vital role in our national food security. Rice stands second in the world after wheat in area and production. About 90 per cent of rice grown in the world is produced and consumed in Asian countries, China and India accounting for more than half of the world's acreage. Direct seeding of rice refers to the process of establishing the crop from seeds sown in the field rather than by transplanting seedlings from the nursery (Farooq*et al*., 2011). Direct seeding avoids three basic operations viz., puddling, transplanting and maintaining standing water. Under present situation of water and labour scarcity, several farmers are shifting to direct sown rice.

The availability of phosphorus in soil is a major concern under direct seeded upland fields where it is deficient and is a major factor contributing to low yield of rice. Phosphorus deficiency is more common in dry seeded rice because of more fixation and decreased mobility in the soil. The poor phosphorus acquisition is a major constraint, and therefore use efficiency of phosphorus is very low (15-20 %). However, phosphorus efficiency can be improved by enhancing internal utilisation efficiency with the use of microbial inoculants.

Phosphate solubilizing microorganisms are more effective in mineralizing the organic phosphates in soil and increase the phosphorus availability by lowering soil pH and producing organic acids like indole acetic acid, gibberellic acid which helped in better crop growth and resulting in higher yield (Awasthi*et al*., 2011). A number of mechanisms involving organic acids (solubilization) and enzyme production (mineralization), the release of H^+, chelation, and respiratory H_2CO_3 production are the documented evidence for P transformation in soils (Khan *et al*.,2010).

Phosphate solubilizing microorganisms are more effective in mineralizing the organic phosphates in soil and increase the phosphorus availability by lowering soil pH and producing organic acids (Awasthi *et al*., 2011). They are also known to produce amino acids, vitamins and growth promoting substances like indole acetic acid, gibberellic acid which helped in better crop growth and resulting in higher yield.

MATERIAL AND METHODS

A field experiment was conducted during *kharif season* of 2018 at the Agricultural college farmBapatla in randomized block design with three replications. The soil was sandy clay in texture,neutral in reaction (pH 7.5),non-saline in nature, low in organic carbon (4.3 g kg^{-1}), available nitrogen (246.00 kg ha^{-1}) and available P_2O_5 (27.00 kg ha^{-1}), high in available potassium (505.00 kg ha^{-1}) and sufficient in all available divalent cationic micronutrients (Zn, Fe. Mn and Cu).The experiment was laid out in RBD with eight treatments replicated thrice. The treatments comprised of T_1- (NO P), T_2 - 100% Recommended Dose of Phosphorus (RDP), T_3 - 100% RDP +Phosphorus Solubilising Bacteria (PSB), T_4 - 100% RDP + Vesicular ArbuscularMycorrhiza (VAM),T_5 - 75% RDP + PSB, T_6 -75% RDP + VAM, T_7 - 50% RDP + PSB, T_8 -50% RDP + VAM.The rice varietyBPT 5204 was sown on 9^{th} August, 2018and was harvested on 8^{th}January, 2019.

Well decomposed farmyard manure @ 5 t $ha^{-1}$was applied to the field as per recommended dose one week before sowing. A common dose of nitrogen @ 180 kg ha^{-1} was applied in the form of urea in three equal splits *i.e.* 1/3 as basal, 1/3 at active tillering and 1/3 at panicle initiation stage. Phosphorus in the form of single super phosphate was applied as per the treatments as basal just before sowing. A common dose of 40 kg K_2O ha^{-1} was applied as muriate of potash, in two equal splits as half at basal and half at panicle initiation stage by taking the plot size into consideration. Biofertilizers (PSB, VAM) were mixed separately with FYM and kept in shade for 3 days and then by ensuring the presence of optimum soil moisture, FYM mixed biofertilizers*viz.*, PSB@ 5 kg ha^{-1} and VAM@ 12.5 kg ha^{-1} were applied at 3 DAS separately.

RESULTS AND DISCUSSION

Plant Height

At tillering, panicle initiation and at harvest stages of crop growth, the maximum plant height of 96.63, 113.78 and 116.82 cm was recorded in the treatment T_4 (100% RDP + Vesicular Arbuscular Mycorrhiza) (VAM) followed by T_3 (100% RDP +Phosphorus Solubilising Bacteria) (PSB) with 94.27 , 110.85 and 111.65 cm respectively. The minimum plant height (70.08, 80.85 and 86.32 cm) was recorded in treatment T_1 (NO P) where, no phosphorus and biofertilizers were applied (Table 1).Phosphorus being constituent of nucleic acid, phytin and phospholipids when supplied in adequate amounts are expected to favour the production of protein to the maximum extent resulting in vigorous plant growth. Thus, plants supplied with adequate amount of phosphorus produced more leaves and greater accumulation of photosynthates, resulting more height. Effect of phosphorus application on plant height might be due to that phosphorus is an important essential macronutrient required for the biosynthesis of energetic compound (ATP, NADP) which supplies the plant by energy required for cell division and elongation of rice organ (Metwally*et al*. (2012).Enhanced availability of phosphorus and its active involvement in shoot and root growth lead to taller plants and similarly enhanced water absorption and nutrient uptake from the soil (Hussain*et al*. 2013, Kato *et al*., 2006). This might be one of the reasons behind higher growth of rice plants due to P fertilization.Innoculation of phosphate solubilizing bacteria (PSB) produce several organic acids (butyric acid, citric acid, fumaric acid, succinic acid, and propionic acid) and converted insoluble form of phosphorus into soluble forms and made them available to plants which resulted in increased plant height and dry matter production.

Drymatter production

Drymatter production ranged from 2073 to 2785, 4577 to 5693 and 8607 to 10773 kg ha^{-1} at tillering, panicle initiation and harvest stages, respectively among different treatments of RDP and P biofertilizers (Table 1). Significantly the highest dry matter production of 2785, 5693 and 10773 kg ha^{-1} was recorded with the application of 100% RDP + Vesicular ArbuscularMycorrhiza (VAM) (T_4), which was on par with $T_3$100% RDP +Phosphorus Solubilising Bacteria (PSB) and $T_2$100% Recommended Dose of Phosphorus (RDP) at tillering, panicle initiation and harvest stages, respectively.

Application of 100% RDP produced significantly higher dry matter production than lower phosphorus levels at all stages. Crop plants supplied with adequate quantity of phosphorus resulted greater accumulation of photosynthates which accounted for higher dry matter production which might be due to increased nitrogen availability which was responsible for profusedtillering and plant height and hence, the higher drymatter accumulated (Stalin *et al.*, 1999 & Dwivedi *et al.*, 2006).

Inoculation of microbial cultures like PSB or VAM showed the beneficial effect on P release and significantly enhanced plant growth and yield attributes of aerobic rice as compared to non-inoculated treatments. Enhanced amount of soluble P in the soil solution and increased plant biomass proved that application of microbial inoculants along with phosphate had a positive effect on plant growth parameters and yield attributes.This was mainly due to higher synthesis and translocation ofphotosynthates which resulted in higher dry matter accumulation (Mahajan*et al*., 2017).

Grain Yield

The highest grain yield (4144 kg ha^{-1}) was recorded with T_4 (100% RDP + Vesicular ArbuscularMycorrhiza (VAM), which was on par with $T_3$100% RDP +Phosphorus Solubilising Bacteria (PSB) and $T_2$100% Recommended dose of phosphorus (RDP) (Table 1). The lowest grain yield (2999 kg ha^{-1}) was recorded with T_1 (NO P) where, no phosphorus was applied.The increase in grain yield might have been due to increase in P concentration and drymatter production. It might be due to phosphorus application which is directly related to the vegetative and reproductive phases of the crop and attributes complex phenomenon of phosphorus utilization in plant metabolism. It also helped in the efficient absorption and utilization of the other required plant nutrients which ultimately increased the grain yield. These findings are confirmed with Girma *et al*., (2006) and Parvez *et al*., (2009).

The action of P biofertilizers like PSB helped in enhancing productivity by releasing plant available P through the production of plant growth promoting and biologically active substances like indole acetic acid, gibberllins and cytokinin (Mahanta, 2008). Similarly, VAM is widely recognized to improve plant acquisition of P by enhancing translocation and transfer of phosphate ions from the soil solution to the root cells and finally the uptake (Yan *et al*., 2004). The compatibility of P and VAM can be attributed to the fact that the vesicular arbuscularmycorrhizamight have increased the surface area of absorption through hyphae, thus availability of nutrients from inaccessible areas. VAM increase P uptake by more through exploration of soil volume thereby making positionally unavailable nutrients available. This is achieved by decreasing the distance for diffusion of phosphate ions by increasing the surface area for absorption (Tinker,1980). This might be due to the release of citric, malonic, malic and succinic acids trough roots, which can solubilize P from soil (Singh*et al*.,2001) and provided higher soil available P to the crop. The application of PSB or VAM biofertilizer along with P source like SSP increased the grain yield which could be due to increased availability of P and suitably matched the requirement of P by crop.

Straw Yield

The highest straw yield (6210 kg ha^{-1}) was recorded with T_4 (100% RDP + Vesicular ArbuscularMycorrhiza (VAM), which was on par with T_3 100% RDP +Phosphorus solubilising bacteria (PSB) and T_2 100% Recommended dose of phosphorus (RDP). The lowest grain yield (4819 kg ha^{-1}) was recorded with T_1 (NO P) where, no phosphorus was applied. Increased straw yield might be due to higher photosynthetic activity because of increased leaf area index, which ultimately promoted dry matter production resulting higher yield. Quyen and Sharma (2003) also reported similar results. The increase in yield might be due to the improvement in leaf photosynthetic rate, biomass production and sink formation, which promoted the grain and straw yields of aerobic rice. Besides P solubilization activity, PSB liberates phytohormone (IAA) that might have an influence on root growth and yield. The extensive root system increased nutrient uptake from the surroundings which boosted plant biomass and subsequently the yield of aerobic rice. These results were alike with the findings of Panhwar *et al*. (2011).

The increased grain and stover yield could be attributed to build up of population of phosphate solubilizing and mobilizing microorganism in rhizosphere due to inoculation which increased the availability of phosphorus to plant through solubilization effect and translocation of nutrient through network of hyphae in soil absorbs P from nonrhizospheric zone and transport to plant roots (Hilda and Fraga, 1999).

Test weight

It was revealed from the data presented in the table 1 that thousand grain weight was not differing significantly among the treatments at any stages of crop growth. The highest thousand grain weight (18.67 g) was recorded with T_4 (100% RDP + Vesicular Arbuscular Mycorrhiza) (VAM). While, the lowest thousand grain weight (17.60 g) was recorded with T_1 (NO P) where no phosphorus and biofertilizers were applied. The thousand grain weight of direct sown rice was not significantly influenced by different levels of phosphorus and biofertilizers. Among the phosphorus levels, 100 % RDP recorded heavier seed weight numerically than other treatments which might be due to increased translocation of photosynthates from source to sink. Such an increase in 1000 grain weight with the application of phosphorus was reported Sharma *et al*. (2009) and Lungmuana*et al*. (2016).

MICROBIAL ACTIVITY

Bacterial

At tillering, panicle initiation and harvest stage of direct sown rice, the highest bacterial population (56×10^7, 68×10^7 and 45×10^7cfu g^{-1} soil) was observed in T_3(100% RDP + Phosphorus Solubilising Bacteria (PSB) which was on par with T_4(53×10^7, 64×10^7 and 42×10^7cfu g^{-1} soil) with 100% RDP + Vesicular Arbuscular Mycorrhiza (VAM), whereas the

Table 1. Influence of phosphorus management on yield and yield parameters of direct sown rice

Treatments	Plant height (cm)			Dry matter production (kg ha^{-1})			Yield (kg ha^{-1})		1000 grain weight (g)
	Tillering	Panicle initiation	Harvest	Tillering	Panicle initiation	Harvest	Grain	Straw	
T_1: (NO P)	70.08	80.85	86.32	2073	4577	8607	2999	4819	17.6
T_2: 100% Recommended Dose of Phosphorus (RDP)	93.92	107.12	109.74	2686	5567	10126	3964	6143	18.62
T_3: 100% RDP +Phosphorus Solubilising Bacteria (PSB)	94.27	110.85	111.65	2714	5678	10340	4083	6203	18.65
T_4: 100% RDP + Vesicular ArbuscularMycorrhiza (VAM)	96.63	113.78	116.82	2785	5693	10773	4144	6210	18.67
T_5: 75% RDP + PSB	86.23	98.42	100.43	2586	5263	9694	3656	5841	18.33
T_6: 75% RDP + VAM	87.52	100.11	103.26	2593	5289	9992	3692	5860	18.45
T_7: 50% RDP + PSB	81.45	93.62	96.57	2342	5033	9244	3412	5458	17.97
T_8: 50% RDP + VAM	83.56	95.52	98.11	2403	5060	9273	3450	5495	18.07
S.Em (±)	3.34	4.06	3.32	81.58	170.01	283.56	130.53	209.08	0.58
CD (0.05%)	10.15	12.33	10.07	247.44	515.67	860.08	395.91	634.19	NS
C.V (%)	6.68	7.04	5.59	5.6	5.59	5.03	6.15	6.29	5.51

Table 2. Effect of phosphorus management on bacteria, fungi, actinomycetes population of soil under direct sown rice

Treatment	Bacterial population ($\times 10^7$ CFU g^{-1} soil)			Fungi ($\times 10^4$ CFU g^{-1} soil)			Actinomycetes ($\times 10^5$ CFU g^{-1} soil)		
	Tillering	Panicle initiation	Harvest	Tillering	Panicle initiation	Harvest	Tillering	Panicle initiation	Harvest
T_1: (NO P)	32	41	28	17	27	20	20	31	28
T_2: 100% Recommended Dose of Phosphorus (RDP)	51	61	38	28	39	32	28	41	38
T_3: 100% RDP +Phosphorus Solubilising Bacteria (PSB)	56	68	45	30	40	31	32	43	41
T_4: 100% RDP + Vesicular Arbuscular Mycorrhiza (VAM)	53	64	42	31	41	34	30	42	40
T_5: 75% RDP + PSB	46	58	36	24	37	29	27	39	35
T_6: 75% RDP + VAM	44	56	34	26	38	30	26	37	34
T_7: 50% RDP + PSB	42	53	32	20	32	24	24	35	31
T_8: 50% RDP + VAM	41	50	30	22	33	25	22	34	30
S.Em(±)	1.65	2.42	1.52	1.52	1.69	2.09	1.36	1.96	2.04
CD (P=0.05 %)	5.01	7.35	4.61	4.6	5.81	6.73	4.11	5.95	6.19
C.V (%)	6.27	7.44	7.39	10.62	9.25	13.66	8.99	9.01	10.21

Table 3. Effect of phosphorus management on Dehydrogenase, Urease, Acid Phosphatase and Alkaline Phosphatase activity of soil under direct sown rice

Treatment	Dehydrogenase (µg TPF $g^{-1} day^{-1}$)			Urease (µg NH_4^+ g^{-1} $2hrs^{-1}$)			Acid Phosphatase (µg PNP g^{-1} hr^{-1})			Alkaline Phosphatase (µg PNP g^{-1} hr^{-1})		
	Tillering	Panicle initiation	Harvest	Tillering	Panicle initiation	Harvest	Tillering	Panicle initiation	Harvest	Tillering	Panicle initiation	Harvest
T_1: (NO P)	8.9	8.2	6.95	27.92	32.78	24.45	47.32	38.12	36.63	58.51	49.66	38.46
T_2: 100% Recommended Dose of Phosphorus (RDP)	12.4	11.5	9.7	30.56	36.41	29.45	68.21	56.03	48.11	76.86	68.11	55.86
T_3: 100% RDP +Phosphorus Solubilising Bacteria (PSB)	12.8	11.7	9.95	31.91	36.82	29.91	68.81	56.22	48.83	77.03	68.46	56.02
T_4: 100% RDP + Vesicular Arbuscular Mycorrhiza	13.3	11.75	10.2	32.2	37.31	30.25	68.95	56.53	48.98	77.13	68.94	56.86
T_5: 75% RDP + PSB	11.2	9.83	8.3	30.21	35.18	28.2	62.12	51.81	45.02	71.16	62.23	52.24
T_6: 75% RDP + VAM	11.35	10.13	8.6	30.45	35.38	28.72	62.45	51.98	45.85	71.94	62.76	52.78
T_7: 50% RDP + PSB	10.7	9.2	7.8	29.71	34.68	27.63	58.21	45.41	41.12	69.06	57.12	45.33
T_8: 50% RDP + VAM	10.9	9.45	8.05	29.87	35.25	27.83	58.93	45.82	41.45	69.59	57.49	45.87
S.Em(±)	0.85	0.8	0.72	1.46	2.05	1.22	2.44	2.28	1.89	2.46	2.49	1.95
CD (P=0.05 %)	NS	NS	NS	NS	NS	NS	7.43	6.94	5.75	7.47	7.57	5.91
C.V (%)	13	13.58	14.33	8.36	10.05	7.49	6.85	7.89	7.38	5.97	6.99	6.69

lowest bacterial population (32×10^7, 41×10^7 and 28×10^7cfu g^{-1} soil) was observed in T_1 (NO P). Phosphorus-solubilizers significantly improved the bacterial population.

Fungal

At tillering, panicle initiation and harvest stage the highest fungal population (31×10^4, 41×10^4 and 34×10^4cfu g^{-1} soil) was observed in T_4(100% RDP + Vesicular Arbuscular Mycorrhiza (VAM) followed by T_3 (30×10^4, 40×10^4 and 32×10^4cfu g^{-1} soil) with 100% RDP + Phosphorus Solubilising Bacteria (PSB) whereas the lowest fungal population (17×10^4, 27×10^4 and 20×10^4cfu g^{-1} soil) was observed in T_1 (NO P).

Actinomycetes

At tillering, panicle initiation and harvest stage, the highest actinomycetes population (32×10^5,43×10^5 and 41×10^5cfu g^{-1} soil) was observed in T_3(100% RDP + Phosphorus Solubilising Bacteria (PSB) followed by T_4(30×10^5,42×10^5 and 40×10^5cfu g^{-1} soil) with 100% RDP + Vesicular Arbuscular Mycorrhiza (VAM) whereas the lowest actinomycetes population (20×10^5,31×10^5 and 28×10^5cfu g^{-1} soil) was observed in T_1 (NO P).

ENZYMATIC ACTIVITY

Dehydrogenase

At tillering, panicle initiation and harvest stage, the highest dehydrogenase activity (13.30, 11.75 and 10.20 µg g^{-1} 24 h^{-1}) was observed in T_4 (100% RDP + Vesicular Arbuscular Mycorrhiza (VAM) followed by T_3 (12.80, 11.70 and 9.95 µg TPF g^{-1} 24 h^{-1}) with 100% RDP +Phosphorus Solubilising Bacteria (PSB) whereas the lowest dehydrogenase activity (8.90, 8.20 and 6.95 µg TPF g^{-1} 24 h^{-1}) was observed in T_1 (NO P).

Ureas

At tillering, panicle initiation and harvest stage the highest urease activity (32.20, 37.31 and 30.25 µg NH_4 + - N g^{-1} soil h^{-1}) was observed in T_4(100% RDP + Vesicular Arbuscular Mycorrhiza (VAM) followed by T_3 (31.91, 36.82 and 29.91 µg NH_4 + - N g^{-1} soil h^{-1}) with 100% RDP +Phosphorus Solubilising Bacteria (PSB) whereas the lowest urease activity (27.92, 32.78 and 24.45 µg NH_4 + - N g^{-1} soil h^{-1}) was observed in T_1 (NO P).

Acid phosphatase

At tillering, panicle initiation and harvest stagesignificantly increased acid phosphatase activity (68.95, 56.53 and 48.98 µg PNP g^{-1} hr^{-1}) was observed in T_4(100% RDP + Vesicular Arbuscular Mycorrhiza (VAM) followed by T_3 (68.81, 56.22 and 48.83µg PNP g^{-1} hr^{-1}) with 100% RDP + Phosphorus Solubilising Bacteria (PSB) whereas the lowest acid phosphatase activity (47.32, 38.12 and 36.63µg PNP g^{-1} hr^{-1}) was observed in T_1(NO P).

Alkaline phosphatase

At tillering, panicle initiation and harvest stage significantly increased alkaline phosphatase activity (77.13, 68.94 and 56.86 µg PNP g^{-1} hr^{-1})was observed in T_4(100% RDP + Vesicular Arbuscular Mycorrhiza (VAM) followed by T_3(77.03, 68.46 and 56.02µg PNP g^{-1} hr^{-1}) with 100% RDP +Phosphorus Solubilising Bacteria (PSB) whereas the lowest alkaline phosphatase activity (58.51, 49.66 and 38.46 µg PNP g^{-1} hr^{-1}) was observed in T_1(NO P).

CONCLUSION

It can concluding that there was a significant improvement in the yield attributes,such as grain and straw yield of direct sown rice with application of recommended dose of phosphorus along with either vesicular arbuscular mycorrhiza or phosphorus solubilizing bacteria.

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