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Impacts of different doses of phosphorus and zinc on growth and yield parameters of wheat (*Triticum aestivum* L.)

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Abstract
During the *Rabi* season of 2022, an experiment named "Effect of doses of phosphorus and zinc on growth and yield of late sown wheat (*Triticum aestivum* L.)" was carried out at the agricultural research facility of Rama University in Kanpur. The experiment used a Factorial Randomized block design with 12 treatments and 3 replications. The 12 treatment combinations include 3 levels of zinc (0 kg, 5 kg, and 10 kg), and 4 levels of phosphorus (40 kg, 60 kg, 80 kg, and 100 kg). The following growth parameters were observed: plant height, number of shoots (m^{-2}), dry matter accumulation at 30, 60, 90, and at harvest; leaf area index at 30, 60, and 90 DAS; yield attributes, including number of spikelets per spike, spike length, number of grains per spike, and test weight (g); and productivity characters, including grain yield (q/ha), straw yield (q/ha), and harvest index (%). According to the research, the levels of phosphorus and zinc at 100 kg per hectare and 10 kg per hectare, respectively, were superior to all other levels. The farmer may be advised to use 100 kg of phosphorus and 10 kg of zinc per hectare to promote the healthy development, productivity, and quality of wheat plants. The cost of cultivation was low, and the net return was high for the phosphorus and zinc combination.

Keywords: Phosphorus, LAI, wheat, Growth and yield

Introduction
Wheat (*Triticum aestivum* L.) is the most important crop in the world. Wheat is produced on 225.07 million hectares and produces 781.31 million tons across 122 countries. India produces 106.84 million tonnes of wheat at 3.5 t ha^{-1} on 30.52 million hectares. There, 34% of the nation's food grain is produced. India produces the second-most wheat. Wheat is the cereal produced in second-place behind rice. 2022–2023 (Statista.com).
Six states- Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan, and Bihar grow almost 91% of the world's wheat. Despite producing less than Haryana and Punjab (3.60 t ha^{-1}), Uttar Pradesh has the largest land (9.85 million ha) and the most crops (35.50 mt) (Anonymous 2022) [1].
Protein metabolism and the flow of energy both depend on phosphorus. It is a crucial structural element of several bio chemicals, such as nucleic acids. RNA and DNA have a role in the regulation of genetic processes. For high yield wheat production, phosphorus is a crucial ingredient. It promotes source-to-sink photosynthesis, quick crop and seed maturity, and vigorous root development. Consequently, phosphorus is crucial for boosting wheat production. Premature leaf fall, the development of dead necrotic regions on leaves or fruits, and a change in the color of the leaves from green to dark brown can all be brought on by a phosphorus deficit. Wheat that was sown in the late stages is anticipated to benefit from phosphorus, an energizer. (Singh *et al.*, 1996) [7].
Zinc is necessary for wheat to produce large amounts of grain because it is essential for plant metabolism, auxin biosynthesis, and growth hormone synthesis. Zinc is also required for wheat to have a good yield. Wheat production is greatly hindered when zinc levels are too low, which also lead to elder leaves developing fluorosis. It is well known that India's soils have a severe zinc deficiency. It has been shown that the nation's arable land is typically 47% zinc deficient. When applied to soil, zinc has a favorable reaction in 60% of cases. (Tiwari and Dwivedi, 1994) [8].

Material and Methods

Experiment site

The experiment was conducted at the Rama University of Kanpur's Faculty of Agricultural Sciences and Allied Industries' Agricultural Research Farm. About 12 kilometers separate the Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, from the Rama University. Kanpur has a subtropical climate and is geographically located along the Ganges River. The soil in this city is typically sandy and alluvial. The vast bulk of the Kanpur district is composed of common soil, often known locally as "Bhur," which is typical of the Indo-Gangetic plains. At about 26.57° N latitude and 80.21° E longitude, the experimental site is situated 126 meters above mean sea level.

Soil of Experimental Field

Prior to applying the treatments, soil samples were randomly chosen from various sites around the field to evaluate the physico-chemical properties of the soil and its fertility status to a depth of 0–15 cm. Each location's soil samples were mixed, and a composite sample was made, which was then analyzed for various soil properties. The experimental field has a sandy loam texture, a pH of 7.40, is neutral in response, contains electrical cunductivity (0.46 dSm^{-1} EC), available N (133.5 kg ha^{-1}), available P (15.5 kg ha^{-1}), and available K (215.3 kg ha^{-1}) and low levels of organic carbon (0.46%). Additionally, the soil offers 11.50 kg ha^{-1} of accessible S.

Study Design

The experiment was laid out in a factorial randomized block design (FRBD) assigning treatment combinations *viz*.: T_1 (P_1Zn_0), T_2 (P_1Zn_1), T_3 (P_1Zn_2), T_4 (P_2Zn_0), T_5 (P_2Zn_1), T_6 (P_2Zn_3), T_7 (P_3Zn_0), T_8 (P_3Zn_1), T_9 (P_3Zn_2), T_{10} (P_4Zn_0), T_{11} (P_4Zn_1) and T_{12} (P_4Zn_2) with three replications. Each treatment was randomly allocated within them.

Leaf area Index (LAI)

According to Gardner *et al*. (1985) [11], the LAI measures how much of the crop's ground area is taken up by its leaf surface (on one side only). A recording was made at 30, 60, and 90 DAS.

$$LAI = \frac{(LA_2 + LA_1)}{2} \times \frac{1}{P}$$

Where, the LA = leaf area/plant
P = ground area /plant

Harvest Index

The harvest index was figured out with the use of a formula, and Singh and Stockopf (1971) were the ones who proposed using it.

$$Harvest\ Index = \frac{Economic\ Yield\ (kg/ha)}{Biological\ Yield (kg/ha)} \times 100$$

Net Profit (ha^{-1})

The formula was used to determine how much of a net profit each therapy would yield when applied individually.
Net profit (ha^{-1}) = Gross return - Cost of cultivation

Benefit: Cost ratio (B: C)

The B:C ratio was calculated with the help of the formula that is presented below:

$$B{:}\ C = \frac{Gross\ monitary\ retern (Rs./ha)}{Total\ cost\ of\ cultivation\ (Rs./ha)}$$

Statistical Analysis

The data were statistically examined according to Fisher (1950) [3], in order to determine whether or not the variance in experimental data acquired for different treatment effects was significant. This was done so that we could assess the significance of the variation. The essential differences were computed in order to evaluate the significance of the treatment mean whenever the 'F' test was shown to be significant at a level of probability equal to or greater than 5%. The preparation of summary tables, as well as SEm ± and CD (P = 0.05), was done in order to shed light on the type and extent of treatment effects.

Result and Discussion

Growth characters

Phosphorus dosage had a favorable impact on plant height at the 60 DAS, 90 DAS, and harvest stages. Phosphorus doses of P_4 (21.03, 50.58, 50.39, 57.12 cm) and P_3 (20.43, 45.35, 57.04, 63.77 cm) were used to measure plant height. Growth stage of (30 DAS) indicated non-significant plant height across zinc dosages. Zinc levels significantly boosted plant height at 60, 90 DAS, and harvest. At 60 and 90 DAS, Zn_2 (20.60, 47.78, 58.38, 64.68 cm) and the harvest of wheat (20.34, 44.82, 56.24, 62.79 cm) were the plants that reached their greatest height. With Zn_0 control, the minimum height of the wheat plant was measured (19.99, 40.50, 52.95, and 59.87 cm). Malghani *et al*.'s (2010) [6] data on plant height at different growth phases were used.

P_4 (5.86, 8.57, 12.73, 15.30) was the phosphorus dose used to count the number of shoots throughout all stages, followed by P_3 (5.63, 7.16, 11.70, 14.06). The control P_1 wheat plant had the fewest number of shoots per plant (4.4, 5.8, 8.2, and 9.0). Number of shoots at the 30 DAS development stage revealed negligible plant height in zinc dosages. Zinc levels considerably boosted the number of shoots at 60, 90 DAS, and harvest. At 60 and 90 DAS and during wheat harvest, Zn_2 (5.62, 7.68, 12.02, 14.27) and Zn_1 (5.45, 7.32, 11.45, 13.47) produced the most shoots per plant. Zn_0 control was shown to have the fewest shoots per plant (4.90, 6.40, 9.2, and 10.42). The research data used in this study were those of Chaturvedi (2006) [2] and Laghari *et al.* (2010) [5].

Phosphorus doses of P_4 (53.53, 285.20, 790.84, and 1053.84) were used to measure the dry matter accumulation, followed by P_3 (52.80, 278.62, 459.82, and 1027.74). The control P_1 wheat plant had the fewest number of shoots per plant (47.46, 263.22, 717.66, and 897.72). Zinc levels significantly boosted the dry matter accumulation at 60, 90 DAS, and harvest. Zn_2 was detected in the highest amounts of dry matter (52.40, 280.48, 772.96, and 1034.46) at 60 and 90 DAS and during wheat harvest. Zn_0 control was found to have the least dry matter (49.77, 270.10, 734.40, and 944.23).

Phosphorus doses of P_4 (0.526, 3.637, 5.097) were used to measure LAI throughout all phases, followed by P_3 (0.503, 3.556, 4.920). At all development stages, the control P_1 (0.414, 3.180, 4.287) followed by the phosphorus dosage P_2 (0.473, 3.497, 4.757) produced the lowest LAI of wheat. Zinc dosages significantly raised the leaf area index during the 30, 60, and 90 DAS growth stages. Zn_2 (0.504, 3.567, 4.935) at

60 and 90 DAS was used to measure the maximal LAI of the wheat plant. The zinc dosage of Zn_1 (0.489, 3.508, and 4.513) was determined to have the lowest LAI of plant (0.444, 3.527, and 4.513) after the Zn_0 control.

Yield attributing and yield characters

Different amounts of phosphorus and zinc had a substantial impact on the number of spikes and the duration of the spikes. The phosphorus level of P_4 had the highest number of spikes per phosphorus dosage, 196.76, and the longest spikes, 8.88 cm. The largest number of spikes and the longest spike length (8.43 cm) for zinc were measured with the dosage of Zn_2 (191.37).

In the phosphorus level of P_4, the greatest number of grains per spike, or 41.67, and 1000 grain weight (35.63 g), were noted. The minimum number of grains per spike was 35.50, and the 1000 grain weight was 25.94 g. Phosphorus dosage P_1 (35.50) and P_2 (38.18) were tallied in that order. The greatest number of spikes (191.37) and weight of 100 grains (33.91 g) for zinc dosage were reported for Zn_2.

Different amounts of phosphorus and zinc significantly impacted the grain yield and straw yield per hectare. Wheat's highest grain and straw yields on phosphorus dosage, or 36.57 q and 48.99 q, respectively, were noted at the P_4 phosphorus level. In phosphorus dosage P_1, the smallest grain yield (32.55 q) and straw yield (43.02 q) were noted. The highest grain production (35.80 q) and straw yield (47.81 q) in terms of zinc dose were noted in the dose of Zn_2.

The yield parameters of wheat of experiment following the data of Kakade *et al.* (2009) [4], and Yousefi *et al.* (2011) [9].

Economics

P_4 (49016 Rs) had the greatest cultivation cost in terms of phosphorus dosages, followed by P_3 (40167 Rs). P_1 (21370 Rs), the bare minimum cost of cultivation, was documented. The zinc dose Zn_2 had the greatest cultivation cost (46121 Rs), followed by Zn_1 (37082 Rs), and Zn_0 (28779 Rs).

The phosphorus dosages with the highest net return were P_4 (47130 Rs) and P_3 (46706 Rs). With P_1 (38854 Rs), the bare minimum net return was recorded. The zinc dosage with Zn_2 had the highest net return (46121 Rs), whereas the zinc dose with Zn_0 had the lowest net return (44968 Rs).

Table 1: Effect of doses of phosphorus and zinc on plant height and number of shoots at various growth stages of wheat

Treatments	Plant height (cm) @ 30 DAS	Plant height (cm) @ 60 DAS	Plant height (cm) @ 90 DAS	Plant height (cm) @ Harvest	No. of Shoot @ 30 DAS	No. of Shoot @ 60 DAS	No. of Shoot @ 90 DAS	No. of Shoot @ Harvest
Phosphorus level (Kg ha^{-1})								
P_1	19.613	38.327	50.393	57.127	4.433	5.893	8.270	9.000
P_2	20.168	43.214	56.028	62.628	5.367	6.928	10.867	12.533
P_3	20.437	45.356	57.044	63.778	5.633	7.167	11.700	14.067
P_4	21.034	50.588	59.974	66.274	5.867	8.574	12.733	15.300
SE(m)	0.093	0.405	0.301	0.314	0.070	0.141	0.108	0.098
C.D.	0.276	1.195	0.890	0.656	NS	0.295	0.226	0.291
Zinc level (Kg ha^{-1})								
Zn_0	19.993	40.503	52.951	59.876	4.900	6.409	9.200	10.425
Zn_1	20.345	44.827	56.243	62.793	5.450	7.327	11.450	13.475
Zn_2	20.601	47.783	58.386	64.686	5.625	7.686	12.028	14.275
SE(m)	0.081	0.350	0.261	0.272	0.061	0.122	0.094	0.085
C.D.	0.239	1.035	0.770	0.568	NS	0.255	0.196	0.252
Interaction (P x Zn)								
SE(m)	0.162	0.701	0.522	0.385	0.086	0.173	0.133	0.171
C.D.	0.478	2.069	1.541	1.137	N/A	0.510	0.391	0.503

Table 2: Effect of doses of phosphorus and zinc on dry matter accumulation and leaf area index at various growth stages of wheat

Treatments	DMA (g m^{-2}) @ 30 DAS	DMA (g m^{-2}) @ 60 DAS	DMA (g m^{-2}) @ 90 DAS	DMA (g m^{-2}) @ Harvest	LAI @ 30 DAS	LAI @ 60 DAS	LAI @ 90 DAS
Phosphorus level (Kg ha^{-1})							
P_1	47.467	263.227	717.660	897.727	0.414	3.180	4.287
P_2	51.400	275.828	751.261	1,017.894	0.473	3.497	4.757
P_3	52.800	278.622	759.822	1,027.744	0.503	3.556	4.920
P_4	53.533	285.208	790.841	1,053.841	0.526	3.637	5.097
SE(m)	0.386	0.578	1.537	2.047	0.004	0.029	0.050
C.D.	1.140	1.705	4.537	6.042	0.011	0.086	0.147
Zinc level (Kg ha^{-1})							
Zn_0	49.775	270.109	734.409	944.234	0.444	3.327	4.513
Zn_1	51.725	276.568	757.318	1,019.210	0.489	3.508	4.847
Zn_2	52.400	280.486	772.961	1,034.461	0.504	3.567	4.935
SE(m)	0.334	0.500	1.331	1.773	0.003	0.025	0.043
C.D.	0.987	1.477	3.929	5.233	0.009	0.074	0.128
Interaction (P x Zn)							
SE(m)	0.669	1.000	2.662	3.546	0.006	0.050	0.087
C.D.	N/A	2.953	7.859	10.466	N/A	N/A	N/A

Table 3: Effect of doses of phosphorus and zinc on yield attributes and yield characters at various growth stages of wheat

Treatments	No. of spike (m-2)	Length of spike (cm)	No. of grain/spike	1000 grain weight (g)	Grain yield (q ha-1)	Straw yield (q ha-1)	Harvest index (%)
Phosphorus level (Kg ha^{-1})							
P_1	167.587	7.273	35.503	25.940	32.553	43.023	43.093
P_2	184.800	7.908	38.181	31.600	34.388	46.778	42.301
P_3	190.720	8.269	39.173	33.613	35.277	47.461	42.679
P_4	196.767	8.881	41.671	35.633	36.578	48.998	42.848
SE (m)	1.495	0.099	0.187	0.283	0.156	0.146	0.092
C.D.	4.413	0.291	0.553	0.835	0.461	0.430	0.272
Zinc level (Kg ha^{-1})							
Zn_0	175.440	7.666	36.648	28.465	33.286	45.076	42.568
Zn_1	188.090	8.147	38.750	32.713	35.005	46.801	42.78
Zn_2	191.375	8.436	40.498	33.912	35.806	47.818	42.84
SE (m)	1.295	0.085	0.162	0.245	0.135	0.126	0.080
C.D.	3.822	0.252	0.479	0.723	0.399	0.372	0.125
Interaction (P x Zn)							
SE (m)	1.295	0.171	0.325	0.490	0.271	0.252	0.159
C.D.	3.822	0.504	0.959	N/A	0.799	0.744	0.471

Table 4: Economics of doses of phosphorus and zinc of wheat

Treatment	Total cost (RS ha-1)	Gross Return (RS ha-1)	Net Return (RS ha-1)	B:C
Phosphorus level (Kg ha^{-1})				
P_1	21370	60225	38854	1.55
P_2	35495	82823	47327	1.75
P_3	40167	86874	46706	1.86
P_4	49016	96147	47130	2.04
Zinc level (Kg ha^{-1})				
Zn_0	28779	73748.5	44968	1.64
Zn_1	37082	84624.5	45541	1.78
Zn_2	46121	92243.5	46121	2.0

Conclusion

According to the research, the levels of phosphorus and zinc at 100 kg per hectare and 10 kg per hectare, respectively, were superior to all other levels. The farmer may be advised to use 100 kg of phosphorus and 10 kg of zinc per hectare to promote the healthy development, productivity, and quality of wheat plants. Phosphorus and zinc together offered low cultivation costs and high net returns.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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