Eco. Env. & Cons. 30 (July Suppl. Issue) : 2024; pp. (S160-S165)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2024.v30i04s.027

Enhancing Chickpea Yield and Nutrient Profile Through Phosphorous and Zinc Application

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(Received 2 November, 2023; Accepted 29 December, 2023)

ABSTRACT

The field experiments conducted at the Student's Instructional Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, during the rabi season of 2021–22 aimed to investigate the impact of phosphorus and zinc on both yield and quality parameters of chickpea. Employing a factorial randomized block design with 16 treatment combinations and three replications, various combinations of phosphorus and zinc were tested, using the chickpea cultivar *RVG-203* and following prescribed agricultural techniques. The most promising results were observed in treatment T_{15} [$P_{90}Zn_6$], which yielded the highest grain yield (18.65 q ha^{-1}) and straw yield (21.86 q ha^{-1}). Conversely, treatment T_0 [P_0Zn_0] exhibited the lowest grain yield (13.24 q ha^{-1}) and straw yield (17.92 qha^{-1}). Furthermore, nutrient content analysis showcased that treatment T_{15} [$P_{90}Zn_6$] boasted maximum values for grain nitrogen (N), phosphorus (P), potassium (K), and zinc (Zn) content at 3.35%, 0.65%, 0.65%, and 0.27 mg kg^{-1}, respectively. In contrast, treatment T_0 [P_0Zn_0] displayed the minimum values in these parameters at 3.13%, 0.46%, 0.53%, and 0.20 mg kg^{-1}, respectively. Similar trends were observed in the nutrient content of straw. Nutrient uptake analysis further emphasized the superiority of the treatment T_{15} [$P_{90}Zn_6$], recording maximum values for grain nitrogen (63.15 kg ha^{-1}), phosphorus (12.25 kg ha^{-1}), potassium (12.25 kg ha^{-1}), and zinc (49.91 g ha^{-1}), as well as in straw nitrogen (33.16 kg ha^{-1}), phosphorus (7.47 kg ha^{-1}), potassium (43.66 kg ha^{-1}), and zinc (52.27 g ha^{-1}). Conversely, treatment T_0 [P_0Zn_0] exhibited the lowest nutrient uptake for both grain and straw. In conclusion, the comprehensive analysis of treatment combinations demonstrated that the judicious application of phosphorus and zinc, as exemplified by treatment T_{15} [$P_{90}Zn_6$], significantly enhances chickpea yield and quality parameters, emphasizing the importance of balanced nutrient management for optimal agricultural productivity.

Key words: *Nutrient content, Nutrient uptake, Phosphorus, Yield and Zinc.*

Introduction

The chickpea (*Cicer arietinum* L.) serves both as a winter pulse crop and a sought-after green vegetable. Globally, it ranks as the third most vital pulse crop, following French beans (*Phaseolus vulgaris* L.). With an expansive geographical distribution encompassing regions such as the Indian subcontinent, the Mediterranean, northern and eastern Africa, southern Europe, western and eastern Asia, and Australia, chickpea stands as a crucial protein source, playing a pivotal role in human nutrition across developing and developed nations. Its composition includes 18-22% protein, 52-70% carbohydrates, 4-10% fat, 3% fiber, along with essential minerals (P, Ca, Mg, Zn, Fe) and vitamins (Venkidasamy *et al.,* 2019).

India takes the lead as the largest producer (25% of global production), consumer (27% of world consumption), and importer (14%) of pulses worldwide. In terms of pulse production, India holds the top position globally, covering 25% of the world's total production. Chickpea cultivation in India spans 10.17 million hectares, yielding 11.35 million tonnes at a productivity rate of 1116 kg ha^{-1}. In Uttar Pradesh, chickpea cultivation spans 0.62 million hectares, producing 0.85 million tonnes with a productivity of 1371 kg ha^{-1} (Anonymous, 2021).

Phosphorus, often referred to as a 'master key' element in crop production, holds the second position among essential nutrients, just after nitrogen. Categorized as a major plant nutrient alongside nitrogen and potassium, phosphorus plays a crucial role in the balanced nutrition of plants, influencing various aspects of plant growth and development. It is integral to processes such as sugar and starch utilization, photosynthesis, nucleus formation, cell division, fat and albumin formation, cell organization, heredity transfer, and serves as a structural component in cell membranes, chloroplasts, mitochondria, and sugar phosphates. Additionally, phosphorus is closely associated with energy transformation and metabolic processes, including nitrogen fixation (Sachan *et al.,* 2022). Zinc, another essential element, is indispensable for various metabolic processes, chlorophyll and carbohydrate production, enzyme systems, auxin and protein synthesis, seed formation, and maturity rate. Zinc deficiency manifests as symptoms like stunted growth, light green or yellowish patches, and chlorotic bands on younger leaves. In the plant, zinc is not translocated, leading to symptoms appearing first on younger leaves and other sections. Achieving sustainable production requires a balanced supply of soil with suitable physical and biological properties to facilitate optimal root growth and nutrient utilization from the rhizosphere (Yadav *et al.,* 2022).

Maintaining a favourable balance between phosphorus and zinc is crucial for the optimum growth of plants. In Uttar Pradesh, most soils are reported to be deficient in available zinc. The uptake and translocation of zinc and phosphorus in plants are mutually exclusive, with P-induced zinc shortage more prevalent due to higher application of P fertilizer than Zn fertilizer. This study aims to investigate the impact of different zinc and phosphorus levels on plant production and their absorption capacities. Given the limited information on the zinc and phosphorus relationship in crops, especially in situations where both nutrients are deficient in soil, this investigation focuses on studying the effects of phosphorus and zinc application on yield, nutrient uptake, and quality in chickpea grown in alluvial soils of Uttar Pradesh. The findings from the investigation suggest that nitrogen content and uptake in grain increased significantly with rising phosphorus levels up to 60 kg ha^{-1}, while nitrogen content and uptake in straw increased significantly up to 40 kg $P_2O_5ha^{-1}$. Similarly, phosphorus content and uptake by grain and straw significantly increased with the application of increasing levels of phosphorus up to 60 and 40 kg $P_2O_5ha^{-1}$, respectively. Notably, zinc content and uptake in grain and straw decreased significantly with increasing levels of phosphorus (Balai *et al.,* 2017).

Resources and Methods

The experiment was conducted during the *rabi* season in 2021-22 at the student's Instructional farm, C.S.A. University of Agriculture and Technology, Kanpur Nagar (U.P.). The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction having pH 7.9 (1:2.5 soil: water suspension method given by Jackson, 1973), electrical conductivity 0.30 dSm^{-1} (1:2.5 soil: water suspension method given by Jackson, 1973), Organic carbon percentage in the soil is 0.45 % (Rapid titration method given by Walkley and Black, 1934), with available nitrogen 210 kg ha^{-1} (Alkaline permanganate method given by Subbiah and Asija, 1956), sodium bicarbonate extractable P was 12.8 kg ha^{-1} (Olsen *et al.,* 1954), available potassium was 198 kg ha^{-1} (Flame photometer method given by Hanwey and Heidel, 1952) and available zinc was 0.55 mg kg^{-1} (DTPA extraction method given by Lindsay and Norvell, 1978). Recommended dose of Nitrogen and Potassium were applied through Urea, and MOP (20:40 kg ha^{-1}). Phosphorus, and Zinc were applied as per treatment at the time of sowing in the form of DAP and Zinc sulphate, respectively. The sowing of seeds of Chickpea variety RGV-203 was done by line sowing by hand at 4-5 cm depth of soil and with line to line spacing of 45 cm to maintain uniform plant population. The 16 treatments combination of nutrient management practices of inorganic fertilizer (DAP and zinc sulphate). Composite grain and straw samples were collected from each treatment at harvest to analyses nitrogen, phosphorous and potassium concentration (%) and their uptake (kg ha^{-1}). The plant material was oven dried (70 ± 5^{0}C for 72 hours) and ground separately and then subjected to analysis. The nutrient concentration in plant (both grain and straw) was determined by micro-kjeldahl's method (Jackson, 1973). The total nutrient uptake was calculated by following formulae

$$\text{Nutrient uptake by grain (kg ha}^{-1}) = \frac{\text{Nutrient concentration in grain (\%)} \times \text{grain yield (kg ha}^{-1})}{100}$$

$$\text{Nutrient uptake by straw (kg ha}^{-1}) = \frac{\text{Nutrient concentration in straw (\%)} \times \text{straw yield (kg ha}^{-1})}{100}$$

Available zinc content of the soil samples was extracted with DTPA-TEA (pH 7.3) extractant following the method of Lindsay and Norvell (1978) and the concentration of Zn in the extracted solution was estimated with the help of Atomic Absorption Spectrophotometer (AAS).

$$\text{Zn uptake by grain (g ha}^{-1}) = \frac{\text{Zn concentration in grain (ppm)} \times \text{grain yield (kg ha}^{-1})}{1000}$$

$$\text{Zn uptake by straw (g ha}^{-1}) = \frac{\text{Zn concentration in straw (ppm)} \times \text{grain yield (kg ha}^{-1})}{1000}$$

The various data recorded in the experiment were analyzed statistically with standard procedure of ANOVA technique for factorial randomized block design (RBD). The standard errors of mean were calculated in each item of investigation and critical differences (CD) at 5 % level were worked out for comparing the treatment mean wherever 'F' test was found significant (Gomez and Gomez, 1984).

Results and Discussion

Grain and straw yields

The grain and straw yields exhibited a noteworthy increase in tandem with escalating doses of phosphorus (P) and zinc (Zn). However, the interaction between P and Zn did not yield a significant beneficial effect on chickpea yield. Notably, there was an observed rise in phosphorus uptake by both grain and straw with the application of P, although this trend saw a decline at higher levels of applied zinc (Zn). Among the various treatments, T_{15} [90 P_2O_5 and 6 kg zinc ha^{-1}] outperformed others, displaying significantly higher grain and straw yields. In particular, at T_{15}, the grain yield and straw yield reached an impressive 18.65 and 21.86 q ha^{-1}, respectively. Conversely, the lowest grain and straw yields were recorded at T_0 [0 P_2O_5 and 0 kg zinc ha^{-1}], amounting to 13.24 and 17.92 qha^{-1}, respectively. An intriguing observation emerged as the combined application of phosphorus (90 kg ha^{-1}P_2O_5) and zinc (9 kg ha^{-1}) led to a reduction in both grain and straw yields, suggesting an antagonistic effect between the two elements. In conclusion, it can be inferred that a combination of 60 kg P_2O_5 + 5 kg Zn ha^{-1} would suffice to achieve higher chickpea yields. These findings align with the outcomes of other recent investigations by Pal *et al.*, (2021), Singh *et al.*, (2022), and Kumar *et al.*, (2022).

Nutrient Content and uptake

Phosphorus and zinc application significantly increased nitrogen, phosphorus, potassium and zinc content in grain and straw. Zinc content in grain and straw non-significant increased with the combine use of 90 kg phosphorus and 9 kg zinc ha^{-1}. Concentration of nitrogen, phosphorus, potassium and zinc concentration in grain and straw significantly increased with the use of 90 kg ha^{-1} P_2O_5 and 6 kg ha^{-1}Zn application (T_{15}). Combined use of zinc and

Table 2. Effect of P and Zn levels on yield (q ha^{-1}).

Treatment		Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1	$P_0 Zn_0$	12.25	17.16
T_2	$P_0 Zn_3$	12.52	17.35
T_3	$P_0 Zn_6$	13.76	18.72
T_4	$P_0 Zn_9$	12.87	17.81
T_5	$P_{30} Zn_0$	13.24	18.25
T_6	$P_{30} Zn_3$	14.86	19.65
T_7	$P_{30} Zn_6$	15.34	20.12
T_8	$P_{30} Zn_9$	14.25	19.10
T_9	$P_{60} Zn_0$	15.77	20.46
T_{10}	$P_{60} Zn_3$	16.96	21.78
T_{11}	$P_{60} Zn_6$	18.24	22.96
T_{12}	$P_{60} Zn_9$	16.71	21.34
T_{13}	$P_{90} Zn_0$	16.10	20.95
T_{14}	$P_{90} Zn_3$	17.65	22.54
T_{15}	$P_{90} Zn_6$	18.85	23.35
T_{16}	$P_{90} Zn_9$	17.31	22.24
S.E (m) ±	P	0.022	0.021
	Zn	0.022	0.021
	P × Zn	0.044	0.043
CDat 5%	P	0.064	0.062
	Zn	0.064	0.062
	P × Zn	NS	NS

Table 3. Effect of P and Zn levels on nutrient concentration in chickpea

Treatment		Grain				Straw			
		N (%)	P (%)	K (%)	Zn (mg kg^{-1})	N (%)	P (%)	K (%)	Zn (mg kg^{-1})
T_1		3.13	0.46	0.53	0.20	1.20	0.22	1.66	0.16
T_2		3.15	0.48	0.54	0.21	1.21	0.23	1.67	0.17
T_3		3.19	0.53	0.56	0.23	1.26	0.25	1.71	0.18
T_4		3.17	0.49	0.55	0.21	1.23	0.23	1.68	0.17
T_5		3.18	0.51	0.56	0.22	1.24	0.24	1.69	0.17
T_6		3.23	0.56	0.57	0.23	1.31	0.26	1.74	0.19
T_7		3.24	0.58	0.58	0.23	1.32	0.27	1.75	0.19
T_8		3.21	0.54	0.57	0.22	1.29	0.26	1.73	0.18
T_9		3.26	0.59	0.59	0.24	1.34	0.28	1.75	0.20
T_{10}		3.30	0.61	0.61	0.25	1.39	0.30	1.79	0.21
T_{11}		3.34	0.64	0.64	0.26	1.41	0.31	1.85	0.22
T_{12}		3.29	0.61	0.61	0.25	1.38	0.29	1.78	0.21
T_{13}		3.27	0.60	0.60	0.24	1.36	0.28	1.77	0.20
T_{14}		3.32	0.63	0.63	0.26	1.40	0.31	1.83	0.22
T_{15}		3.35	0.65	0.65	0.27	1.42	0.32	1.87	0.23
T_{16}		3.31	0.62	0.62	0.25	1.40	0.30	1.81	0.21
S.E(m) ±	P	0.25	0.31	0.30	0.42	0.52	0.47	0.59	0.61
	Zn	0.25	0.31	0.30	0.42	0.52	0.47	0.59	0.61
	P × Zn	0.38	0.41	0.44	0.51	0.69	0.58	0.62	0.44
CD at 5%	P	0.76	0.94	0.92	1.27	1.57	1.42	1.78	1.85
	Zn	0.76	0.94	0.92	1.27	1.57	1.42	1.78	1.85
	P × Zn	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Effect of P and Zn levels on nutrient uptake by chickpea

Treatment		Grain				Straw			
		N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Zn (g ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Zn (g ha^{-1})
T_1		38.34	5.63	6.49	24.79	20.59	3.77	28.48	28.17
T_2		39.44	6.01	6.76	26.10	20.99	3.99	28.97	28.88
T_3		43.89	7.30	7.70	29.92	23.59	4.68	32.01	33.49
T_4		40.80	6.31	7.08	27.18	21.90	4.09	29.92	30.18
T_5		42.10	6.75	7.41	28.41	22.63	4.38	30.84	31.66
T_6		48.00	8.32	8.47	33.80	25.74	5.11	34.19	37.04
T_7		49.70	8.89	8.90	35.75	26.56	5.43	35.21	39.07
T_8		45.74	7.69	8.12	31.66	24.63	4.97	33.04	34.95
T_9		51.41	9.30	9.30	37.62	27.41	5.73	35.80	40.67
T_{10}		55.96	10.34	10.34	42.57	30.27	6.53	38.98	46.52
T_{11}		60.92	11.67	11.67	47.60	32.37	7.12	42.47	50.78
T_{12}		54.97	10.19	10.19	41.25	29.45	6.19	37.98	44.68
T_{13}		52.64	9.66	9.66	38.83	28.49	5.86	37.08	42.75
T_{14}		58.59	11.12	11.11	45.67	31.55	6.98	41.25	49.56
T_{15}		63.15	12.25	12.25	49.91	33.16	7.47	43.66	52.67
T_{16}		57.29	10.73	10.73	44.10	31.14	6.67	40.25	48.19
S.E(m) ±	P	0.82	0.22	0.19	0.84	0.44	0.12	0.50	0.85
	Zn	0.82	0.22	0.19	0.84	0.44	0.12	0.50	0.85
	P × Zn	1.64	0.44	0.38	1.68	0.87	0.25	1.01	1.71
CD at 5%	P	2.38	0.64	0.55	2.44	1.27	0.36	1.46	2.48
	Zn	2.38	0.64	0.55	2.44	1.27	0.36	1.46	2.48
	P × Zn	NS	NS	NS	NS	NS	NS	NS	NS

phosphorus decreased NPK content in grain and straw due to antagonistic effect of each other. Maximum values in relation to nutrient content in grain N (3.35 %), P (0.65 %) and K (0.65 %), and Zn (0.27 mg kg^{-1}) and nutrient content in straw N (1.42 %), P (0.32 %), K (1.87 %), and Zn (0.23 mg kg^{-1}) were found in the treatment T_{15} [$P_{90}Zn_6$]. Corresponding minimum values in relation to nutrient content in grain N (3.13 %), P (0.46 %), K (0.53 %) and Zn (0.20 mg kg^{-1}) and nutrient content in straw N (1.20 %), P (0.22 %), K (1.66 %), and Zn (0.16 mg kg^{-1}) were observed in the treatment T_1 [P_0Zn_0]. When phosphorus combined with zinc it further decreased nutrient content in grain and straw as a fact individual of these nutrients are well recognized on nutrient content in grain and straw. Phosphorus uptake negatively decreased with combine use of phosphorus and zinc. As a fact phosphorus and zinc involved in metabolic process of plants and their effects on nutrient uptake in grain and straw are quite expected. Both nutrients are helping plant growth and ultimately increased nutrients uptake in grain and straw both. The Similarly maximum nutrient uptake by grain N (63.15 kg ha^{-1}), P (12.25 kg ha^{-1}), K (12.25 kg ha^{-1}) and Zn (49.91 g ha^{-1}), nutrient uptake in straw N (33.16 kg ha^{-1}), P (7.47 kg ha^{-1}), K (43.66 kg ha^{-1}) and Zn (52.27 g ha^{-1}) were found in the treatment T_{15} [$P_{90}Zn_6$]. Corresponding minimum values in relation to nutrient uptake by grain N (38.34 kg ha^{-1}), P (5.63 kg ha^{-1}), K (6.49 kg ha^{-1}), and Zn (24.79 g ha^{-1}) and nutrient uptake by straw N (20.59 kg ha^{-1}), P (3.77 kg ha^{-1}), K (28.48 kg ha^{-1}) and Zn (28.17 g ha^{-1}) were found in treatment T_0 [P_0Zn_0]. When phosphorus combined with zinc it further decreased nutrient uptake in grain and straw as a fact individual of these nutrients are well recognized on nutrient uptake in grain and straw. Therefore, their combination is also expected in considerable decrease of nutrient uptake in grain and straw. The results of the present investigation are also in agreement with the findings of Singh *et al.* (2012) and Singh *et al.* (2021).

Conclusion

In essence, the judicious application of phosphorus at a rate of 90 kg ha^{-1} and zinc at 6 kg ha^{-1} emerges as a promising strategy to augment chickpea yields. Beyond the evident increase in yield, this approach holds potential for enhancing the nutrient content of the harvested produce and improving overall nutrient uptake by the chickpea plants. The findings of this research not only contribute valuable insights to the existing knowledge on optimal agricultural practices but also emphasize the crucial role of effective nutrient management in fostering sustainable chickpea production. This underscores the significance of integrating advanced nutrient management strategies into contemporary agricultural practices for the long-term benefit of crop cultivation and agricultural sustainability.

Confli ct of Interest: None

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