Original Research Article

“Influence of Phosphorus and Micronutrients on Growth and Yield of Rice (*Oryza sativa* L.)”

ABSTRACT

A field experiment was conducted during *Kharif* 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj (U.P) to determine the "Influence of Phosphorus and Micronutrients on growth and yield of Rice (*Oryza sativa* L.)". The results showed that treatment 7 [Phoshorus (70 kg/ha)+ Zinc(10 kg/ha)] recorded significantly higher plant height (119.5 cm), plant dry weight (g) (42.79), number of tillers/hill (16.5), number of panicles/plant (13.20), number of grains/panicle (126.5), test weight (16.6 g), grain yield (5.34 t/ha), straw yield (7.24 t/ha) and harvest index (13.20 %) as compared to other treatments.

.

Keywords: *Rice, Phosphorus, Micronutrients, Growth, Yield.*

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 and pottery. Rice is also used in manufacturing of paper pulp and livestock bedding.

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 tones and the yield is about 2713 kg/ha **(GOI, 2021).** In Uttar Pradesh state ranks third in the country in production of rice. it grown over area 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, 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 bio chemicals like nucleic acid, nucleotides, phospholipids and phosphoproteins. 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).** Also phosphorus is majore component in ATP, the molecule that provides energy to that plant for such processes as nutrient translocation, nutrient uptake and respiration. Phosphorus is also component of other compound necessary for protein synthesis and transfer of genetic material DNA, RNA**.**

Micronutrients are as important as macronutrients in plant nutrition and the deficiency of micronutrients is considered one of the major causes of declining the productivity trends in rice growing countries, micronutrients are needed in trace amounts but their 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. The presence of micronutrient deficiency renders it impossible for the plants to gain maximum benefit from NPK fertilizers application.

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 micronutrients for the normal growth and metabolism of the plant plays an important role in membrane integrity, synthesis of carbohydrates, enzyme activation such as dehydogenise, carbonic anhydride, super oxide dismutase, alkaline phosphatise etc.

Among the micronutrients, zinc (Zn) deficiency is considered as a major threat to the global and regional food security **(Rana and Kashif, 2014).** In high rice consuming areas, zinc deficiency caused yield reduction and Zn malnutrition in humans. It was subsequently found to be 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 ($ZnSO_4$) before flooding or after transplanting to prevent Zn deficiency and increased grain yield **(Naik and 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 and 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),

Boron deficiency causes delay in flowering, induces flower bud abortion and causes panicle sterility **(Rehman *et al.*, 2018).** Also affect cell wall biosynthesis and affects structure and plasma membrane integrity. 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 **(Choudary *et al.*, 2020).** Keeping in view the above fact, the experiment was conducted to find out the **"Influence of Phosphorus and Micronutrients on Growth and Yield of rice (*Oryza sativa* L.)".**

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 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 experiment was laid out in RBD with 10 treatments each replicated thrice. 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 experiment was laid out in Randomized Block Design, with 10 treatments replicated thrice. The observations were recorded for plant height, number of tillers/hill, plant dry weight (g), Crop growth rate (g/m2/day), Relative growth rate (g/g/day), number of pannicles/plant, number of grains/panicle, test weight (g), grain yield (t/ha), strover yield (t/ha) and harvest index (%). The collected data were subjected to statistical analysis by analysis of variance method.

RESULT AND DISSCUSSION

Growth parameters

Plant height (cm):

The data revealed that significant and higher plant height (119.5 cm) was recorded in the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)]. However, treatment 9

[Phosphorus (70 kg/ha) + Boron (4 kg/ha)] was found statistically at par with treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] (Table 1).

The significant and higher plant height was observed with the application of phosphorus (70 kg/ha) might be due to Phosphorus, stimulates root development and growth in the seedling stage and thereby it helps to establish the seedling quickly, resulted higher plant height. Similar results were reported by **Majeed *et al.* (2014)** in wheat. Further, increase in plant height with the application of Zn (10 kg/ha) might be due to role of Zn in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthesis towards them which resulted in better flowering and fruiting, resulting in higher plant height. These findings similar to **Himanshu *et al.* (2013).**

Number of tillers/hill:

The result revealed that significant and higher number of tillers/hill (12.6) was recorded in the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)]. However, treatment 9 [Phosphorus (70 kg/ha) + Boron (4 kg/ha)] was found statistically at par with treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] (Table 1).

The significant and higher number of tillers per hill was observed with the application Phosphorus (70 kg/ha) its might be due to improved the nutritional status of mother culm in its early growth, resulting higher number of tillers/hill. Similar result were reported by **Figeria *et al*. (2004**) in wheat. Further, increase in number of tillers/hill with the application of Zinc (10 kg/ha) might be due to the effect of increased photosynthetic process, chlorophyll synthesis, protein synthesis and nitrogen fixation in response to the application of Zn. Similar result was reported by **Rao *et al.* (2019).**

Plant dry weight (g):

Data found that significant and higher plant dry weight (42.79 g/plant) was recorded in the treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)]. However, treatment 9

[Phosphorus (70 kg/ha) + Boron (4 kg/ha)] was found statistically at par with treatment 7 [Phosphorus (70 kg/ha)+ Zinc(10 kg/ha)] (Table 1).

The Significant and higher plant dry weight was observed with the application of Phosphorus (70 kg/ha) might be due to increased supply of phosphorus were due to more proliferation of roots buildup higher concentration of nutrient in soil that hasten cell division and elongation, resulting highr plant dry weight. Similar result was reported by **Sathish *et al.* (2017)** in wheat. Further, increase in plant dry weight with the application of Zinc (10 kg/ha) may be due to its role in various enzymatic reaction, growth processes, hormone production, protein synthesis and translocation of photosynthates in various plant parts. Similar result were reported by **Singh *et al.* (2011)** and **Choudary *et al.* (2014)** in wheat.

Crop Growth Rate (g/m^2/day):

The data recorded that significant and higher crop growth rate (7.70 g/m^2/day) was recorded in treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] and the treatment 10 [Control] recorded lowest crop growth rate (5.77 g/m^2/day) (Table 1).

The significant and higher crop growth rate was recorded with the application of Phosphorus (70 kg/ha) might be due to phosphorus stimulate root growth and leads to development of extensive root system, which turn enhances plant's ability to gather water and nutrients; increased phosphorus levels also encourage various plant metabolic processes such as photosynthesis and cellular energy transfer. Similar result was reported by **Fageria *et al*. (2013)**. Further, higher crop growth rate was observed with the application of Zinc (10 kg/ha) it may be due to xylem and re-translocation in phloem which increase vegetative tissue formation resulted in improves photosynthetic activity which slows boosted growth of the plants parts and increment in dry matter. Similar result was reported by **Rao *et al.* (2019).**

Relative Growth Rate (g/g/day):

The data showed that during 80-100 DAT, treatment 7 [Phosphorus (70 kg/ha) + Zinc (10 kg/ha)] recorded significantly higher relative growth rate (0.037 g/g/day), though there was significant among the treatment (Table 1).

The significant and higher relative growth rate was recorded with the application of Phosphorus (70 kg/ha) might be due to rapid growth caused by maintenance of adequate and continues supply of nutrients to crop resulted in maintaining better establishment of root and various metabolic process which contributed to rapid cell division ,cell elongation and thus resulted in higher growth of the plant. Similar result was reporte by **Satish *et al.* (2017)** in wheat. Further, higher relative growth rate was recorded with the application of Zinc (10 kg /ha) it may be due to zinc which as facilitated the growth of the plant, due to its involvement in many metallic enzyme system, regulatory function and auxin production. Similar result were reported by **Slaton *et al.* (2005).**

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 2).

The significant 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 **Rehman *et al.* (1996)** and **Memon *et al.* (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 2).

The significant and higher number of grains/panicle was recorded with the application of Phosphorus (70 kg/ha) may be 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 **lonova (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 2).

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 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. Similar result was reported 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 2).

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. Similar result was 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).**

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 2).

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 stare 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. Similar 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 2).

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. Similar result was reported by **Kadam *et al.* (2018) and Singh *et al*. (2018).**

Table 1. Influences of Phosphorus and micronutrients on growth parameters of rice.

Sl. No.	Treatments	Plant heights (cm)	Number of tillers/hill	Plant dry weight (g)	Crop growth rate ($g/m^2/day$)	Relative growth rate (g/g/day)
1	Phosphorus 50 kg/ha + Zinc (10kg/ha)	106.93	14.47	38.80	26.71	0.0580
2	Phosphorus 50 kg/ha + Iron (15kg/ha)	105.37	14.13	38.30	26.39	0.0587
3	Phosphorus 50 kg/ha + Boron (4 kg/ha)	106.60	14.47	38.56	26.49	0.0580
4	Phosphorus 60 kg/ha + Zinc (10kg/ha)	109.53	16.00	39.31	26.89	0.0560
5	Phosphorus 60 kg/ha + Iron (15kg/ha)	107.70	15.00	38.95	26.51	0.0573
6	Phosphorus 60 kg/ha + Boron (4 kg/ha)	108.87	15.60	39.15	26.74	0.0563
7	Phosphorus 70 kg/ha + Zinc (10kg/ha)	110.63	16.27	39.71	27.55	0.0567
8	Phosphorus 70 kg/ha + Iron (15kg/ha)	108.33	15.27	39.08	26.58	0.0567
9	Phosphorus 70 kg/ha + Boron (4 kg/ha)	109.80	16.47	39.53	27.10	0.0560
10	Control - 120:60:60 NPK (kg/ha)	103.73	13.73	38.12	26.24	0.0597
	F test	S	S	S	S	S
	SE(m)±	0.17	0.13	0.07	0.16	0.0038
	CD (p=0.05)	0.53	0.40	0.22	0.50	0.0012

Table 2. Influences of Phosphorus and micronutrients on yield and yield parameters of rice.

Sl 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

CONCLUSION:

Based on above findings it can be concluded that combination of Phosphorus (70 kg/ha) along with Zinc (10 kg/ha) (Treatment 7) was observed better growth paramerters and yield attributes.

REFERENCES:

1. **Atique-ur-Rehman & Muhammad Farooq & Abdul Rashid & Faisal Nadeem & Sabine Stuerz4& Folkard Asch & Richard W. Bell & Kadambot H. M. Siddique. (2018).** Boron nutrition of rice in different production systems. A review. Agronomy for Sustainable Development 38: 25.
2. **Chaudhary S., Singh H., Singh S. and Singh V. (2014).** Zinc requirement of greengram (Vigna radiate)-wheat (*Triticum aestivum* L.*)* crop sequence in alluvial soil. Indian Journal of Agronomy **59**(1):48-52.
3. **Choudhary, S., A. Zehra, M. Naeem, M. Khan and T. Aftab. (2020).** Effects of boron toxicity on growth, oxidative damage, antioxidant enzymes and essential oil fingerprinting in Mentha arvensis and Cymbopogon flexuosus. Chem. & Biol. Technol. in Agri., **7**(1): 1-11.
4. **Devideen yadav1, Y.V. singh , Dinesh kumar, Sunita gaind and Anil kumar. (2015).** Influence of sources and rates of phosphorus on plant growth, productivity and economics of aerobic rice (*Oryza sativa* L.). Indian Journal of Agronomy **60** (1): 157-159.
5. **Fadma Juwita Nasution1,a), Hamidah Hanum, and Jonatan Ginting**. **(2021).** Effect of Dose and Time Application of Phosphorus Fertilizer on Phosphorus Availability, Growth and Production of Rice (*Oryza sativa* L.) AIP Conference Proceedings 2342.
6. **Fageria, N.K., Slaton, N.A. and Baligar, V.C. (2004).** Nutrient management for improving lowland rice productivity and sustainability. Adv. Agron., **80**: 63- 152.
7. **Fageria, N.K., Moreira, A. and dos Santos, A.B. (2013).** Phosphorus uptake and use efficiency in field crops. J. Plant Nutr., **36:** 2013-2022.
8. **Gharib, H. S.1 ; B. A. A. Zayed2 ; S. Gh. R. Sorour1 and Amira M. E. Okasha. (2011).** Effect of zinc and phosphorus fertilization on rice crop under saline soil conditions. Plant Production, Mansoura Univ., Vol. **2** (5): 755 – 771.
9. **Gulshan naheed, Muahmmad shahbaz and Nudrat aisha akram. (2008).** Interactive effect of rooting medium application of phosphorus and nacl on plant biomass and mineral nutrients of rice (oryza sativa l.). Pak. J. Bot., **40**(4): 1601-1608.
10. **Himanshu, Ali Javed, Singh SP, Singh Sandeep. (2013)**. Response of fababean to boron, zinc and sulphur spplication in alluvial soil. Journal of the Indian Society of Soil Science**. 61**(3):202-206.

11. **Ishizuka, Y. (1971).** Physiology of rice plant. Advs. Agro.,**23**:241-315
12. **Ionov FV, Ionova VG.** (1977). Fertilization of rice under conditions of high phosphate level of chestnut soils. ShornilsStatei, DonskoiSel, sKokhozyais. **12**(1):107-111.
13. **Jones, J. R. & Benton. J. (2012).** Fifth. Iron Chelation in Plants and Soil Microorganisms, 447.
14. **M. Umar Khan, M. Qasim and Israrullah Khan. (2007).** effect of zn fertilizer on rice grown in different soils of dera Ismail khan. Sarhad J. Agric. **23** (4)
15. **Maclean, J.C., Dawe, D.C., Hardy, B. and Hettel, G.P. (2002).** Rice almanac (3rd edition) CABI publishing willing ford, p. 253.
16. **Md. Ibrahim Ali1, M. A. Islam , Q. A. Khaliq and M. A. Rouf. (2019).** Effect of Zinc Fertilizer Application on Growth Yield and Yield Contributing Characters in Rice. Asian Journal of Advances in Agricultural Research **9**(2): 1-10.
17. **Memon, K. S. and H. K. Puno. 2005.** Effect of different nitrogen and phosphorus levels on the yield and yield components of wheat variety Pavan. Agriculture Research Station Dadu, Sindh, Pakistan. Indus. J. Plant Sci., **4(**3): 273-277
18. **Muhammad Atif Majeed1 , Rashid Ahmad2 , Muhammad Tahir1 , Asif Tanveer1 and Muhammad Ahmad. (2014).** Effect of phosphorus fertilizer sources and rates on growth and yield of wheat (*Triticum aestivum* L.). Asian J Agri Biol. **2**(1):14-19.
19. **Naik SK, Das DK (2007)**. Effect of split application of zinc on yield of rice (Oryza sativa L.) in an inceptisol. Arch Agron. Soil Sci **53**(3):305–313
20. **Rahman et al. (1996)**. Effect of phosphorus applied as superphosphate on rate of development and spikelet number per ear of different cultivars of wheat. Australian. J. of Agr. Res., **28**(2): 183– 86.
21. **Rana, W.H. and S.R. Kashif (2014).** Effect of different zinc sources and methods of application on rice yield and nutrients concentration in rice grain and straw. Journal of Environmental and Agricultural Sciences, 1–9.
22. **S.R. Kadam, V.M. Bhale, A.B. Chorey and M.R. Deshmukh. (2018).** Influence of Zinc and Iron Fortification on Yield and Post-Harvest Studies of Different Rice Cultivars (Oryza sativa L.). Int.J.Curr.Microbiol.App.Sci **7(**1): 1878-1888.
23. **Sanzo R, Saborit R, Yara VC. (1989).** Effect of zinc on the yield of rice cultivar J 104 and on plant iron and zinc content. Ciencia-YTencia-en-la. Agriclutura.**12**(1):123- 127

24. **Satish mishra, Akhtar ali, A.K. singh, Gajendra singh and R.R. singh. (2017).** Response of late sown wheat to phosphorus and zinc nutrition in eastern Uttar Pradesh. Annals of Plant and Soil Research **19**(1): 23 – 28
25. **Shaik Wasim Akram, Rajesh Singh, Pratyasha Tripathi and Gera Roopa Lavanya. (2022).** Effect of Phosphorus and Sulphur on yield and economics of Wheat *(Triticum aestivum* L.). The Pharma Innovation Journal **11**(5): 599-602.
26. **Singh, N.; Yadav, R.K.; Prasad S. and Dikshit, S. (2011)**. Physio- chemical response of appropriate zinc application on wheat under sodic soil condition. Asian Journal Bio-Science **6**(1):46-50.
27. **Slaton NA, Norman RJ, Wilson EC. (2005).** Effect of zinc sources and application time on zinc uptake and grain yield of flood-irrigated rice. Agronomy Journal. **97**:272-278.
28. **Sudhagar Rao G.B., R. Rex Immanuel*, S. Ramesh, G. Baradhan and S.M. Sureshkumar. (2019).** Effect of zinc and iron fertilization on growth and development of rice. Plant Archives. **19**(2):1877-1880
29. **Waikhom Jiten Singh, Mahua Banerjee1 and L. Nabachandra Singh. (2018).** Effect of Sulphur and Zinc on Yield Attributes, Yield and Economics of Rice. Int.J.Curr.Microbiol.App.Sci **7**(3): 531-537.