
*International Journal of Environment and Climate Change*

***Volume 13, Issue 8, Page 162-169, 2023; Article no.IJECC.99895***
***ISSN: 2581-8627***
*(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)*

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

**M. G. Thrupthi [a++*], Victor Debbarma [a#] and Darla Harika [a++]**

[a] *Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj–211007, Uttar Pradesh, India.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/IJECC/2023/v13i81941

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/99895

***Original Research Article***

***Received: 05/03/2023***
***Accepted: 08/05/2023***
***Published: 22/05/2023***

## 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 experiment was laid out in Randomized Block Design comprising of 10 treatments which include of three levels three Phosphorus viz @ 50,60 and 70 kg/ha. and three levels of micronutrients viz. Zinc @ 10kg/ha, Iron @ 15kg/ha and Boron @ 4 kg/ha.The results showed that treatment 7 [Phoshorus (70 kg/ha)+ Zinc(10 kg/ha)] recorded significantly higher plant height, number of of tillers/hill, plant dry weight (g), number of panicles/plant, number of grains/panicle, test weight, grain yield, straw yield and harvest index.

*Keywords: Rice; phosphorus; micronutrients; growth; yield.*

---

[++] *M.Sc. Scholar;*
[#] *Assistant Professor;*
**Corresponding author: E-mail: thrupthimg2699@gmail.com;*

## 1. INTRODUCTION

Rice is a majore staple food of (70%) of Indian population, it provide (21%) and (15%) dietary protein and energy per capita, respectively [1] if Carbohydrate (starch), which is another material that offers rapid energy, is also extremely important. Starch-rich rice flour is used to make a variety of culinary products. In some cases, brewers use it to create alcoholic malt. Likewise, proclean, glass, and pottery are made from rice straw combined with other elements. In addition, rice is used to make paper pulp and bedding for animals [2].

The yield of the 165.12 million ha of rice grown globally is around 4.61 metric tons/ha, and the total production is 509.42 million tonnes [3]. India has the largest rice-growing area and is the second-largest producer of rice in the world, after the wheat. Rice is grown on 45.07 million ha in India, with a yield of roughly 2713 kg/ha and a production level of 122.27 million metric tonnes [4]. The state of Uttar Pradesh is third in the country for rice production. It occupies an area of 5.68 million hectares and contributes to 13.5% of all the rice produced in India. 15.66 million metric tonnes of rice are grown annually, with a yield average of 2759 kg/ha [4].

One of the major problems to crop production is a phosphorus deficiency. Due to slow diffusion and strong soil fixation, P has a special property that makes it limited. After nitrogen, phosphorus is the second most important nutrient for plant growth since it is an essential component of several biochemicals, including nucleic acids, nucleotides, phospholipids, and phosphoproteins. The capacity of plants to carry out various functions, including the process of photosynthesis nitrogen fixation, flowering, seed formation, root development, and crop maturity, is improved by proper P nutrition. According to discoveries, P fertilizer decreased the amount of $Na+$ in shoots, which improved rice survival, growth, and yield [5]. Additionally, phosphorus has a major part in the molecule ATP, which gives that plant energy for actions like respiration, nutrient uptake, and nutrient translocation. In addition, phosphorus is a component of other compounds required for the transfer of DNA and RNA and for the synthesis of proteins.

Micronutrients are just as essential to plant nutrition as macronutrients, and their deficiency is one of the primary contributors causing declining productivity trends in countries where rice is grown. Micronutrients are only required in trace amounts, but their adequate supply increases nutrient availability and has a positive impact on cell physiology, which is reflected in yield as well. Crop growth and results suffer significantly when micronutrient levels are low. Insufficient levels of micro nutrients make it impossible for plants to benefit fully from the use of NPK fertilizers.

In India, after phosphorus, potassium, and nitrogen, respectively, zinc is considered as the fourth important nutrient that limits crop productivity. In addition to being an important micronutrient for the proper growth and metabolism of the plant, zinc is essential to ensuring the integrity of plant membranes and for the activation of enzymes like alkaline phosphatase, carbonic anhydride, super oxide dismutase, and hydrolyzes.

The global and regional food security is seen to be severely compromised by zinc (Zn) lack among the micronutrients [6] Zinc lack resulted in lower yields and Zn malnutrition among people in regions with significant consumption of rice. It was later discovered to be a common problem in Asia's lowland rice regions, together with N and P shortages. At the seedling stage in a nursery and three weeks after transplanting to the main field, rice begins to show signs of zinc deficiency. Low plant-available Zn in the soil delays maturity and significantly decreases production in rice by causing leaf bronzing and poor tillering in the early stages of growth. Application of zinc sulphate ($ZnSO_4$) before flooding or after transplanting is usually employed to treat zinc deficiency with the goal to prevent Zn deficiency and increased grain yield [7].

For crops to develop and develop, iron (Fe) is one of the basic metals required. Fe is the micronutrient that plants need the most of the seven [8]. It helps in the production and breakdown of chlorophyll in addition to the synthesis of proteins and nucleic acids. Iron is a constituent of ferredoxins and iron porphyrins, both of which are essential elements in the light phase of photosynthesis. Iron also plays a significant part in respiration and growth of healthy, green leaves. Iron is also necessary for electron transport in photosynthesis. Catalase, which succinic dehydrogenase, and aconitase are just a few of the enzymes that it activates.

Inadequate boron delays flowering, causes flower bud abortion, and makes panicles sterility

[9] affects plasma membrane integrity, structure, and cell wall biosynthesis as well. Inadequate levels of boron in rice plants result in undeveloped leaves that are white and rolled at the tips, the death of growing points, and, if affected at the time of panicle development, the inability to create panicles. For lignification, nucleotide synthesis, respiration, pollen viability, carbohydrate metabolism, sugar transport, and other processes, boron is required. According to [10] mineral carbonate can affect photosynthesis and activate a variety of enzyme systems involved in the metabolism of nucleic acids and proteins in plants.

In considering the previously mentioned fact, an experiment has been carried out to find out the "Influence of Phosphorus and Micronutrients on Growth and Yield 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 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 data was computed and analysed by following statistical method of Gomez and Gomez [11].

## 3. RESULTS AND DISSCUSSION

### 3.1 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 application of phosphorus (70 kg/ha) resulted in a significant and higher plant height, which may be due to Phosphorus, stimulates root development and growth in the seedling stage and thereby it helps to establish the seedling quickly. Similar results were reported by Majeed et al. [12] in wheat. In addition, the application of Zn (10 kg/ha) increase plant height. This might be attributed to Zn's role in the biosynthesis of indole acetic acid (IAA) and, in particular, to its role in the beginning of primordial for reproductive parts and the partitioning of photosynthesis towards them, which enhanced flowering and fruiting and raised plant height. These results similar to Himanshu et al. [13].

### 3.2 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).

With the application of phosphorus (70 kg/ha), a significant and higher number of tillers appeared on each hill. This might be due to improved the nutritional status of mother culm in its early growth. Similar result were reported by Figeria et al. [14] in wheat. In addition, an increase in number of tillers/hill with zinc application (10 kg/ha) could be due to increased nitrogen fixation, protein synthesis, chlorophyll synthesis, and photosynthetic growth in response to zinc application. Reported similar result Rao et al. [15].

**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 |

### 3.3 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 application of phosphorus (70 kg/ha) resulted in significantly higher plant dry weight, which may be related to increased phosphorus supply caused on by increased root proliferation and increased levels of nutrients in the soil, which speed up cell division and increasing and lead to higher plant dry weight. Sathish et al. [16] Reported the same finding 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. In wheat, Singh et al. [17] and Choudary et al. [18] reported findings that were comparable.

### 3.4 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).

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. [19] In addition, a faster rate of crop growth was observed after zinc (10 kg/ha) application. This could be explained through xylem and phloem certainly-translocation, which boost photosynthetic activity and increase the synthesis of vegetative tissue, which slows the fast growth of the plant's components and raises dry matter. The same result was reported in Rao et al. [15].

## 3.5 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).

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.in wheat were reported by Satish et al. [16] In addition, a higher relative growth rate was found with the application of zinc (10 kg/ha). This may be because zinc, which plays a role in many metallic enzyme structures, regulatory functions, and auxin production, has aided plant growth. Slaton et al. [20] reported a similar result.

## 3.6 Yield Parameters

### 3.6.1 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 application of phosphorus (70 kg/ha), which significantly increased the number of panicles per plant, may have been a result of balanced fertiliser application. Phosphorus also encouraged normal plant growth, which led to an increase in the number of panicles each plant. Rehman et al. [9] and Memon et al. [21] noticed similar findings in wheat. In addition, the application of zinc (10 kg/ha) resulted in a higher number of panicles per plant, which may be due to the adequate supply of zinc expanding the availability and uptake of other crucial nutrients that improve crop growth. Sanzo et al. [22] reported a similar result.

### 3.6.2 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).

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. Ishizuka [23] reported a similar result. Zinc (10 kg/ha) use additionally resulted in a higher number of grains per panicle, which may have been caused by a boost in the crop's physiological processes such as photosynthesis and the transport of plant nutrients. Lonova [24] reported a similar finding.

### 3.6.3 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 that was noted with the application of phosphorus (70 kg/ha) may be due to the fact that phosphorus is essential for enzyme reactions that depend on phosphorylase as well as for cell division and the development of meristem tissue. Juwita et al. [25] reported a similar result. In addition, the increase in test weight noticed with zinc application (10 kg/ha) may be due to zinc's more effective participation in the various metabolic processes necessary for the production of healthy seeds. Ali et al. [26] reported a similar result.

## 3.7 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 that occurred with the application of phosphorus (70 kg/ha) could be due to more phosphorus being available to support the rice plant's metabolic processes, root development, and energy conversion, which in turn led to a greater translocation of photosynthesis to the productive part and increased grain yield. Gharib et al. [27] reported a similar result. In addition, a significant and higher grain yield was observed with the application of zinc (10 kg/ha). This may be as zinc participates in many metallic enzyme structures, controls auxin production, and plays a role in the control of many metallic enzyme systems, all of which help to a higher grain yield. Ali et al. [26] reported a similar finding.

### 3.8 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 that occurred with phosphorus application (70 kg/ha) may be due to increased phosphorus availability and thus, increased phosphorus uptake. This increased ATP formation, which is the main source of energy for crops, may encourage rice growth, metabolism, photosynthesis, and nucleic acid in addition to improvement in biomass production and sink formation, resulting in increases in straw yield. Gharib et al. [27] and Yadav et al. [28] also reported results that were comparable. In addition, a significant and higher yield of straw was found with the application of zinc (10 kg/ha). It may be due to zinc's beneficial impact on root proliferation, which improves the uptake of nutrients by plants from the soil and materials them to their aerial parts, ultimately promoting the vegetative growth of plants. Khan et al. [29] reported a similar result.

### 3.9 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).

**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 |

The significant and higher harvest index that was found with the application of phosphorus (70 kg/ha) could be due to enhanced cell activities, increased cell multiplication and enlargement, and luxuriant growth and yield attributes of the crops. This could be because more nutrients were absorbed and utilised, which improved the overall growth of the crops and the source-sink relationship, leading to an increase in yield. In wheat, Akram et al. [30] reported a similar result. In addition, a higher harvest index was found with the application of zinc (10 kg/ha). This may be related to the maximum dry matter partitioning towards grain, which increased grain yield, as well as the plant's capacity to maintain a higher supply of photosynthates in reproductive parts than in vegetative biomass. Singh et al. [31] and Kadam et al. [32] reported a similar result.

## 4. 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.

## ACKNOWLWDGEMENT

The authors are thankful to Department of Agronomy, Naini Agricultural Institute, Prayagraj, Sam Higginbottom University of Agriculture Technology And Sciences, (U.P) India for providing necessary facilities to undertaken the studies.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Maclean JC, Dawe DC, Hardy B, Hettel GP. Rice almanac (3rd edition) CABI Publishing Willing Ford. 2002:253.
2. Atique-ur-Rehman, Muhammad Farooq, Abdul Rashid, Faisal Nadeem, Sabine Stuerz, et al. Boron nutrition of rice in different production systems. A review. Agronomy for Sustainable Development 2018;38:25.
3. USDA. Foreign Agricultural service, World Agricultural production; 2022. Available:https://apps.fas.usda.gov
4. GOI. Ministry of Agriculture and Farmers Welfare; 2021. Available:www.agricoop.nic.in
5. Gulshan Naheed, Muahmmad Shahbaz, Nudrat Aisha Akram. Interactive effect of rooting medium application of phosphorus and nacl on plant biomass and mineral nutrients of rice (*Oryza sativa* l.). Pak. J. Bot. 2008;40(4):1601-1608.
6. Rana WH, Kashif SR. 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. 2014:1–9.
7. Naik SK, Das DK. Effect of split application of zinc on yield of rice (*Oryza sativa* L.) in an inceptisol. Arch Agron. Soil Sci. 2007;53(3):305–313.
8. Jones JR, Benton J. Fifth. Iron chelation in plants and soil microorganisms. 2012;447.
9. Rahman et al. 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. 1996;28(2):183–86.
10. Choudhary S, Zehra A, Naeem M, Khan M, Aftab T. 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. 2020;7(1): 1-11.
11. Gomez KA, Gomez AA. Three or more factor experiment. (In:) Statistical Procedures for Agricultural Research 2nd ed. 1976:139-141.
12. Muhammad Atif Majeed, Rashid Ahmad, Muhammad Tahir, Asif Tanveer, Muhammad Ahmad. Effect of phosphorus fertilizer sources and rates on growth and yield of wheat (*Triticum aestivum* L.). Asian J Agri Biol. 2014;2(1):14-19.
13. Himanshu, Ali Javed, Singh SP, Singh Sandeep. Response of fababean to boron, zinc and sulphur spplication in alluvial soil. Journal of the Indian Society of Soil Science. 2013;61(3):202-206.
14. Fageria NK, Slaton NA, Baligar VC. Nutrient management for improving lowland rice productivity and sustainability. Adv. Agron. 2004;80:63-152.
15. Sudhagar Rao GB, Rex Immanuel R, Ramesh S, Baradhan G, Sureshkumar SM. Effect of zinc and iron fertilization on growth and development of rice. Plant Archives. 2019;19(2):1877-1880.
16. Satish Mishra, Akhtar Ali, Singh AK, Gajendra Singh, Singh RR. Response of late sown wheat to phosphorus and zinc

nutrition in eastern Uttar Pradesh. Annals of Plant and Soil Research. 2017;19(1):23–28.

17. Singh N, Yadav RK, Prasad S, Dikshit S. Physio- chemical response of appropriate zinc application on wheat under sodic soil condition. Asian Journal Bio- Science. 2011;6(1):46-50.
18. Chaudhary S, Singh H, Singh S, Singh V. Zinc requirement of greengram (*Vigna radiate*)-wheat (*Triticum aestivum* L.*)* crop sequence in alluvial soil. Indian Journal of Agronomy. 2014;59(1):48-52.
19. Fageria NK, Moreira A, et al. Phosphorus uptake and use efficiency in field crops. J. Plant Nutr. 2013;36:2013-2022.
20. Slaton NA, Norman RJ, Wilson EC. Effect of zinc sources and application time on zinc uptake and grain yield of flood-irrigated rice. Agronomy Journal. 2005; 97:272278.
21. Memon KS, Puno HK. 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. 2005;4(3):273-277.
22. Sanzo R, Saborit R, Yara VC. Effect of zinc on the yield of rice cultivar J 104 and on plant iron and zinc content. Ciencia-YTencia-en-la. Agriclutura. 1989;12(1): 123-127.
23. Ishizuka Y. Physiology of rice plant. Advs. Agro. 1971;23:241-315.
24. Ionov FV, Ionova VG. Fertilization of rice under conditions of high phosphate level of chestnut soils. Shornils Statei, DonskoiSel, sKokhozyais. 1977;12(1):107-111.
25. Fadma Juwita Nasution, Hamidah Hanum, Jonatan Ginting. Effect of dose and time application of phosphorus fertilizer on phosphorus availability, growth and production of rice (*Oryza sativa* L.) AIP Conference Proceedings. 2021;2342.
26. Md. Ibrahim Ali, Islam MA, Khaliq QA, Rouf MA. Effect of zinc fertilizer application on growth yield and yield contributing characters in rice. Asian Journal of Advances in Agricultural Research. 2019; 9(2):1-10.
27. Gharib HS, Zayed BAA, Sorour SGhR, Amira ME Okasha. Effect of zinc and phosphorus fertilization on rice crop under saline soil conditions. Plant Production, Mansoura Univ. 2011;2(5):755–771.
28. Devideen yadav1, Singh YV, Dinesh Kumar, Sunita Gaind, Anil Kumar. Influence of sources and rates of phosphorus on plant growth, productivity and economics of aerobic rice (*Oryza sativa* L.). Indian Journal of Agronomy. 2015;60(1):157159.
29. Umar Khan M, Qasim M, Israrullah Khan. Effect of Zn fertilizer on rice grown in different soils of dera Ismail khan. Sarhad J. Agric. 2007;23(4).
30. Shaik Wasim Akram, Rajesh Singh, Pratyasha Tripathi, Gera Roopa Lavanya. Effect of Phosphorus and Sulphur on yield and economics of Wheat *(Triticum aestivum* L.). The Pharma Innovation Journal. 2022;11(5):599-602.
31. Waikhom Jiten Singh, Mahua Banerjee, Nabachandra Singh L. Effect of sulphur and zinc on yield attributes, yield and economics of rice. Int. J. Curr. Microbiol. App. Sci. 2018;7(3):531-537.
32. Kadam SR, Bhale VM, Chorey AB, Deshmukh MR. 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 2018;7(1):1878-1888.



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*https://www.sdiarticle5.com/review-history/99895*