



Influence of Phosphorus and Zinc Nutrition on Growth and Yield of Wheat

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Authors' contributions

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

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ABSTRACT

A field experiment was conducted during *Rabi* season of 2020-21 at Agronomy Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The soil of experimental field was loamy sand in texture with neutral in reaction (pH 7.01) and electrical conductivity within safe limit (0.19 dSm⁻¹). The soil was low in organic carbon content (0.39 %), DTPA-extractable Fe (2.59 mg kg⁻¹), DTPA-extractable Mn (4.51 mg kg⁻¹); medium in available P₂O₅ (41.26 kg ha⁻¹), K₂O (162.65 kg ha⁻¹), DTPA-extractable Zn (0.71 mg kg⁻¹) and DTPA-extractable Cu (0.31 mg kg⁻¹). The experiment consisted of two factors each having four levels each of phosphorus (P₀–0 kg P₂O₅ ha⁻¹, P₁–30 kg P₂O₅ ha⁻¹, P₂–60 kg P₂O₅ ha⁻¹ and P₃–90 kg P₂O₅ ha⁻¹) and zinc (Zn₀–0 kg Zn ha⁻¹, Zn₁–2.5 kg Zn ha⁻¹, Zn₂–5.0 kg Zn ha⁻¹ and Zn₃–7.5 kg Zn ha⁻¹). Total sixteen treatment combinations were laid out in randomized block design with factorial concept and replicated three times. The results revealed that application of 90 kg P₂O₅ ha⁻¹ (P₃) and 7.5 kg Zn ha⁻¹ recorded significantly the higher no. of effective tillers/plant, length of ear

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head, no. of spikelets per ear head and grain and straw yields; which was found at par with 60 kg P₂O₅ ha⁻¹ and 5.0 kg Zn ha⁻¹. Thus, application of 90 kg P₂O₅ ha⁻¹ + 7.5 kg Zn ha⁻¹ in wheat were optimum doses for obtaining higher productivity, growth parameters.

Keywords: Phosphorus; zinc; wheat; quality.

1. INTRODUCTION

“The acceptance of wheat (*Triticum* spp.) as “Staff of life or king of cereals” and one of the most important staple food crops. Family of wheat is *poaceae*. Followed by rice, wheat is the second most important food grain crop of India. This crop is mainly responsible for the green revolution and mitigating the problem of food insecurity in India. About 35 per cent of the world’s population directly or indirectly depends upon wheat for food and providing 20 per cent of human dietary and serving as the main source of protein in developing actions. The nutritive value of wheat is fairly high as compared to other cereals; it contains 11.80, 1.50, 71.20, 1.50, 0.50 and 0.32 per cent protein, fat, carbohydrates, mineral matter, calcium and phosphorus, respectively” (Swaminathan *et al.*, 1981). Apart from food purposes, wheat grains have also industrial importance for manufacturing paste, alcohol, gluten, *etc.* Residues obtained after milling *i.e.* bran used as cattle feed. Wheat straw is utilized as a fodder for feeding the livestock and also useful in manufacturing mattresses, straw hats, paper and articles of art purposes.

“India occupies second position next to China in the world with regard to area 29.14 million hectares and production 102.19 million tonnes with average productivity of 35.07 q ha⁻¹ of wheat” (Anon., 2018-19). “It is an important winter cereal contributing about 32.04 % of the total food grain production in India. Major states *viz.*, UP, MP, Punjab, Rajasthan, Haryana and Bihar occupy 32.74%, 18.95%, 12.08%, 10.29%, 8.76% and 7.23% area of total wheat cultivation in India, respectively. whereas UP, Punjab, MP, Haryana, Rajasthan and Bihar share are 32.04%, 17.85%, 15.14%, 12.30%, 10.27% and 6.02% in total production of wheat in India. In India, the highest productivity of wheat is recorded in Punjab, whereas Gujarat stands 7th rank with productivity of 3010 kg ha⁻¹. In Gujarat, wheat has an area of 7.97 lakh hectares with the production of 2.4 million tonnes. The average productivity of wheat in the state is 30.19 q ha⁻¹” (Anon, 2018-19). In Gujarat, wheat is being cultivated under irrigated as well as rainfed conditions. Gujarat ranks 7th in area, 7th in production and 5th in terms of wheat yield per

hectare in India. The most important wheat growing districts of the state are Junagadh, Ahmedabad, Sabarkantha, Rajkot, Kheda, Banaskantha, Mehsana and Bhavnagar.

“Phosphorus is one of the most important major nutrients required for the growth and development of crop plants. It plays a vital role in virtually every plant process like photosynthesis, energy storage and transfer, stimulating root development and growth, giving plant rapid and vigorous start leading to better tillering in wheat and encouraging earlier maturity and seed formation. Phosphorus is component of DNA and RNA, which carries genetic information used to synthesize proteins. It also has a significant role in sustaining and building up of soil fertility, particularly under intensive system of agriculture. But phosphorus is one of the most immobile, inaccessible and unavailable nutrients presents in the soil. Deficiency of soil phosphorus is one of the important chemical factors restricting plant growth in soil. Therefore, sufficient quantity of soluble form of phosphorus fertilizers is applied to achieve maximum plant productivity. However, the applied soluble forms of phosphatic fertilizers rapidly become unavailable to plants by conversion into inorganic P fractions that are fixed by chemical adsorption and precipitation. Similarly, organic P fractions are immobilized in soil organic matter” (Swaminathan *et al.*, 1981).

“Zinc is an essential element for the normal growth and development of plants. It plays vital role in enzyme activation and also involved in the biosynthesis of some enzymes and growth hormones” (Marschner, 1993). “Zinc deficiency is a very important nutrient problem in the Indian soils. Total Zn concentration is sufficient in many agricultural areas, but available Zn concentration is deficient because of different soil and climatic conditions. Soil pH, lime content, organic matter content, clay type and amount and the amount of applied phosphorus fertilizer affect the available Zn concentration in soil” (Adiloglu and Adiloglu, 2006). In soil Zn deficiency is very common in cereal based cropping system (Cakmak, 2002). “Zinc deficiency is a prevalent micronutrient deficiency in wheat, leading to severe reduction in wheat production and nutritional quality of grains” (Cakmak *et al.*, 1999). “Zinc exerts a

great influence on basic plant life processes, such as nitrogen metabolism and uptake of nitrogen and protein quality; photosynthesis and chlorophyll synthesis, carbon anhydrase activity; resistance to abiotic and biotic stresses and protection against oxidative damage” (Swaminathan et al., 1981).

“In wheat, high soil P supply induced Zn deficiency which was the main cause for reduced shoot growth. In maize, high soil P supply resulted in reduced shoot growth and higher than adequate shoot P concentrations and lower than adequate shoot Zn concentrations suggested that P toxicity and Zn deficiency were the main contributing factors for reduced shoot growth” (Kizilgoz and Sakin, 2010).

2. MATERIALS AND METHODS

A field experiment entitled “effect of phosphorus and zinc application on growth, yield and quality of wheat in loamy sand” was carried out during *Rabi*, season 2020-21. The experiment was carried out at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha (Gujarat) during *Rabi*, season 2020-21. Geographically, this place is located at 72°19' East longitude and 24°19' North latitude at 154.52 meters above the mean sea level and situated in North Gujarat agro climatic zone of Gujarat state. The soil of the experimental field had a uniform topography with gentle slope with good drainage. In order to know the physico-chemical properties of the soil before sowing a composite soil sample was taken from the experimental field to know the initial status of nutrients in soil as well as physico-chemical properties of soil. The soil of experimental field was loamy sand in texture with neutral in reaction (pH 7.01) and electrical conductivity within safe limit (0.19 dSm⁻¹). The soil was low in organic carbon content (0.39 %), DTPA-extractable Fe (2.59 mg kg⁻¹), DTPA-extractable Mn (4.51 mg kg⁻¹); medium in available P₂O₅ (41.26 kg ha⁻¹), K₂O (162.65 kg ha⁻¹), DTPA- extractable Zn (0.71 mg kg⁻¹) and DTPA- extractable Cu.

The experiment consisted of two factors each having four levels each of phosphorus (P₀ - 0 kg P₂O₅ ha⁻¹, P₁ - 30 kg P₂O₅ ha⁻¹, P₂ - 60 kg P₂O₅ ha⁻¹ and P₃ - 90 kg P₂O₅ ha⁻¹) and zinc (0 kg Zn ha⁻¹, 2.5 kg Zn ha⁻¹, 5.0 kg Zn ha⁻¹ and 7.5 kg Zn ha⁻¹). Total sixteen treatment combinations were laid out in randomized block design with factorial concept and replicated three times. Wheat

variety GW- 451 was sown at a row distance of 22.5 cm. The weather conditions were almost favorable for the crop growth and there was no any severe attack of insect and disease during the course of investigation.

3. RESULTS AND DISCUSSION

3.1 Plant Population Per Meter Row Length 60 DAS

A perusal of data presented in Table 1 showed that plant population per meter row length 60 DAS did not differ significantly due to different levels of phosphorus. The results clearly indicated that plant population per meter row length was uniform. Hence, various growth and yield attributes as well as yield of wheat crop was not influenced due to variation in the plant population. These findings are in agreement with those of Jat *et al.* (2018) in wheat. The maximum plant population per meter row length 60 DAS (29.31) was observed with the application of 90 kg P₂O₅ ha⁻¹; while minimum plant population per meter row length 60 DAS (27.28) was noted under control.

The data given in Table 1 indicated that different levels of zinc had no significant effect on plant population per meter row length 60 DAS. Application of zinc @ 7.5 kg ha⁻¹ obtained maximum plant population (29.31) per meter row length 60 DAS and minimum plant population (29.03) per meter row length 60 DAS was noted under control. Comparable outcomes have been accounted for by Jat *et al.* (2018). The interaction effect of P and Zn failed to show its significant effect on plant population per meter row length at harvest.

3.2 Plant Height

A perusal of data presented in Table 1 showed that plant height (cm) at harvest did not differ significantly due to different levels of phosphorus. The maximum plant height (92.76 cm) measured at harvest was observed with the application of 90 kg P₂O₅ ha⁻¹; while minimum plant height (86.71 cm) was recorded under control. The data presented in Table 1 indicated that different levels of zinc had no significant effect on plant height (cm) at harvest. The maximum plant height (92.22 cm) measured at harvest was recorded with the application of Zn @ 7.5 kg ha⁻¹; while, the minimum plant height (87.29 cm) was recorded under control. The interaction effect of phosphorus and zinc failed to show its significant effect on plant height (cm) at harvest.

3.3 Number of Effective Tillers Per Plant

The results presented in Table 2 shows that effect of different levels of phosphorous on no. of effective tillers/plant was found to be significant. The maximum no. of tillers/ plant (8.78) was found with the application of 90 kg P₂O₅ ha⁻¹ and lowest (5.72) was observed at control. The treatment 90 kg P₂O₅ ha⁻¹ gave significantly higher no. of effective tillers/ plant over the control. However, it was at par with 60 kg P₂O₅ ha⁻¹. The magnitude of increase in mean number of effective tillers per plant due to P₂O₅ @ 90 kg ha⁻¹ was 53.49 and 24.18 percent over control and 30 kg P ha⁻¹, respectively. Reason for the highest no. of effective tillers from the plots that were treated with 90 kg P₂O₅ ha⁻¹ is that phosphorus enhances many physiological processes and also enhances respiration, cell enlargement and cell division. These results are in conformity with the findings of Bairwa *et al.* (2018) and Savaliya *et al.* (2017).

The results presented in Table 2 illustrates that application of zinc significantly influenced the no. of effective tillers/ plant. Significantly higher no. of effective tillers/ plant (8.44) was recorded with the application of 7.5 kg Zn ha⁻¹; while the lowest no. of effective tillers/ plant (6.71) was recorded with control. Application of 7.5 kg Zn ha⁻¹ significantly increased mean number of effective tillers per plant by 25.78 and 19.37 per cent over control and 2.5 kg Zn ha⁻¹, respectively. Similar result was reported by Khan *et al.* (2008) and

Yadav *et al.* (2015). The interaction effect of levels of phosphorus and zinc failed to show its significant effect on number of effective tillers per plant.

3.4 Length of Ear Head

Examination of results recorded in Table 2 indicated that effect of different levels of phosphorus show significant difference in length of ear head. Significantly higher length of ear head (12.26 cm) was observed with the application of phosphorus @ 90 kg ha⁻¹; which was found at par with 60 kg P ha⁻¹. Application of 90 kg P₂O₅ ha⁻¹ increased length of ear head by 13.83 and 6.70 per cent over control and 30 kg P₂O₅ ha⁻¹, respectively. It was observed that application of 90 kg P₂O₅ ha⁻¹ significantly increased the number of effective tillers, number of grains per spike, spike length. This could be attributed to overall improvement in crop growth as reflected by plant height, dry matter accumulation, number of tillers and chlorophyll content in leaves. The favorable effect of phosphorus fertilization on yield components might be due to the fact that phosphorus plays a key role in the root development, energy transformation and various vitally important metabolic processes in plant. Dewal and Pareek (2004) also observed "beneficial effect of phosphorus on the fruiting of plants and ascribed this beneficial effect to better translocation of desired metabolites to the yield contributing parts of the plant".

Table 1. Effect of phosphorus and zinc application on plant population and plant height at harvest of wheat

Treatment	Plant population at 60 DAS (per meter row length)	Plant height (cm)
Phosphorus levels (kg ha⁻¹)		
P ₀ : 0 kg P ₂ O ₅ ha ⁻¹	27.28	88.70
P ₁ : 30 kg P ₂ O ₅ ha ⁻¹	28.56	86.71
P ₂ : 60 kg P ₂ O ₅ ha ⁻¹	28.81	91.25
P ₃ : 90 kg P ₂ O ₅ ha ⁻¹	29.31	92.76
S.Em. ±	0.77	1.78
C.D. (P = 0.05)	NS	NS
Zinc levels (kg ha⁻¹)		
Zn ₀ : 0 kg Zn ha ⁻¹	27.95	87.29
Zn ₁ : 2.5 kg Zn ha ⁻¹	28.20	88.90
Zn ₂ : 5.0 kg Zn ha ⁻¹	28.78	91.01
Zn ₃ : 7.5 kg Zn ha ⁻¹	29.03	92.22
S.Em. ±	0.77	1.78
C.D. (P = 0.05)	NS	NS
Interaction		
P x Zn	NS	NS
C.V. (%)	9.37	6.85

Table 2. Effect of phosphorus and zinc application on number of effective tillers per plant, length of ear head and number of spikelets per ear head of wheat

Treatment	Number of effective tillers per plant	Length of ear head (cm)	No. of spikelets/ear head
Phosphorus levels (kg ha⁻¹)			
P ₀ : 0 kg P ₂ O ₅ ha ⁻¹	5.72	10.77	14.90
P ₁ : 30 kg P ₂ O ₅ ha ⁻¹	7.07	11.49	15.81
P ₂ : 60 kg P ₂ O ₅ ha ⁻¹	8.42	11.52	15.98
P ₃ : 90 kg P ₂ O ₅ ha ⁻¹	8.78	12.26	16.85
S.Em. ±	0.21	0.26	0.39
C.D. (P = 0.05)	0.59	0.74	1.14
Zinc levels (kg ha⁻¹)			
Zn ₀ : 0 kg Zn ha ⁻¹	6.71	11.07	15.03
Zn ₁ : 2.5 kg Zn ha ⁻¹	7.01	11.24	15.77
Zn ₂ : 5.0 kg Zn ha ⁻¹	7.83	11.63	16.05
Zn ₃ : 7.5 kg Zn ha ⁻¹	8.44	12.10	16.69
S.Em. ±	0.21	0.26	0.39
C.D. (P = 0.05)	0.59	0.74	1.14
Interaction			
P x Zn	NS	NS	NS
C.V. (%)	9.50	7.70	8.58

It is evident from the data (Table 2) that length of ear head was significantly affected due to different doses of zinc. Application of Zn @ 7.5 kg ha⁻¹ observed significantly higher length of ear head (12.10 cm) as compared to control; which was found at par with 5.0 kg Zn ha⁻¹. Application of Zn @ 7.5 kg ha⁻¹ increased mean length of ear head by 9.3 and 7.65 per cent over control and 2.5 kg Zn ha⁻¹, respectively. Reason for increase length of ear head is fertilization with zinc at the rate of 5.0 kg Zn ha⁻¹ significantly increased the number of effective tillers, spike length and number of grains per spike of wheat crop. The increase in yield attributes is due to increased supply of available zinc to plants through its addition to soil which resulted in proper growth and development as discussed earlier. The increase in yield attributes might be due to role of zinc in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordia for reproductive parts and partitioning of photosynthates towards them, which resulted in better flowering and fruiting. Khan *et al.* (2008) and Yadav *et al.* (2015) also recorded "significant improvement in wheat length of ear head with increase in zinc levels. The effect of P and Zn was found to be non-significant with respect to length of ear head of wheat".

3.5 Number of Spikelets Per Ear Head

Examination of results recorded in Table 2 indicated that effect of different levels of phosphorus showed significant difference in number of spikelets per ear head. Significantly

higher number of spikelets per ear head (16.85) was recorded with the application of 90 kg P₂O₅ ha⁻¹ over control. However, it was at par with 30 and 60 kg P₂O₅ ha⁻¹. Application of P₂O₅ @ 90 kg ha⁻¹ increased number of spikelets per ear head by 12.37 per cent over control. The results presented in Table 2 and illustrates that application of Zn significantly influenced the number of spikelets per ear head. Significantly higher number of spikelets per ear head (16.69) was recorded with the application of 7.5 kg Si ha⁻¹; while the lowest number of spikelets per ear head (15.03) was recorded with control. However, it was at par with 2.5 and 5.0 kg Zn ha⁻¹. Application of 7.5 kg Zn ha⁻¹ significantly increased mean number of spikelets per ear head by 6.75 per cent over control. The interaction effect of phosphorus and zinc failed to show its significant effect on number of spikelets per ear head.

3.6 1000 Grain Weight

It is evident from the data presented in the Table 3 that different levels of phosphorus did not differ with respect to test weight (g) of wheat grain. Application of 90 kg P₂O₅ ha⁻¹ to wheat recorded maximum test weight (39.94 g). Test weight (g) of wheat was not significantly influenced by the application of different levels of zinc (Table 3). The highest test weight (39.76 g) was recorded with the application of 7.5 kg Zn ha⁻¹ and lowest (39.49 g) was found under control. The interaction effect of phosphorus and zinc was found to be non-significant with respect to test weight (g).

Table 3. Effect of phosphorus and zinc application on grain yield and straw yields of wheat

Treatment	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	1000 grain weight (g)
Phosphorus levels (kg ha⁻¹)			
P ₀ : 0 kg P ₂ O ₅ ha ⁻¹	3229	3903	39.54
P ₁ : 30 kg P ₂ O ₅ ha ⁻¹	3630	4440	39.23
P ₂ : 60 kg P ₂ O ₅ ha ⁻¹	3886	4809	39.71
P ₃ : 90 kg P ₂ O ₅ ha ⁻¹	4040	4980	39.94
S.Em. ±	77	124	0.26
C.D. (P = 0.05)	222	359	NS
Zinc levels (kg ha⁻¹)			
Zn ₀ : 0 kg Zn ha ⁻¹	3327	4079	39.49
Zn ₁ : 2.5 kg Zn ha ⁻¹	3563	4433	39.53
Zn ₂ : 5.0 kg Zn ha ⁻¹	3917	4770	39.65
Zn ₃ : 7.5 kg Zn ha ⁻¹	3978	4850	39.76
S.Em. ±	77	124	0.26
C.D. (P = 0.05)	222	359	NS
Interaction			
P x Zn	NS	NS	NS
C.V. (%)	7.20	9.50	2.30

3.7 Grain Yield

Data presented in Table 3 illustrated that application of phosphorus had significant effect on grain yield of wheat. The lowest grain (3229 kg ha⁻¹) yield was observed under control. The maximum grain (4040 kg ha⁻¹) yield was recorded due to application of 90 kg P₂O₅ ha⁻¹. The treatment 90 kg P₂O₅ ha⁻¹ gave significantly higher grain yield over the control and 30 kg P₂O₅ ha⁻¹. However, it was at par with 60 kg P₂O₅ ha⁻¹. The maximum improvement over control was to the tune of 25.10 per cent higher. Application of phosphorus at 30, 60 and 90 kg ha⁻¹ has resulted in the increase in mean grain yield by 12.43, 20.36 and 25.10 percent, respectively over control. The main reason for increase in grain yield with different levels of phosphatic fertilizer might be due to the higher 1000-grain weight which might be due to higher rate of photosynthesis and better crop health which ultimately increased the final grain yield. Plants showed normal growth with the application of phosphorus and resulted in improved agronomic traits which lead toward improved grain yield Vyas *et al.* (2012); Jat *et al.* (2016); Muhammad *et al.* (2016); Panotra *et al.* (2016) and Bairwa *et al.* (2018) also recorded significant improvement in wheat grain yield with increase in phosphorus levels.

The data given in Table 3 indicated that grain yield was significantly affected due to different doses of zinc. Significantly higher grain yield

(3978 kg ha⁻¹) was recorded with the application of Zn @ 7.5 kg ha⁻¹; which was at par with 5.0 kg Zn ha⁻¹. Minimum grain yield (3327 kg ha⁻¹) was noted under control. Application of Zn @ 7.5 kg ha⁻¹ increased the grain yield by 19.55 and 11.64 per cent over control and 2.5 kg Zn ha⁻¹, respectively. The increase in the yield due to zinc application may be attributed to the fact that the initial status of available zinc in the experimental soil was low. Under such a situation an increase in the yield is quite natural. Further, increased grain yield is the manifestation of increase in yield attributes i.e. number of effective tillers, number of grains per spike and spike length. Similar results reported by Dwivedi *et al.* (2002); Khan *et al.* (2008) and Sharma *et al.* (2016). The interaction effect of phosphorus and zinc was found to be non-significant with respect to grain yield of wheat.

3.8 Straw Yield

Data in Table 3 illustrated that application of phosphorus had significant effect on straw yield of wheat. The lowest straw (3903 kg ha⁻¹) yield was observed under control. The maximum straw (4980 kg ha⁻¹) yield was recorded due to application of 90 kg P₂O₅ ha⁻¹. The treatment 90 kg P₂O₅ ha⁻¹ gave significantly higher straw yield over the control and 30 kg P₂O₅ ha⁻¹; while, it was at par with 60 kg P₂O₅ ha⁻¹. The maximum improvement over control was to the tune of 27.12 per cent higher straw. Application of phosphorus at 30, 60 and 90 kg P₂O₅ ha⁻¹

resulted in the increase in mean straw yield by 13.76, 23.20 and 27.59 percent, respectively over control. Early tiller formation is vital to plant health and ultimately final yield potential. The initial tillers formed by the plant have higher yield potential than late tillers or delayed tillers. Tillers are just healthier and productive when adequate phosphorus is available. The significant increase in straw yield due to application of phosphorus could be attributed to the increased vegetative growth, possibly a result of the effective uptake and utilization of nutrients absorbed through its extensive root system developed under phosphorus fertilization. The results are in line with the findings of Jat *et al.* (2018) and Singh *et al.* (2018).

The results presented in Table 3 show that wheat straw yields per plot were significantly influenced by zinc application. Significantly higher straw (4850 kg ha^{-1}) yield was recorded due to Zn application @ 7.5 kg ha^{-1} ; while the lowest straw yield (4079 kg ha^{-1}) was recorded under control. There was 18.91 per cent increase in straw yield of wheat by $7.5 \text{ kg Zn ha}^{-1}$ over control. The treatment $7.5 \text{ kg Zn ha}^{-1}$ gave significantly higher straw yield over the control; however, it was at par with $5.0 \text{ kg Zn ha}^{-1}$.

4. CONCLUSION

Deficiency of soil phosphorus is one of the important chemical factors restricting plant growth in soil. Therefore, sufficient quantity of soluble form of phosphorus fertilizers is applied to achieve maximum plant productivity. Graded levels of Zn application at 2.5, 5.0 and 7.5 kg ha^{-1} resulted in the increase in mean straw yield by 8.70, 16.95 and 18.91 percent, respectively over control. The interaction effect of P and Zn failed to show its significant effect on straw yield of wheat.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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