

Original Research Article

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Influence of PGPR and Zinc Enriched FYM on Growth and Yield of Rice at Different Levels of Phosphors in an Inceptisol of Varanasi, India

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ABSTRACT

Field experiments were carried out during *Kharif* seasons of 2013-14 and 2014-15 at the Agricultural Research Farm, Banaras Hindu University, Varanasi (U.P.) to study the effect of PGPR and Zinc enriched FYM on yield and growth attributes of rice at different levels of phosphors in an Inceptisol of Varanasi. The treatments consisted five levels of enriched FYM (M_0 = No FYM, M_1 = only FYM, M_2 = PGPR enriched FYM, M_3 = PGPR and Zn @ 2.5 kg ha⁻¹ enriched FYM and M_4 = PGPR and Zn @ 5.0 kg ha⁻¹ enriched FYM) and four levels of phosphors (0, 20, 40 and 60 kg P₂O₅ ha⁻¹). The experiment was replicated thrice in a Randomized block design in Factorial experiment. The results showed that, the application of PGPR and Zinc enriched FYM was significantly increased the yield and growth attributes of rice. All the growth and yield attributes showed that treatment M_4 was found significantly highest over all the treatments but it was at par with treatment M_3 except plant height. As regards the 4 levels of phosphors (0, 20, 40 and 60 kg P₂O₅ ha⁻¹), an application of 60 kg P₂O₅ gave the significant highest result over the control and all other treatments for yield and growth attributes of rice except chlorophyll content. Interactive effects of enriched FYM and phosphorus levels were found significant on plant height, grain yield, straw yield and biological yield. Application of PGPR and Zn @ 5.0 kg ha⁻¹ enriched FYM along with 60 kg P₂O₅ ha⁻¹ resulted in markedly higher plant height (109.07 cm), grain yield (59.62 q ha⁻¹), straw yield (79.94 q ha⁻¹) and biological yield (139.56 q ha⁻¹) but showed at par result with PGPR and Zn @ 2.5 kg ha⁻¹ enriched FYM applied in conjunction with 40 kg P₂O₅ ha⁻¹. The aim of this experiment was to minimize excess use of fertilizers for optimum yield and quality of rice without harming soil and environment health by the application of PGPR and Zinc enriched FYM.

Keywords

PGPR and Zinc enriched FYM, Phosphorus, Rice Yield and growth attributes.

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Introduction

Rice (*Oryza sativa* L.) crop is a principal source of staple food for more than half of the world population and hence becomes a main source of Zinc to human (Fitzgerald *et al.*, 2009). This crop is an important energy source of more than half of the world and 65% of the Indian population (Liu *et al.*, 2008). It is an important crop in India which

occupied 43.40 million hectare area with the production of 157.20 million tonnes and have 3.62 t ha⁻¹ productivity which is less than world's average productivity (4.52 t ha⁻¹) (FAO, 2014). To meet the future food requirements of ever increasing population and maintain self sufficiency, the estimated rice production in India is targeted at 350

million tonnes by 2020 AD (Veeraputhiran and Balasubramanian, 2013).

Phosphorous is a second an essential plant nutrient after nitrogen, whose deficiency restricts growth and yield of crop severely. The low level of phosphorous is due to high reactivity of soluble phosphate with other elements in soil. The phosphate solubilizing micro-organisms increase the potential availability of soluble phosphates and they also enhance plant growth by increasing the efficiency of biological nitrogen fixation or enhancing the availability of trace elements to plants such as iron, zinc etc., and by production of plant growth promoting regulators (Ponmurugan and Gopi, 2006). Many plant growth promoting rhizobacteria are able to solubilise fixed phosphates in the soil, usually by releasing chelating organic acids and increase the acquisition to plants (Vessey *et al.*, 2004).

Rice crop requires high amount of Zn (Brady and Weil, 2007; Havlin *et al.*, 2007), under deficient condition of Zn in soil, therefore Zn deficiency becomes in the rice plants, then plant growth is restricted and quality of rice grain deteriorates and human health is also adversely affected (Pathak *et al.*, 2008; Singh, 2010). To ameliorate Zn deficiency in the Zinc deficient soils, the Zn fertilizers are being used but the Zn availability is less to the plants due to very high Zn fixation in soil. Organic manures provide major as well as minor nutrients and improve soil health by improving physical condition of soil. The combined use of inorganic fertilizers with organic manures namely, farmyard manure (FYM), green manure, poultry manure, pig manure increased the rice yield, Nitrogen, Phosphorus and Potassium uptake, use efficiency of nutrients and available nutrient status of soil (Laxminarayana, 2006; Laxminarayana and Patiram, 2006).

The recovery of micronutrients is very poor in crop that necessitates the adoption of improved techniques like use of micronutrients synthetic chelates. Since it is a costly technology, therefore enrichment of soil with organic manures and micronutrients, which acts as natural chelates in the soil, seems to be economically viable. Zinc application in the enriched form with organic manure, enhances the fertilizer use efficiency and increases the rice yield. The enrichment of micronutrients with organic manures not only enhances the rate of decomposition but also improves the nutrient status and health of soil (Singh, 1987).

In the last few years, the number of PGPR strain has seen a great importance, mainly due to role of the rhizosphere as an ecosystem that gained importance in the functioning of the biosphere. Various species of rhizobacteria like *Pseudomonas*, *Azospirillum*, *Azotobacter*, *Klebsiella*, *Enterobacter*, *Alcaligenes*, *Arthrobacter*, *Burkholderia*, *Bacillus* and *Serratia* have been reported to enhance the plant growth by providing nutrients and Phytohormones (Joseph *et al.*, 2007).

The use of Plant Growth Promoting Rhizobacteria offers an attractive way to replace chemical fertilizer (as biofertilizer), pesticides (as biocontrol), and supplements; most of the PGPR isolates result in a significant increase in plant height, root length, and dry matter production of shoot and root of plants. They also help in the suppression of disease in plants. PGPR is as a component factor in the integrated management systems in which reduced rates of agrochemicals and cultural control practices are used as biocontrol agents (Kloepper *et al.*, 2004). Considering all facts as given above, the aim of this experiment was reducing the excess use of chemical fertilizer and to increase the use efficiency of nutrients. Therefore, Yield and quality of rice

could be increase by using zinc and PGPR enriched FYM.

Materials and Methods

A field experiment was conducted during the *Kharif* season of 2013–14 and 2014-15 at the Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi (25° 18' N, 88° 03' E and 128.93 m above mean sea-level). District Varanasi is in semi-arid to sub humid climate zone, mean maximum temperature ranged from 21.1 to 36.7°C and while minimum temperature from 6.2 to 28.7 °C. The mean annual rainfall is about 1,100 mm. The soil belongs to Inceptisol, had sandy loam texture, particle density 2.68 Mg m⁻³, bulk density 1.41 Mg/m³, pH (1:2.5, soil: water) 8.04; electrical conductivity 0.21 dSm⁻¹ organic carbon 0.37 % and available nitrogen 195.40 kg ha⁻¹, available phosphorus 18.20 kg ha⁻¹ and available potassium 203.50 kg ha⁻¹. A total of 20 treatment combinations comprising of five levels of PGPR and Zinc enriched FYM (M₀ = No FYM, M₁ = only FYM, M₂ = PGPR enriched FYM, M₃ = PGPR and Zn @ 2.5 kg ha⁻¹ enriched FYM and M₄ = PGPR and Zn @ 5.0 kg ha⁻¹ enriched FYM) and four levels of phosphors (0, 20, 40 and 60 kg P₂O₅ ha⁻¹) with 3 replications under Randomized block design in Factorial experiment. The enriched FYM was applied @ 5 tonnes tonnes ha⁻¹ in experimental field as per treatments. Full dose of potassium and half dose of nitrogen were applied at the time of transplanting of rice seedling. Twenty five days old seedlings of rice 'HUR 105' were transplanted at a spacing of 20 cm × 20 cm. Remaining half dose of nitrogen at 25 DAT. N, P₂O₅ and K₂O were applied through urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) respectively. Rice was sown in the first week of August and harvested during last week of November during 2013-14 and 2014-15. All improved packages of practices were followed to raise the crop.

Yield components and the grain and straw yields were recorded at harvest and the data were statistically analysed.

Preparation of enriched FYM

The known quantity of FYM was filled in four pits. The solution of ZnSO₄.7H₂O was prepared on the basis of 2.5 and 5.0 kg Zn ha⁻¹ and thoroughly mixed in respective pits of known quantity of FYM as required of one hectare of soil. After 21 days, a composite microbial culture consisting of PGPR consortium (*Azospirillum brasiliense*, *Pseudomonas fluorescens*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Paenibacillus polymyxa*, *Trichoderma harzianum*) was added and thoroughly mixed to ensure complete contact with the decomposing materials (FYM). PGPR consortium was added after 21 days of initial composting to protect the microbes from direct exposure to excess heat generated from the materials. The moisture percentage of organic manures after mixing with ZnSO₄.7H₂O and PGPR was maintained around 60% throughout enrichment process. The cattle dung slurry @ 1% was applied as starter inoculums of microorganism to boost up the microbiological activities for enhancement of natural process of composting to fix the externally added Zn through zinc sulphate. The pits were covered by polythene sheet and allowed to decompose. The mixture was turned over weekly and also maintained moisture.

Results and Discussion

Effect of PGPR and zinc enriched FYM

Growth and yield attributes as well as grain and straw yields of rice were significantly influenced by different type of enriched FYM (Table 1, 2 and 3) Chlorophyll content, plant height, tillers hill⁻¹, grains panicle⁻¹, test

weight, yields and harvest index of rice were significantly highest in the treatment of FYM enriched with PGPR and zinc @ 5 kg ha⁻¹ (M₄) over the other treatments and remained at par with the treatment of FYM enriched with PGPR and zinc @ 2.5 kg ha⁻¹ (M₃) except plant height.

The beneficial effect of enriched FYM with PGPR and Zn was clearly noticed over without enriched FYM and control in rice. The data presented in table 1 revealed that chlorophyll content was found highest in the treatment M₄ but remained at par to treatment M₃ and rest of the treatments were significant to each other and over the control. Data showed in table 2 that plant height significantly increased by application of different types of enriched FYM. Highest plant height (106.44 cm) was in the treatment M₄ and lowest plant height (91.44 cm) was found in M₀ which is control. Treatment M₄ and M₃ gave at par result in case of increasing number of tillers hill⁻¹. Treatment M₃ was significantly increased tillers hill⁻¹ over the treatment M₂, M₁ and control. Treatment M₃, M₂ and M₁ were increased by 51.8, 36.6 and 17.4 %, respectively over the control. Grains panicle⁻¹ was found highest (133.77) in the treatment M₄ but it was at par with M₃ and order of increasing no. of grains was M₀ < M₁ < M₂ < M₃ < M₄. Test weight value was found lowest (22.21 g) in control while significantly highest value of test weight (23.77 g) was recorded in treatment M₄ which was at par with M₃.

The result of the investigation showed in table 3 that grain and straw yield varied between 40.57 to 56.92 and 56.21 to 76.83 q ha⁻¹, respectively. Grain yield significantly increased over control due to application of PGPR and Zn enriched FYM. Highest grain yield (56.92 q ha⁻¹) was obtained in the treatment M₄ which is increased 40.3 % over control but it was at par with treatment M₃

while remaining treatment showed significantly differ to each other. Similar result was also found in the straw yield. Highest straw yield was observed in M₄ which was at par with M₃ and M₃ was increased 34.4 % over control.

Data related to biological yield of rice was ranged from 96.78 to 133.75 q ha⁻¹. Biological yield increased highest in treatment M₄ and lowest value was found in the treatment M₀ which was control. Harvest Index was also influenced by PGPR and Zn enriched FYM. All the treatments were not significant to each other but it was increased with addition of different types of FYM (Table 3). It might be due to enrichment of FYM with PGPR and Zn which provides nutrients in available form like N, P and other essential nutrients, growth stimulating hormones along with chelated Zn which is available to plant during growth period and FYM also improves the physico-chemical and biological properties of soil. The result reveals that application of FYM increased yield parameters as compare to control (no FYM) might be due to its successive decomposition that enabled the wheat crop to ensure an almost continuous supply of nutrients efficiently throughout the growth period of crop (Patil *et al.*, 1998) and along with it is also improved the physical, chemical and biological properties of soil. The results are in line with the findings of Kumar and Singh, (2010). The results are in accordance with those reported by Kumar (1999), Jena (2006) Sudhakar *et al.*, (2006) and Meena *et al.*, (2006).

Effect of levels of phosphorus

Tables 1, 2 and 3 shows that yield and growth attributes *viz.* Chlorophyll content, Plant height, and no. of tillers hill⁻¹, markedly influenced by phosphorus levels which were highest at 60 kg P₂O₅ ha⁻¹ and proved

significantly superior to other lower dose of phosphorus.

Result indicates that application of 60 kg P₂O₅ ha⁻¹ significantly increased the Chlorophyll (SPAD value) by 37.32 over control (33.39). Plant height observed significantly greater in the treatment P₃ (103.85 cm) and the effect of the treatments on other yield attributes as number of tillers hill⁻¹, grains panicle⁻¹ and test weight (g) were also depicted similar trends where obtained highest value 14.42, 132.02 and 23.70, respectively were recorded under P₃ treatment.

Grain yield was observed highest (54.24 q ha⁻¹) in the treatment P₃ which was increased 21.6 % to control. Straw yield also increased gradually with increasing dose of P₂O₅ and lowest straw yield (61.42 q ha⁻¹) was obtained in the control which increased up to 73.61 q ha⁻¹ in treatment P₃ (60 kg P₂O₅). Similarly biological yield was increased with application of different dose of P₂O₅. It was significantly highest due to application of 60 kg P₂O₅ which increased 20.6 % over the control. Statistically, harvest index (%) was not influenced by addition of different levels of Phosphorus and showed non-significant result. It might be due to optimum dose of fertilizers (120 kg N ha⁻¹, 60 kg P₂O₅ ha⁻¹ and 60 kg K₂O ha⁻¹) because 60 kg P₂O₅ was applied as a treatment P₃ and N and K₂O were added as recommended dose in the whole experimental field.

The improvement in growth and yield attributes was might be due to the supply of available form of NPK fertilizers. Except that plant processes *viz.* cell division and root elongation in merismatic tissues and component of ADP and ATP in plant cell followed by a large canopy development by the increased levels of fertilizer seems to have a greater absorption and utilization of radiant energy resulting high growth and yield

attributing characters of crop plants (Sharma *et al.*, 2012). Meena *et al.*, (2015) also reported that addition of highest levels of Phosphorus (60 kg P₂O₅ ha⁻¹) along with bio organics increases the highest yield and growth attributes of rice.

Interaction effect of Enriched FYM and Phosphorus levels

Interaction between different levels of enriched FYM and phosphorus on plant height, grain yield, straw yield and biological yield of rice were found significant (Table 4). Combined application of PGPR and Zinc @ 5 kg ha⁻¹ enriched FYM + 60 kg ha⁻¹ P₂O₅ was recorded highest grain yield (59.62 q ha⁻¹) but it was at par with PGPR and zinc @ 2.5 kg ha⁻¹ enriched FYM + 40 kg ha⁻¹ P₂O₅ which had minimum input over rest of the other closest treatment combinations (M₃P₃ and M₄P₂).

Further, the data indicates that straw yield (79.94 q ha⁻¹) and biological yield (139.56 q ha⁻¹) were highest in the treatment combination of PGPR and Zinc @ 5 kg ha⁻¹ enriched FYM + 60 kg P₂O₅ ha⁻¹. It was also at par with M₃P₂ and other (M₃P₃ and M₄P₂) but the treatment combination M₃P₂ is preferable treatment because it had less input and gets more output then control and other treatment combination. The result reveals by Parewa and Yadav (2014) that highest grain and straw yields can be obtained by the application of optimum doses of NPK in combination with FYM @ 10 tonnes ha⁻¹ followed by 100% NPK. However, balanced application of NPK with FYM and bio-inoculants were found high responses in the yield in the comparison of sub optimal and super optimal doses of NPK. Similarly, Plant height (109.7 cm) was highest in the treatment M₄P₃ and it was remained at par with M₃P₂, M₃P₃ and M₄P₂. Here, PGPR and zinc @ 2.5 kg ha⁻¹ enriched FYM + 40 kg ha⁻¹ P₂O₅ treatment combination was

economically beneficial for the farmers due to low cost of inputs than other closest treatments. Increment in growth and yield may be due to the effect of PGPR and Zinc enriched FYM in which PGPR plays an important role in the nutrient acquisition (P solubilization and N fixation), stimulation of growth by producing growth hormones, so that rice plants reflected on enhancement in the growth and yield characteristics. Phytohormones like IAA and GA which promote the plant growth, cell division,

breaking the special dormancies, hence encouraging the photosynthesis and assimilate accumulation in plant (El-Khawas and Adachi, 1999). Similar improvements in yield attributes have also been observed by Namvar and Khandan (2013). It is also concluded by Sharma *at al.*, (2015) that the integrated use of 75% recommended dose of NPK fertilizer along with 5 t FYM ha⁻¹+BGA+PSB+5 kg Zn ha⁻¹ sustains rice production as well as improve the soil fertility status of Vertisols.

Table.1 Effect of PGPR and zinc enriched FYM and phosphorus levels on chlorophyll content (SPAD value) at 60 DAT of rice

Treatments	Chlorophyll content (SPAD value)		
	2013-14	2014-15	Pooled
Enriched FYM			
M ₀	32.05	32.40	32.23
M ₁	34.14	34.87	34.50
M ₂	35.40	36.15	35.78
M ₃	37.04	37.89	37.47
M ₄	37.51	38.47	37.99
SEm±	0.56	0.61	0.31
CD(P=0.05)	1.60	1.73	0.88
Phosphorus Levels			
P ₀	33.15	33.63	33.39
P ₁	34.71	35.46	35.09
P ₂	36.15	36.98	36.56
P ₃	36.90	37.75	37.32
SEm±	0.50	0.54	0.27
CD(P=0.05)	1.43	1.55	0.78

M₀ = Control, M₁ = only FYM @ 5 t ha⁻¹, M₂ = PGPR enriched FYM @ 5 t ha⁻¹, M₃ = PGPR and Zn at 2.5 kg ha⁻¹ enriched FYM @ 5 t ha⁻¹ and M₄ = PGPR and Zn at 5 kg ha⁻¹ enriched FYM @ 5 t ha⁻¹. P₀ = Control, P₁ = 20, P₂ = 40 and P₃ = 60 kg P₂O₅

Table.2 Effect of PGPR and zinc enriched FYM and phosphorus levels on plant height, tillers hill⁻¹, grains panicle⁻¹ and test weight of rice

Treatments	Plant height (cm)			Tillers hill ⁻¹			Grains panicle ⁻¹			Test Weight (g)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Enriched FYM												
M ₀	91.28	91.59	91.44	9.20	9.56	9.38	117.88	118.97	118.43	22.18	22.24	22.21
M ₁	95.78	96.85	96.31	10.63	11.39	11.01	122.73	124.48	123.60	22.58	22.78	22.68
M ₂	99.91	101.60	100.75	12.42	13.22	12.82	127.65	129.80	128.73	22.92	23.30	23.11
M ₃	104.41	106.02	105.21	13.73	14.76	14.24	131.09	133.42	132.26	23.36	23.93	23.65
M ₄	105.43	107.44	106.44	14.63	15.48	15.05	132.55	135.00	133.77	23.52	24.02	23.77
SEm±	0.61	0.46	0.42	0.37	0.39	0.37	0.85	0.56	0.64	0.11	0.14	0.09
CD(P=0.05)	1.75	1.32	1.20	1.05	1.10	1.07	2.43	1.59	1.83	0.33	0.40	0.26
Phosphorus Levels												
P ₀	94.08	94.53	94.30	9.99	10.40	10.19	120.54	121.42	120.98	22.40	22.54	22.47
P ₁	98.92	100.49	99.70	11.56	12.37	11.96	125.58	127.70	126.64	22.75	23.00	22.88
P ₂	101.39	103.15	102.27	12.99	13.87	13.43	128.61	130.96	129.79	23.06	23.54	23.30
P ₃	103.06	104.64	103.85	13.95	14.89	14.42	130.79	133.26	132.02	23.45	23.95	23.70
SEm±	0.55	0.41	0.37	0.33	0.34	0.33	0.76	0.50	0.57	0.10	0.12	0.08
CD(P=0.05)	1.57	1.18	1.07	0.94	0.99	0.96	2.17	1.42	1.64	0.29	0.36	0.23

M₀= Control, M₁= only FYM @ 5 t ha⁻¹, M₂= PGPR enriched FYM @ 5 t ha⁻¹, M₃= PGPR and Zn at 2.5 kg ha⁻¹ enriched FYM @ 5 t ha⁻¹ and M₄= PGPR and Zn at 5 kg ha⁻¹ enriched FYM @ 5 t ha⁻¹. P₀= Control, P₁=20, P₂= 40 and P₃= 60 kg P₂O₅.

Table.3 Effect of PGPR and zinc enriched FYM and phosphorus levels on grain yield, straw yield, biological yield and harvest index of rice

Treatments	Yield (q ha ⁻¹)									Harvest index (%)		
	Grain			Straw			Biological					
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Enriched FYM												
M ₀	40.63	40.51	40.57	56.24	56.18	56.21	96.87	96.69	96.78	41.92	41.86	41.89
M ₁	46.93	48.64	47.78	64.64	67.36	66.00	111.57	115.99	113.78	42.04	41.91	41.97
M ₂	50.20	51.80	51.00	68.53	70.81	69.67	118.72	122.61	120.67	42.29	42.27	42.28
M ₃	55.26	56.17	55.71	74.76	76.32	75.54	130.01	132.48	131.25	42.49	42.39	42.44
M ₄	56.46	57.39	56.92	76.21	77.45	76.83	132.67	134.84	133.75	42.55	42.56	42.55
SEm±	0.45	0.50	0.45	0.63	0.72	0.64	1.01	1.14	1.02	0.14	0.15	0.14
CD(P=0.05)	1.29	1.42	1.29	1.79	2.05	1.82	2.90	3.27	2.93	0.41	0.44	0.40
Phosphorus Levels												
P ₀	44.62	44.58	44.60	61.39	61.44	61.42	106.01	106.02	106.02	42.06	41.98	42.02
P ₁	49.18	50.82	50.00	67.25	69.79	68.52	116.43	120.60	118.52	42.21	42.12	42.17
P ₂	52.04	53.46	52.75	71.01	72.68	71.85	123.05	126.14	124.60	42.27	42.36	42.31
P ₃	53.73	54.75	54.24	72.65	74.58	73.61	126.38	129.32	127.85	42.50	42.31	42.41
SEm±	0.40	0.44	0.40	0.56	0.64	0.57	0.91	1.02	0.92	0.13	0.14	0.12
CD(P=0.05)	1.16	1.27	1.15	1.60	1.83	1.63	2.59	2.92	2.62	NS	NS	NS

M₀ = Control, M₁ = only FYM @ 5 t ha⁻¹, M₂ = PGPR enriched FYM @ 5 t ha⁻¹, M₃ = PGPR and Zn at 2.5 kg ha⁻¹ enriched FYM @ 5 t ha⁻¹ and M₄ = PGPR and Zn at 5 kg ha⁻¹ enriched FYM @ 5 t ha⁻¹. P₀ = Control, P₁ = 20, P₂ = 40 and P₃ = 60 kg P₂O₅.

Table.4 Interactive effect of enriched FYM and phosphorus levels on plant height, grain yield, straw yield, and biological yield of rice (pooled data of 2 years)

Treatments	Plant height (cm)				Grain yield (q ha ⁻¹)				Straw yield (q ha ⁻¹)				Biological yield (q ha ⁻¹)			
	P ₀	P ₁	P ₂	P ₃	P ₀	P ₁	P ₂	P ₃	P ₀	P ₁	P ₂	P ₃	P ₀	P ₁	P ₂	P ₃
M ₀	83.00	91.65	94.18	96.92	33.58	40.41	43.15	45.14	47.19	56.27	59.68	61.72	80.76	96.68	102.82	106.87
M ₁	88.65	96.53	99.77	100.30	39.54	47.58	51.25	52.77	55.79	65.53	70.40	72.27	95.33	113.11	121.66	125.04
M ₂	94.33	99.58	103.62	105.48	44.47	50.27	53.91	55.36	60.07	68.83	73.85	75.92	104.54	119.10	127.75	131.27
M ₃	101.75	104.92	106.70	107.48	51.85	55.24	57.44	58.31	70.67	75.91	77.35	78.22	122.52	131.14	134.79	136.53
M ₄	103.78	105.83	107.07	109.07	53.56	56.51	58.01	59.62	73.37	76.05	77.96	79.94	126.93	132.56	135.96	139.56
SEm±		0.84				0.90				1.27				2.05		
CD (P=0.05)		2.39				2.58				3.64				5.86		

M₀ = Control, M₁ = only FYM @ 5 t ha⁻¹, M₂ = PGPR enriched FYM @ 5 t ha⁻¹, M₃ = PGPR and Zn at 2.5 kg ha⁻¹ enriched FYM @ 5 t ha⁻¹ and M₄ = PGPR and Zn at 5 kg ha⁻¹ enriched FYM @ 5 t ha⁻¹. P₀ = Control, P₁ = 20, P₂ = 40 and P₃ = 60 kg P₂O₅.

Lavakush *et al.*, (2014) have also reported that 60 kg ha⁻¹ phosphorus gave highest enhancement in growth parameters while approximate similar enhancement in growth attribute can be obtained by combined application of PGPR and 30 kg ha⁻¹ phosphorus. So that treatment combination of PGPR with 30 kg ha⁻¹ phosphorus was found economically cheaper than with 60 kg ha⁻¹ and beneficial at farmer's level. Afzal *et al.*, (2005) observed that Grain yield and biological yield were significantly increased by application of the PSM, phosphorus and FYM. Highest yield was recorded when PSM was used with phosphorus alone or along with organic matter. It is concluded that PSM alone or along with other combinations produced profound effect on grain yield, biological yield, tillers per m² and seed phosphorus content.

Here, it was found that all the growth and yield parameters were significantly influenced by PGPR and Zn enriched FYM and phosphorus levels. It may be concluded that application of enriched FYM (PGPR and Zinc @ 2.5 kg ha⁻¹) at 40 kg P₂O₅ ha⁻¹ is best option for higher productivity and profitability for growing of rice without endangering the soil health. Combination of enriched FYM and phosphorus applied to rice crop will be carry-over beneficial effects on succeeding crop on the farmer's levels. So, we can minimize excess use of fertilizers and also increase the fertilizer use efficiency by enrichment of FYM with PGPR and Zinc. Therefore, it was conferred that 20 kg P₂O₅ and 2.5 kg Zn could be saved and optimum grain and straw yield of rice could be obtained with application of 5 t ha⁻¹ FYM enriched with PGPR consortium + Zn @ 2.5 kg ha⁻¹, 120 kg N, 40 kg P₂O₅ ha⁻¹ and 60 kg K₂O ha⁻¹ in the soils of eastern Uttar Pradesh.

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