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Opendra Singh
Department of Soil Science and
Agricultural Chemistry, R.B.S. College,
Bichpuri, Agra, Uttar Pradesh, India

Manoj Pandey
Department of Soil Science and
Agricultural Chemistry, R.B.S. College,
Bichpuri, Agra, Uttar Pradesh, India

Vipin Kumar
Department of Soil Science and
Agricultural Chemistry, R.B.S. College,
Bichpuri, Agra, Uttar Pradesh, India

Rajesh Samota
Department of SSAC, Acharya Narendra
Deva University of Agriculture &
Technology, Kumarganj, Ayodhya,
Uttar Pradesh, India

Akash Pratap Singh
Department of SSAC, Dr. Bhim rao
Ambedkar University, Agra, Uttar
Pradesh, India

Puspendra
Department of SSAC, Dr. Bhim rao
Ambedkar University, Agra, Uttar
Pradesh, India

Abhishek Kumar Singh
Department of Agronomy, Sardar
Vallabhbhai Patel University of
Agriculture and Technology Modipuram,
Meerut, Uttar Pradesh, India

Tarun Tomar
Department of Agronomy, Sardar
Vallabhbhai Patel University of
Agriculture and Technology Modipuram,
Meerut, Uttar Pradesh, India

Dushyant
Department of Agronomy, Sardar
Vallabhbhai Patel University of
Agriculture and Technology Modipuram,
Meerut, Uttar Pradesh, India

Mayank Kumar
Department of SSAC, Chandra Shekhar
Azad University of Agriculture &
Technology, Kanpur, Uttar Pradesh, India

Ankit Chauhan
Department of Horticulture, R B S College,
Bichpuri, Agra, Uttar Pradesh, India

Corresponding Author:
Manoj Pandey
Department of Soil Science and
Agricultural Chemistry, R.B.S. College,
Bichpuri, Agra, Uttar Pradesh, India

Response of Wheat (*Triticum aestivum* L.) to phosphorus and zinc application in alluvial soil: Growth, yield attributes, yield and quality

Opendra Singh, Manoj Pandey, Vipin Kumar, Rajesh Samota, Akash Pratap Singh, Puspendra, Abhishek Kumar Singh, Tarun Tomar, Dushyant, Mayank Kumar and Ankit Chauhan

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Abstract

A field experiment was conducted during the *rabi* season of 2018-19 on a sandy loam alluvial soil at R.B.S. College, Bichpuri, Agra (U.P.), to study the response of wheat (cv. Raj 3765) to four levels of phosphorus (0, 30, 60, 90 kg P₂O₅ ha⁻¹) and four levels of zinc (0, 2.5, 5.0, 7.5 kg Zn ha⁻¹) in a randomised block design with three replications. Phosphorus applied up to 90 kg P₂O₅ ha⁻¹ significantly and progressively increased plant height (79.02 to 92.16 cm), tillers, dry-matter accumulation, ear length, grains per ear, test weight, grain (21.5%) and straw (20.8%) yields, protein content (11.94 to 12.31%) and protein yield (509 to 638 kg ha⁻¹) over the control. Zinc improved these parameters up to 5.0 kg Zn ha⁻¹ (grain and straw yields higher by 11.5 and 12.3%), with a decline at 7.5 kg ha⁻¹. The P × Zn interaction was non-significant. Application of 60-90 kg P₂O₅ ha⁻¹ with 5.0 kg Zn ha⁻¹ is optimum for higher productivity and quality of wheat in alluvial soils of the Agra region.

Keywords: Phosphorus, zinc, wheat, growth, yield attributes, grain yield, protein, alluvial soil

Introduction

Wheat (*Triticum aestivum* L.) is one of the world's most important cereal and food-grain crop of India after rice. and serves as a staple food for a large proportion of the global population. It contributes substantially to food security by providing carbohydrates, proteins, vitamins, and essential minerals. In India, wheat is the second most important food crop after rice, occupying a significant share of the cultivated area and contributing considerably to national food grain production. With the increasing demand for wheat driven by population growth and changing dietary patterns, enhancing productivity while maintaining grain quality has become a major challenge. Achieving this objective requires balanced nutrient management that ensures adequate availability of both macronutrients and micronutrients throughout the crop growth period.

Among the essential plant nutrients, phosphorus (P) plays a vital role in energy transfer, photosynthesis, cell division, root development, and reproductive growth. Adequate phosphorus nutrition promotes early crop establishment, vigorous root growth, timely maturity, and improved grain formation. However, phosphorus deficiency is widespread in many agricultural soils due to its low mobility and fixation by soil constituents, particularly in alluvial soils where a considerable proportion of applied phosphorus becomes unavailable to plants. Continuous use of high-analysis phosphatic fertilizers under intensive cropping has widened zinc deficiency, which now ranks third after nitrogen and phosphorus in many Indian soils (Cakmak, 2008) [2]. Consequently, phosphorus use efficiency remains low, necessitating appropriate fertilizer management strategies to maximize crop response and nutrient utilization.

Zinc (Zn) is an essential micronutrient required for numerous physiological and biochemical processes in plants. It acts as a structural and catalytic component of several enzymes and is involved in protein synthesis, auxin metabolism, chlorophyll formation, membrane integrity, and antioxidant defense mechanisms. Zinc deficiency has emerged as one of the most widespread micronutrient disorders affecting cereal production worldwide, particularly in intensively

cultivated alluvial soils characterized by low organic matter, high soil pH, and continuous application of phosphorus fertilizers (Alloway, 2009) ^[1]. In wheat, zinc deficiency results in reduced plant growth, impaired photosynthetic activity, poor grain filling, lower yields, and deterioration in grain nutritional quality.

The interaction between phosphorus and zinc in soil-plant systems is complex and has significant implications for crop productivity. While adequate phosphorus promotes plant growth, excessive phosphorus application may induce zinc deficiency by reducing zinc availability and uptake, thereby adversely affecting crop performance (Chaudhari and Totawat, 1985) ^[4]. Conversely, balanced application of phosphorus and zinc can improve nutrient acquisition, enhance physiological efficiency, increase biomass production, and improve grain yield and quality. Therefore, optimizing the combined application of these nutrients is essential for achieving sustainable wheat production, particularly in alluvial soils where nutrient imbalances frequently occur.

Alluvial soils occupy extensive agricultural areas and are among the most productive soils for wheat cultivation. Nevertheless, continuous cropping, imbalanced fertilizer use, and declining micronutrient reserves have led to widespread deficiencies of phosphorus and zinc, limiting crop productivity and soil fertility. Adoption of integrated nutrient management practices involving balanced phosphorus and zinc fertilization offers considerable potential for improving nutrient use efficiency, sustaining soil health, and enhancing crop productivity and grain quality. The soils of the Agra region are light-textured, alkaline and low in fertility, and systematic information on the combined response of wheat to phosphorus and zinc under these conditions is limited. The present study was undertaken to evaluate the effect of phosphorus and zinc levels on the growth, yield attributes, yield and quality of wheat.

Therefore, the present investigation entitled "Response of wheat (*Triticum aestivum* L.) to phosphorus and zinc application in alluvial soil: Growth, yield attributes, yield and quality" was undertaken to evaluate the individual and combined effects of different levels of phosphorus and zinc on wheat growth, yield attributes, grain and straw yield, and quality parameters under alluvial soil conditions. The findings of this study are expected to contribute toward developing balanced nutrient management strategies for sustainable wheat production and improved soil fertility

Materials and Methods

A field experiment was conducted during the *rabi* season of 2018-19 at the Research Farm of Raja Balwant Singh College, Bichpuri,

Agra (U.P.), India (27.2° N, 77.91° E; 168 m above mean sea level), which has a semi-arid subtropical climate. A composite surface soil sample (0-23 cm) showed the soil to be sandy loam in texture, alkaline (pH 8.0), non-saline (EC 0.12 dS m⁻¹), low in organic carbon (3.1 g kg⁻¹), low in available N (165.0 kg ha⁻¹) and P (9.2 kg ha⁻¹), medium in available K (110.0 kg ha⁻¹) and deficient in DTPA-extractable zinc (0.54 mg kg⁻¹).

The experiment comprised four levels of phosphorus (0, 30, 60 and 90 kg P₂O₅ ha⁻¹) and four levels of zinc (0, 2.5, 5.0 and 7.5 kg Zn ha⁻¹), giving sixteen treatment combinations laid out in a randomised block design with three replications (Fig. 1). Wheat variety Raj 3765 was sown in the second week of November at 20 cm row spacing with a seed rate of 100 kg ha⁻¹. A uniform basal dose of 120 kg N ha⁻¹ (urea) and 40 kg K₂O ha⁻¹ (muriate of potash) was applied; phosphorus was applied as single super-phosphate and zinc as zinc oxide as per treatments at sowing. Five irrigations were given and recommended agronomic practices followed.

At harvest, plant height, tillers per plant, dry-matter accumulation, yield attributes (ear length, grains per ear, test weight) and grain and straw yields were recorded. Grain and straw samples were washed, oven-dried at 65–70 °C, ground and analysed. Nitrogen was determined colorimetrically after wet digestion (Snell and Snell, 1955) ^[15] and crude protein computed as N% × 6.25; phosphorus by the vanadomolybdate yellow-colour method (Chapman and Pratt, 1961) ^[3]; potassium by flame photometry; sulphur turbidimetrically; and zinc by atomic absorption spectrophotometry. Nutrient uptake was computed as content × yield. Data were analysed by ANOVA for a randomised block design and means compared using the critical difference (CD) at 5% (Fisher's test).

Results and Discussion

Growth characters

Phosphorus application significantly and progressively increased all growth characters (Table 1). Plant height increased from 79.02 cm in the control to 92.16 cm at 90 kg P₂O₅ ha⁻¹, tillers from 6.15 to 7.33 and dry-matter accumulation from 12.32 to 17.39 g plant⁻¹, reflecting the role of phosphorus in root proliferation, cell division and metabolic activity in a P-deficient soil (Sepat and Rai, 2013; Mishra *et al.*, 2017) ^[11, 8]. Zinc improved growth up to 5.0 kg Zn ha⁻¹ (89.42 cm, 7.16 tillers, 17.00 g plant⁻¹), with a significant decline at 7.5 kg ha⁻¹, indicating an adverse effect of zinc beyond the optimum (Singh, 2010; Pandey and Chauhan, 2016) ^[10, 9]. The P × Zn interaction was non-significant.

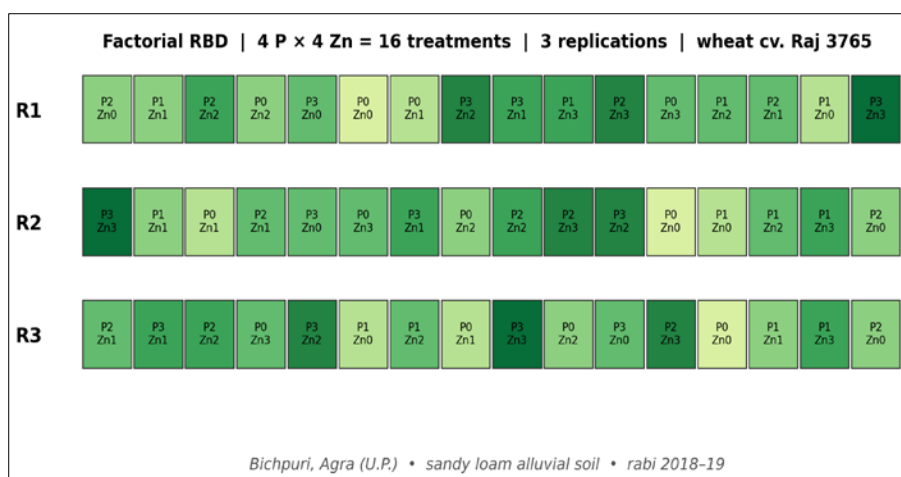


Fig 1: Schematic of the factorial randomised block design (4 P × 4 Zn = 16 treatments, 3 replications).

Table 1: Effect of phosphorus and zinc levels on growth characters and yield attributes of wheat

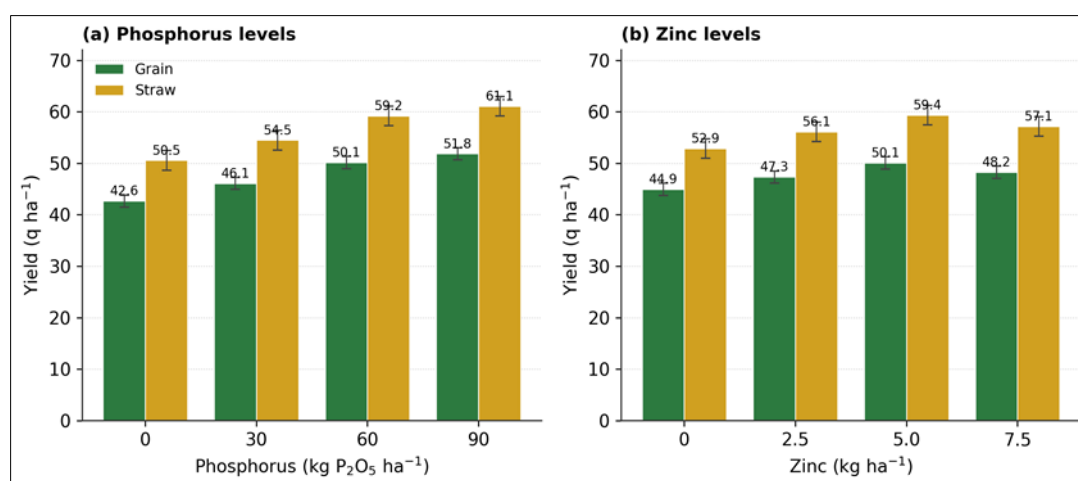
Treatment	Plant ht. (cm)	Tillers plant ⁻¹	Dry matter plant ⁻¹ (g)	Ear length (cm)	Grains ear ⁻¹	Test wt. (g)
Phosphorus (kg P₂O₅ ha⁻¹)						
0	79.02	6.15	12.32	7.31	43.56	36.30
30	82.92	6.60	13.78	7.68	45.00	38.10
60	89.47	7.15	16.28	8.20	46.21	40.60
90	92.16	7.33	17.39	8.41	47.60	42.05
Zinc (kg ha⁻¹)						
0	82.44	6.64	13.70	7.61	44.90	37.45
2.5	84.52	6.89	15.08	7.84	45.72	39.27
5.0	89.42	7.16	17.00	8.34	46.81	41.41
7.5	87.18	6.30	14.79	7.82	44.93	38.92
S.Em ±	1.27	0.10	0.51	0.11	0.26	0.63
CD (P=0.05)	3.70	0.29	1.47	0.31	0.76	1.83

Yield attributes and yield

All yield attributes improved significantly with phosphorus (Table 1): ear length, grains per ear and test weight rose from 7.31 cm, 43.56 and 36.30 g to 8.41 cm, 47.60 and 42.05 g at 90 kg P₂O₅ ha⁻¹, respectively. Zinc improved the attributes up to 5.0 kg Zn ha⁻¹, with a decline at the highest level, owing to its role in the reproductive phase and in translocation of photosynthates to the sink (Kumar *et al.*, 2001; Sahay *et al.*, 2009) [6, 10].

Grain and straw yields increased significantly with each increment of phosphorus (Table 2, Fig. 2a): grain yield rose by

8.1, 17.6 and 21.5% and straw yield by 7.8, 17.0 and 20.8% over the control due to 30, 60 and 90 kg P₂O₅ ha⁻¹, respectively. Zinc increased grain and straw yields up to 5.0 kg Zn ha⁻¹ (50.07 and 59.35 q ha⁻¹; 11.5 and 12.3% over no zinc), with a reduction at 7.5 kg ha⁻¹. Comparable responses have been reported by Jain and Dahama (2006) [5], Singh and Singh (2017) [14] and, under an identical 4 × 4 P × Zn design, by Malav *et al.* (2025) [7]. The interaction, though non-significant, gave the highest yields at P₉₀Zn₅.

**Fig 2:** Effect of (a) phosphorus and (b) zinc levels on grain and straw yield of wheat (error caps = ± ½ CD, P = 0.05).

Quality - protein content and protein yield

Protein content of grain increased significantly with phosphorus to 12.31% at 90 kg P₂O₅ ha⁻¹, and with zinc to 12.31% at 7.5 kg Zn ha⁻¹, reflecting greater nitrogen accumulation and the role of zinc in nitrogen metabolism. Protein yield, a function of protein

content and grain yield, rose to 638.0 kg ha⁻¹ at 90 kg P₂O₅ ha⁻¹ and to a maximum of 613.3 kg ha⁻¹ at 5.0 kg Zn ha⁻¹, in agreement with Sharma *et al.* (2012) [12] and Singh and Singh (2017) [14]. The interaction was non-significant.

Table 2: Effect of phosphorus and zinc levels on grain yield, straw yield and quality of wheat

Treatment	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)	Protein, grain (%)	Protein, straw (%)	Protein yield (kg ha ⁻¹)
Phosphorus (kg P₂O₅ ha⁻¹)					
0	42.64	50.55	11.94	3.18	509.1
30	46.09	54.47	12.12	3.25	558.6
60	50.13	59.16	12.25	3.37	614.0
90	51.83	61.06	12.31	3.50	638.0
Zinc (kg ha⁻¹)					
0	44.92	52.85	12.00	3.25	539.0
2.5	47.32	56.07	12.06	3.31	570.2
5.0	50.07	59.35	12.25	3.37	613.3
7.5	48.25	57.15	12.31	3.44	594.0
SEm ±	0.82	1.30	0.028	0.05	10.05
CD (P=0.05)	2.38	3.79	0.078	0.14	29.14

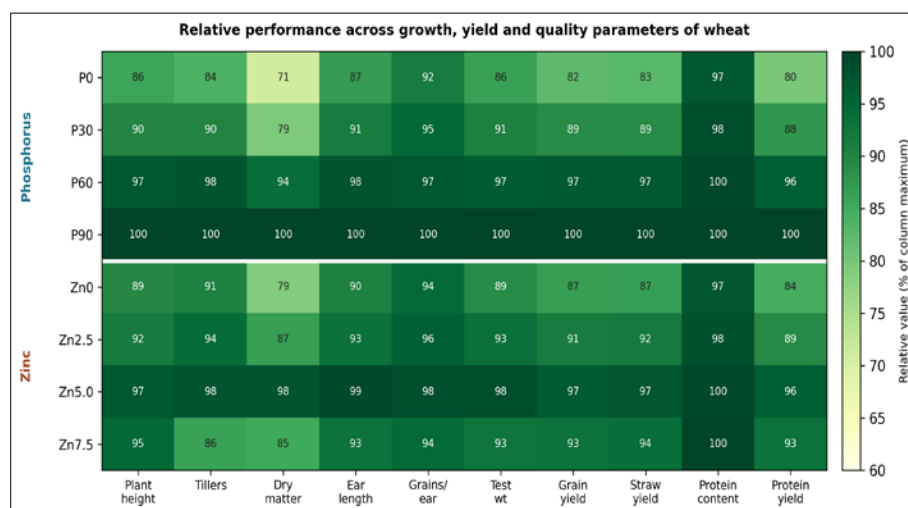


Fig 3: Relative performance (% of column maximum) of phosphorus and zinc levels across growth, yield and quality parameters of wheat

Conclusion

Wheat responded significantly and positively to phosphorus and zinc, the response being more pronounced for phosphorus. For higher productivity and quality of wheat in the sandy loam alluvial soil of the Agra region, the application of 60–90 kg P_2O_5 ha^{-1} together with 5.0 kg Zn ha^{-1} is recommended.

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