



Determining the Effect of Phosphorus and Micronutrients on Yield and Economics of Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A field study took place in *Kharif* 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P) to determine the "Effect of Phosphorus and Micronutrients on yield and Economics of Rice (*Oryza sativa* L.). The results revealed that treatment 7 [Phosphorus (70 kg/ha) + Zinc(10 kg/ha)] recorded significantly higher number of panicles/plant (12.76), number of grains/panicle (126.5), test weight (16.6 g), grain yield (5.34 t/ha), straw yield (7.24 t/ha), harvest index (42.45 %) and maximum gross returns, (1,70,880.00 INR/ha), net return (1,18,075.50 INR/ha) and highest benefit cost ratio (2.23) was recorded compare to other treatments.

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1. INTRODUCTION

“Rice is a major staple food of (70%) of Indian population, it provide (21%) and (15%) per capita of dietary energy and protein, respectively” (Maclean *et al.*, 2002). And also which provides instant energy as its most important component is carbohydrate (starch). “Rice flour is rich in starch and is used for making various food materials. It is also used in some instances by brewers to make alcoholic malt. Likewise, rice straw mixed with other materials is used to produce porcelain, glass pottery and also used in manufacturing of paper pulp and livestock bedding” (Lakhvir Singh *et al.*, 2021).

“In world rice growing in 165.12 million ha, the production is 509.42 million tonnes and the yield is about 4.61 metric tons/ha” (USDA, 2022). “Among the rice growing countries of the world, India has the largest rice acreage and ranked second in production after wheat in the world. In India rice is grown in 45.07 million ha, the production level is 122.27 million tonnes and the yield is about 2713 kg/ha” (GOI, Annual Report 2021). “In Uttar Pradesh state ranks third in the country in production of rice. It is grown over an area of about 5.68 mha which comprise of (13.5%) of total rice in India. Annual rice production is around 15.66 million metric ton, the average yield is 2759 kg/ha” (GOI, Annual Report 2021).

“Phosphorus deficiency is one of the major constraints to crop production. The unique feature of P is its low availability due to slow diffusion and high fixation in soils. Phosphorus is the second major nutrient for plant growth after nitrogen as it is an integral part of different biochemicals like nucleic acid, nucleotides, phospholipids and phosphor proteins. Sufficient P nutrition improves several plant processes such as photosynthesis, nitrogen fixation, flowering, seed formation, root development and crop maturation. It has been observed that P fertilizer reduced the concentration of Na⁺ in shoots, resulting in better survival, growth and yield of rice” (Naheed *et al.*, 2008).

“Micronutrients are important nutrition to plant and the deficiency is considered one of the major causes of declining the productivity trends in rice growing countries, adequate supply improves nutrient availability and positively affects the cell physiology that is reflected in yield as well. When micronutrients are in short supply, the growth

and yield of crops are severely depressed” (Rana & Kashif, 2014).

In India, zinc is considered as the fourth important yield limiting nutrient after nitrogen, phosphorus, and potassium respectively. Zinc plays an important role in the nutrition of rice, and also essential for the normal growth and metabolism of the plant like membrane integrity, synthesis of carbohydrates, enzyme activation such as dehydrogenase, carbonic anhydrase, superoxide dismutase, alkaline phosphatase etc.

Zinc (Zn) deficiency is considered as a major threat to the global and regional food security (Rana & Kashif, 2014). “In high rice consuming areas, zinc deficiency caused yield reduction and Zn malnutrition in humans. It was subsequently found to be a widespread phenomenon in lowland rice areas of Asia, next to N and P deficiencies. Zinc deficiency in rice appears right from seedling stage in nursery and three weeks after transplanting in main field. In rice, low plant available Zn in soil cause leaf bronzing and poor tillering at early growth stages, leading to delayed maturity and significant yield loss. Zinc deficiency is usually corrected by application of zinc sulfate (ZnSO₄) before flooding or after transplanting to prevent Zn deficiency and increased grain yield” (Naik & Das, 2007).

Iron (Fe) is one of the essential elements required for plant growth and reproduction. Of the 7 micronutrients, Fe has the highest plant requirement (Jones & Benton, 2012). “It is involved in chlorophyll formation and degradation and in the synthesis of proteins and nucleic acids. Iron plays an important role in respiration and the production of healthy green leaves and also required for electron transport in photosynthesis and is a constituent of iron porphyrins and ferredoxins, both of which are essential components in the light phase of photosynthesis. It is an activator for several enzymes (e.g. catalase, succinic dehydrogenase, and aconitase), but inhibits K absorption” (Meng *et al.*, 2005) reported that improving the iron content and bioavailability in rice is a perspective and an effective way to alleviate or even solve the widespread iron deficiency in humans.

“Boron deficiency causes delay in flowering, induces flower bud abortion and causes panicle sterility” (Rehman *et al.*, 2018). “Boron deficient rice plants show white and rolled leaf tips of

young leaves, death of growing points and unable to produce panicles if affected at panicle formation stage. Boron required for carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration, and pollen viability. Boron can influence photosynthesis and activate number of enzymatic system of protein and nucleic acid metabolism in plants” (Choudhary *et al.*, 2020). Keeping in view the above fact, the experiment was conducted to Determining the Effect of Phosphorus and Micronutrients on Yield and Economics of rice (*Oryza sativa* L.).

2. MATERIALS AND METHODS

The experiment was conducted during *Kharif* season of 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P). The soil of the field constituting a part of central gangetic alluvium is neutral and deep. The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH 7.8), low level of organic carbon (0.62%), available N (225 Kg/ha), P (38.2 kg/ha) and K (240.7 kg/ha). The experiment laid out in RBD with 10 treatment consists of 3 different Phosphorus *viz.* (50 kg/ha), (60 kg/ha) and (70 kg/ha) with combination of 3 micronutrients *viz.* Zinc (10 kg/ha), iron (15 kg/ha), and boron (4 kg/ha). The treatment combinations are T1- Phosphorus (50 kg/ha) + Zinc(10 kg/ha), T2- Phosphorus (50 kg/ha) + Iron (15 kg), T3- Phosphorus (50 kg/ha) + Boron (4 kg/ha), T4- Phosphorus (60 kg/ha) + Zinc (10 kg/ha), T5- Phosphorus (60 kg/ha) + Iron (15 kg), T6 - Phosphorus (60 kg/ha) + Boron (4 kg/ha), T7- Phosphorus (70 kg/ha) +Zinc (10 kg/ha), T8- Phosphorus(70 kg/ha)+ Iron (15 kg), T9- Phosphorus (70 kg/ha) + Boron (4 kg/ha). T10- 120:60:60 (NPK Kg/ha). The data was collect on yield parameters (number of panicles/plant, number of grains/panicle, test weight (g), grain Yield (t/ha), straw Yield (t/ha), harvest index (%)) and economics (gross return, net return, and benefit cost ratio).

Data were subject to stastical analysis of variance method.

3. RESULT AND DISSCUSSION

3.1 Yield Parameters

Number of panicles/plant: The data recorded that significant and higher number of

panicles/plant (12.76) was recorded in the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] However, the treatment 9 [Phosphorus (70 kg/ha) + Boron (4 kg/ha)] was found to be statistically at par to the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)](Table 1). Thesignificant and higher number of panicles/plant was recorded with the application of Phosphorus (70 kg/ha) might be due to balanced fertilizer application and also phosphorus promoted normal growth of the plant, as a result number of panicles/plant increased. Similar result was reported by Rahman, (1996) and Memon& Puno, (2005) in wheat. Further, higher number of panicles/plant was recorded with the application of Zinc (10 kg/ha) may be due to adequate supply of zinc that might have increased the availability and uptake of other essential nutrients and thereby resulting in improvement of crop growth. Similar result was reported by Sanzo *et al.*, (1989).

Number of grains/panicle: The data showed that significantly highest number of grains /panicle (126.5) was recorded in the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] among all the treatments. However, the treatment 9 [Phosphorus (70 kg/ha) + Boron (4 kg/ha)] was found to be statistically at par to the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] (Table 1). The significant and higher number of grains/ panicle was recorded with the application of Phosphorus (70 kg/ha) maybe due to phosphorus plays an important role in the translocation of assimilates to the panicles and also as a constituent of protoplasm, resulted higher number of grains/ panicle. Similar result was reported by Ishizuka, (1971). Further, higher number of grains/panicle was observed with the application of Zinc (10 kg/ha)might be due to effect on enhancing the physiological function of crop like photosynthesis and translocation of plant nutrients which ultimately increased the number of grains/panicle. Similar result was reported by Ionov & Ionova, (1977).

Test weight (g): Significant and higher test weight (16.6 g) was recorded in the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] However, the treatment 9 [Phosphorus (70 kg/ha) + Boron (4 kg/ha)] was found to be statistically at par to the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] (Table 1). The significant and higher test weight was recorded with the application of Phosphorus (70 kg/ha) may be due to phosphorus plays an important role in enzyme reactions that depend on

Table 1. Effect of phosphorus and micronutrients on yield and yield parameters of rice

SI No.	Treatments	Number of panicles/plant	Number of grains/panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
1	Phosphorus 50 kg/ha + Zinc (10kg/ha)	12.06	122.93	13.16	3.93	5.88	40.08
2	Phosphorus 50 kg/ha + Iron (15kg/ha)	11.48	120.80	12.99	3.54	5.62	38.67
3	Phosphorus 50 kg/ha + Boron (4 kg/ha)	11.66	121.47	13.08	3.66	5.50	39.96
4	Phosphorus 60 kg/ha + Zinc (10kg/ha)	12.99	125.40	15.09	4.86	6.86	41.47
5	Phosphorus 60 kg/ha + Iron (15kg/ha)	12.19	123.73	13.30	4.03	6.16	39.55
6	Phosphorus 60 kg/ha + Boron (4 kg/ha)	12.76	125.00	14.42	4.56	6.70	40.51
7	Phosphorus 70 kg/ha + Zinc (10kg/ha)	13.20	126.47	16.59	5.34	7.24	42.45
8	Phosphorus 70 kg/ha + Iron (15kg/ha)	12.38	124.60	13.86	4.28	6.53	39.60
9	Phosphorus 70 kg/ha + Boron (4 kg/ha)	13.09	125.73	15.94	5.10	7.06	41.94
10	Control - 120:60:60 NPK (kg/ha)	11.05	119.80	12.85	3.42	5.21	39.61
	F test	S	S	S	S	S	S
	SE(m)±	0.05	0.21	0.12	0.07	0.09	0.64
	CD (p=0.05)	0.16	0.64	0.38	0.24	0.29	1.91

Table 2. Effect of phosphorus and micronutrients on the economics of rice

SI No.	Treatments	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C ratio
1	Phosphorus 50 kg/ha + Zinc (10kg/ha)	50,304.49	1,25,760.00	75,455.51	1.49
2	Phosphorus 50 kg/ha + Iron (15kg/ha)	50,284.49	1,13,280.00	62,995.51	1.25
3	Phosphorus 50 kg/ha + Boron (4 kg/ha)	49,979.49	1,17,120.00	67,140.51	1.34
4	Phosphorus 60 kg/ha + Zinc (10kg/ha)	51,554.49	1,55,520.00	1,03,965.50	2.01
5	Phosphorus 60 kg/ha + Iron (15kg/ha)	51,534.49	1,28,960.00	77,425.51	1.50
6	Phosphorus 60 kg/ha + Boron (4 kg/ha)	51,229.49	1,45,920.00	94,690.51	1.84
7	Phosphorus 70 kg/ha + Zinc (10kg/ha)	52,804.49	1,70,880.00	1,18,075.50	2.23
8	Phosphorus 70 kg/ha + Iron (15kg/ha)	52,784.49	1,36,960.00	84,175.51	1.59
9	Phosphorus 70 kg/ha + Boron (4 kg/ha)	52,479.49	1,63,200.00	1,10,720.50	2.10
10	Control -120:60:60 NPK (kg/ha)	44,554.49	1,09,440.00	64,885.51	1.45

phosphorylase and also phosphorus is part of the cell nucleus, so it was important in cell division and also for the development of meristem tissue. Similar result was reported by Juwita *et al.*, (2021). Further, "increase in test weight with the application of Zinc (10 kg/ha) might be due to more efficient participation of zinc in various metabolic processes involved in the production of healthy seeds" which is similar as described by Ali *et al.*, (2019).

Grain Yield (t/ha): The data revealed that significant and higher grain yield (5.34 t/ha) was recorded in the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] However, the treatment 9 [Phosphorus (70 kg/ha) + Boron (4 kg/ha)] was found to be statistically at par to the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] (Table 1) (Shreya & Debbarma, 2023).

"The significant and higher grain yield was recorded with the application of Phosphorus (70 kg/ha) might be due to more availability of phosphorus on root development, energy transformation and metabolic processes of the rice plant, which in turn resulted in greater translocation of photosynthates towards the productive part, resulted increased in grain yield" which is similar as reported by Gharib *et al.*, (2011). Further, significant and higher grain yield was recorded with the application Zinc (10 kg/ha) may be due to involvement in many metallic enzyme system, regulatory functions and auxin production enhanced synthesis of carbohydrates and their transport which increases grain yield. Similar result was reported by Ali *et al.*, (2019); Nasution *et al.*, (2021).

Straw yield (t/ha): The data showed that significant and higher straw yield (7.24 t/ha) was recorded in the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] However, the treatment 9 [Phosphorus (70 kg/ha) + Boron (4 kg/ha)] was found to be statistically at par to the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] (Table 1). The significant and higher straw yield was recorded with the application of Phosphorus (70 kg/ha) may be due to increasing phosphorus availability and subsequently increased its uptake, leading to more ATP formation that is the main source for energy in plant and might encourage rice growth, metabolism, photosynthesis and nucleic acid and also improvement in biomass production and sink formation, resulted increases straw yield. Similar result was reported by Gharib *et al.*, (2011) and Yadav *et al.*, (2015). Further, significant and

higher straw yield was recorded with the application of Zinc (10 kg/ha) might be due to favorable effect of zinc on the proliferation of roots and thereby increasing the uptake of plant nutrients from the soil, and supplying it to the aerial parts of the plant, ultimately enhancing the vegetative growth of plants. Result was reported by Khan *et al.*, (2007).

Harvest index (%): Data recorded that significant and higher harvest index (42.45 %) was recorded in treatment 7 [Phosphorus 70 kg/ha + Zinc (10 kg/ha)]. However, the treatment 9 - [Phosphorus 70 kg/ha + Boron (4kg/ha)] (41.94%) was found to be statistically at par to the treatment 7 [Phosphorus 70 kg/ha + Zinc (10 kg/ha)] (Table 1). The significant and higher harvest index was recorded with the application of Phosphorus (70 kg/ha) might be due to improved cell activities, enhanced cell multiplication and enlargement and luxuriant growth and yield attribute of the crops probably due to more absorption and utilization of available nutrients leading to overall improvement of crop growth reflected to source-sink relationship, which in turn enhanced the yield attributes that ultimately more yield. Similar result was reported by Akram *et al.*, (2022) in wheat. Further, higher harvest index was recorded with the application of Zinc (10 kg/ha) may be due to maximum dry matter partitioning towards grain hence grain yield was more and also plant maintain a higher supply of photosynthates to reproductive parts as compare to vegetative biomass. findings similar to Kadam *et al.*, (2018) and Singh *et al.*, (2018).

Economics: The result showed that maximum gross returns (1,70,880.00 INR/ha), higher net return (1,18,075.50 INR/ha) and highest benefit cost ratio (2.23) was recorded in treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)]. As compared to other treatments (Table 2). Higher gross return, higher net return, and highest benefit cost ratio was recorded with the application of Phosphorus (70 kg/ha) might be due to higher productivity as well as efficient use of fertilizer. Similar result was reported by Devi & Luikham, (2018). Further, higher gross return, higher net return, highest benefit cost ratio was recorded with the application of Zinc (10 kg/ha) might be due to zinc is an essential plant nutrient and its involvement in the physiological process is well pronounced, therefore increased in both grain and straw yield. Similar result was reported by Reddy *et al.*, (2020).

4. CONCLUSION

Based on the aforementioned results it can be stated that phosphorus 70 kg/ha combined with zinc 10 kg/ha have improved in yield characteristics while also being economically viable.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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