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Influence of Phosphorus and Zinc on Physio-chemical Properties of Soil on Cowpea (*Vigna unguiculata* L.)

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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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Original Research Article

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ABSTRACT

The field experiment was conducted at the central research farm Soil Science Research Farm of SHUATS Prayagraj, (U.P.) on, sandy loam soil to "Influence of Phosphorus and Zinc on Physio-chemical Properties of Soil on Cowpea (*Vigna unguiculata* L.)" during Kharif season of 2022. There are nine treatment combinations comprised in randomized block design with three replications making a total of 27 experimental plots. The soil samples were taken in two depths (0-15 cm & 15-30 cm) for analysis. The results showed that the application of Phosphorus and Zinc had a significant and non-significant effect on soil physico-chemical properties. The maximum bulk density (1.52 and 1.52 Mg^{-3}), particle density (2.61 and 2.63 Mg m-3), and pH (7.20 and 7.25) were recorded in T_1 (Absolute control) at 0-15 and 15-30 cm depth. Similarly, the maximum percentage EC (0.48 and 0.49 dS m^{-1}), pore space (48.49 and 47.99%), water holding capacity (44.75 and 44.03%), percentage organic carbon (0.47 and 0.46%), available nitrogen (288.14 and 287.68 kg

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ha-1), phosphorus (29.60 and 28.85 kg ha-1) and potassium (192.41 and. 191.54 kg ha-1) was recorded in T_9 (P_2O_5 @100% + Zn @ 100%)

Keywords: Soil parameters; phosphorus; zinc; cowpea.

1. INTRODUCTION

Soil plays a critical role in the proper functioning of the agricultural system, as its fertility is crucial for sustainable crop production [1] (FAO, 2015). However, continuous rice-wheat cultivation in the Indo-Gangetic region has led to soil fertility deterioration, raising serious concerns about the sustainability of Indian agriculture (Singh et al., 2021). The overuse of high-yielding varieties, extensive tillage, and imbalanced application of chemical fertilizers and pesticides have disturbed the soil ecosystem (Latare et al., 2015).

In this context, cowpea emerges as a promising solution, well-suited to impoverished soil conditions and regions with limited rainfall. Thriving best in fertile, loamy soils with an annual rainfall ranging from 760 to 1150 mm during the growing season, cowpea holds significant importance for both human and livestock nutrition. Being a cost-effective protein source compared to meat, it addresses food scarcity efficiently (Moura et al., 2012).

Zinc (Zn) plays a pivotal role in cowpea's nitrogen metabolism and protein accumulation in grains, also influencing water absorption and mitigating adverse effects of heat and salt stress [12,16]. Similarly, phosphorus is another vital mineral nutrient that promotes the development of a robust root system and expedites plant maturity (Prem et al., 2020).

“Cowpea's ability to fix atmospheric nitrogen allows it to respond well to small quantities of nitrogenous fertilizers applied as a starter dose. An application of 15-25 Kg N ha-1 has been found optimum to get better response, contributing to increased yield, nutrition, and protein content. Conversely, deficient plants may exhibit stunted growth and develop a yellow-green color, impacting their photosynthetic behavior and overall growth” [2,13,15].

“Phosphorus, another essential nutrient, plays a key role in increasing pulse productivity, particularly in promoting root growth, nodule formation, and nitrogen fixation in legume crops. Fixation of atmospheric nitrogen in leguminous crops is an energy-intensive process requiring sufficient phosphorus supply to meet its ATP requirement” [3].

“Furthermore, potassium is essential for the growth and development of plants, improving yield, and quality of various crops. Its influence on photosynthesis, water use efficiency, and plant tolerance to diseases, drought, and cold, makes it crucial for balancing protein and carbohydrate levels” [4,14]. Pulses, including cowpea, hold significant value in the Indian diet, providing high-quality protein and essential nutrients. However, the productivity of pulses in India lags behind cereals, creating a need for increased productivity to address protein malnutrition amidst a growing population [5-8]. Cowpeas, with their elevated protein content ranging from 21.2% to 30.6%, can play a crucial role in bridging this gap (Ghosh and Hassan, 1979). Despite its potential, cowpea productivity remains subpar in India, including Karnataka, primarily due to low seed replacement rates, imbalanced fertilizer application on nutrient-deficient soils, and shifting rainfall patterns [9-11]. Therefore, it is imperative to improve productivity and address these challenges effectively.

In summary, cowpea stands out as a valuable crop in India, well-adapted to adverse conditions while providing essential nutrition. However, addressing soil nutrient deficiencies and augmenting cowpea productivity is crucial for achieving sustainable agriculture and meeting the nutritional requirements of the population. Moreover, incorporating food sources with a high zinc content, such as cowpea, into the diet can help mitigate widespread zinc deficiency.

2. MATERIALS AND METHODS

The field experiment was conducted at the Research Farm of Soil Science and Agricultural Chemistry at Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj. It is situated at $25^0 24' 23''$ N latitude, $81^0 50' 38''$ Longitude, and at an altitude of 98 meters above sea level. Nine treatment combinations were comprised of randomized block designs with three replications. The treatment combination is T_1 [P_2O_5 @ 0% + Zn @ 0% Control], T_2 [P_2O_5 @ 0% + Zn @ 50%], T_3 [P_2O_5 @ 0% + Zn @

100%], T_4 [P_2O_5 @ 50% + Zn @ 0%], T_5 [P_2O_5 @ 50% + Zn @ 50%], T_6 [P_2O_5 @ 50% + Zn @ 100%], T_7 [P_2O_5 @ 100% + Zn @ 0%], T_8 [P_2O_5 @ 100% + Zn @ 50%], T_9 [P_2O_5 @ 100% + Zn @ 100%]. Healthy seeds of cowpea variety Gomti were sown 30 × 15 cm spacing in sandy loam soil. The recommended doses of N P K were applied @ 20:60:60 Kg ha-1. The graded level of N P K was applied through Urea, Diammonium phosphate, and Murate of potash. Half the dose of nitrogen and the full dose of phosphorus and potassium were applied basally at the time of sowing. The soil samples were collected randomly from the experimental field to ascertain the nutrient status of each plot at 0-15 and 15-30 cm depth. The size of the soil sample was reduced by air-drying and crushing with the wooden hammer and then passing through a 2 mm sieve, conning, and quartering to prepare the composite soil sample for physical and chemical analysis.

Table 1. Treatment combination for Cowpea

Treatment	Treatment combination
T_1	**(**Absolute control)
T_2	P_2O_5 @ 0% + Zn @ 50%
T_3	P_2O_5 @ 0% + Zn @ 100%
T_4	P_2O_5 @ 50% + Zn @ 0%
T_5	P_2O_5 @ 50% + Zn @ 50%
T_6	P_2O_5 @ 50% + Zn @ 100%
T_7	P_2O_5 @ 100% + Zn @ 0%
T_8	P_2O_5 @ 100% + Zn @ 50%
T_9	P_2O_5 @ 100% + Zn @ 100%

3. RESULTS AND DISCUSSION

3.1 Effect on Soil Physical Properties

“The interaction effect of Phosphorus and Zinc on the bulk density of soil after crop harvest was also found significant. The maximum bulk density of 1.52 and 1.52 Mg m^{-3} of soil was revealed at 0-15 and 15-30 cm depth in T_1 [P_2O_5 @ 0% + Zn @ 0%] and minimum bulk density of 1.18 and 1.18 Mgm^{-3} of soil was found in T_9 [P_2O_5 @ 100% + Zn @ 100%]”. [17] The interaction effect of Phosphorus and Zinc on the Particle density of soil after crop harvest was found significant. The maximum Particle density of 2.61 and 2.63 Mg m^{-3} of soil was revealed at 0-15 and 15-30 cm depth in T_1 [P_2O_5 @ 0% + Zn @ 0%] and minimum Particle density of 2.46 and 2.48 Mg m^{-3} of soil was found in T_9 [P_2O_5 @ 100% + Zn @ 100%]. The interaction effect of Phosphorus and Zinc on the Pore space of soil after crop harvest was found significant. The maximum Pore space of 48.49 and 47.99% of the soil was revealed at 0-15 and 15-30 cm depth in T_9 [P_2O_5 @ 100% + Zn @ 100%] and minimum Pore space of 45.69 and 45.30% of the soil was found in T_1 [P_2O_5 @ 0% + Zn @ 0%]. The interaction effect of Phosphorus and Zinc on the Water Holding Capacity of soil after crop harvest was found significant. The maximum Water Holding Capacity of 44.75 and 44.03% of soil was revealed at 0-15 and 15-30 cm depth in T_9 [P_2O_5 @ 100% + Zn @ 100%] and the minimum Water Holding Capacity of 41.68 and 40.95% of soil was found in T_1 [P_2O_5 @ 0% + Zn @ 0%].

3.2 Effect on Soil Chemical Properties

The interaction effect of Phosphorus and Zinc on the pH of soil after crop harvest was found significant. The maximum pH of 7.20 and 7.25 of soil was revealed at 0-15 and 15-30 cm depth in T_1 [P_2O_5 @ 0% + Zn @ 0%] and minimum pH 6.75 and 6.77 of soil was found in T_9 [P_2O_5 @ 100% + Zn @ 100%]. The interaction effect of Phosphorus and Zinc on the EC (dS m^{-1}) of soil after crop harvest was found significant. The maximum EC (dS m^{-1}) 0.48 and 0.49 of soil was revealed at 0-15 and 15-30 cm depth in T_9 [P_2O_5 @ 100% + Zn @ 100%] and minimum EC (dS m^{-1}) 0.33 and 0.34 of soil was found in T_1 [P_2O_5 @ 0% + Zn @ 0%]. The interaction effect/response of Phosphorus and Zinc on the % Organic carbon of soil after crop harvest was found significant. The maximum % Organic carbon 0.47 and 0.46 of soil was revealed at 0-15 and 15-30 cm depth in T_9 [P_2O_5 @ 100% + Zn @ 100%] and the minimum % Organic carbon 0.34 and 0.32 of soil was found in T_1 [P_2O_5 @ 0% + Zn @ 0%]. The interaction effect of Phosphorus and Zinc on the Nitrogen (Kg ha-1) of soil after crop harvest was found significant. The maximum Nitrogen (Kg ha-1) 288.14 and 287.68 of soil was revealed at 0-15 and 15-30 cm depth in T_9 [P_2O_5 @ 100% + Zn @ 100%] and minimum Nitrogen (Kg ha-1) 261.56 and 261.19 of soil was found in T_1 [P_2O_5 @ 0% + Zn @ 0%]. The interaction effect of Phosphorus and Zinc on the Phosphorus (Kg ha^{-1}) of soil after crop harvest was found significant. The maximum Phosphorus (Kg ha^{-1}) 29.60 and 28.85 of soil was revealed at 0-15 and 15-30 cm depth in T_9 [P_2O_5 @ 100% + Zn @ 100%] and minimum Phosphorus (Kg ha^{-1}) 20.92 and 19.78 of soil was found in T_1 [P_2O_5 @ 0% + Zn @ 0%]. The interaction effect of Phosphorus and Zinc on the Potassium (Kg ha^{-1}) of soil after crop harvest was found significant. The maximum Potassium (Kg ha^{-1}) 192.41 and 191.54 of soil was revealed at 0-15 and 15-30 cm depth in T $_9$ [P_2O_5 @ 100% + Zn @ 100%] and minimum Potassium (Kg ha^{-1}) 175.44 and 174.08 of soil was found in T_1 [P_2O_5 @ 0% + Zn @ 0%].

Table 2. Influence of phosphorus and zinc on bulk density particle density pore space and water holding capacity of post-harvest soil

Treatment	BD (Mg m^{-3})		PD (Mg m^{-3})		Pore space (%)		WHC (%)	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
T_1	1.52	1.52	2.61	2.63	45.69	45.30	41.68	40.95
T_2	1.48	1.49	2.60	2.61	46.01	45.62	42.10	41.20
T_3	1.44	1.45	2.58	2.60	46.52	46.15	42.42	41.72
T_4	1.37	1.38	2.56	2.58	46.85	46.44	43.08	42.30
T_5	1.37	1.37	2.55	2.57	47.04	46.64	43.49	42.68
T_6	1.30	1.30	2.53	2.54	47.31	46.94	43.78	43.05
T_7	1.26	1.26	2.51	2.52	47.79	47.39	44.12	43.38
T_8	1.22	1.22	2.48	2.51	47.95	47.52	44.48	43.70
T_9	1.18	1.18	2.46	2.48	48.49	47.99	44.75	44.03

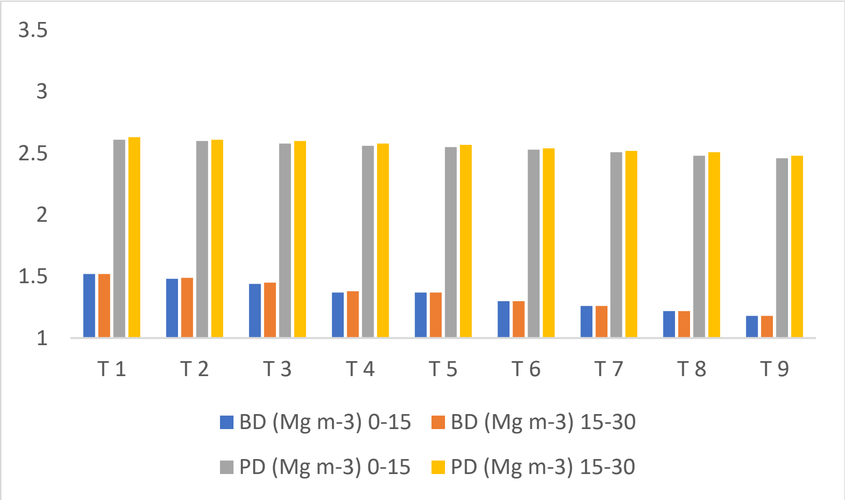

Fig. 1. The influence of phosphorus and zinc on the bulk density and particle density of soil after crop harvest

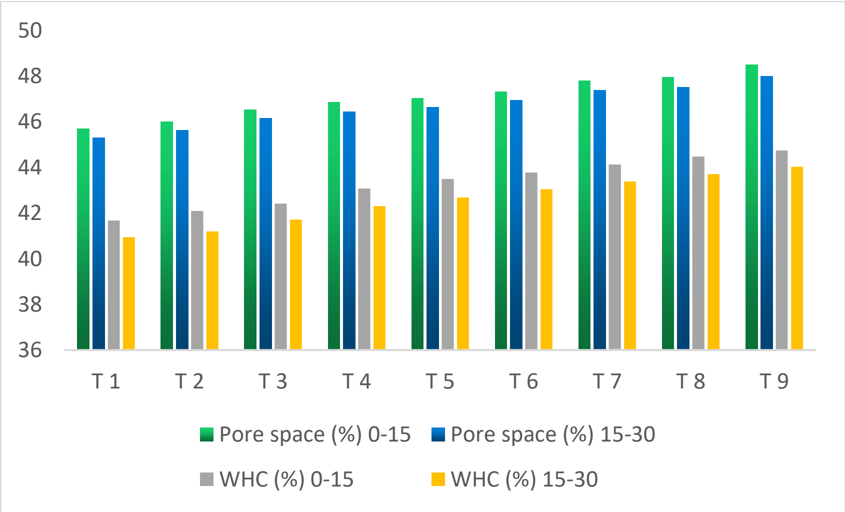

Fig. 2. The influence of phosphorus and zinc on pore space (%) and water retaining capacity of soil after crop harvest

Table 3. Influence of phosphorus and zinc on pH electrical conductivity and organic carbon of post-harvest soil

Treatment	pH		EC (dS m^{-1})		OC (%)	
	0-15	15-30	0-15	15-30	0-15	15-30
T_1	7.20	7.25	0.33	0.34	0.34	0.32
T_2	7.17	7.22	0.35	0.36	0.35	0.34
T_3	7.12	7.18	0.38	0.39	0.38	0.36
T_4	7.15	7.13	0.37	0.39	0.37	0.35
T_5	7.10	7.12	0.40	0.41	0.39	0.38
T_6	6.97	7.03	0.43	0.44	0.42	0.41
T_7	6.90	6.97	0.43	0.45	0.42	0.41
T_8	6.84	6.87	0.45	0.47	0.44	0.44
T_9	6.75	6.77	0.48	0.49	0.47	0.46

Table 4. Influence of phosphorus and zinc on available nitrogen available phosphorus and available potassium of post-harvest soil

Treatment	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	0-15	15-30	0-15	15-30	0-15	15-30
T_1	261.56	261.19	20.92	19.78	175.44	174.08
T_2	266.52	265.96	22.49	21.28	176.38	175.47
T_3	269.27	267.71	23.04	22.01	178.61	177.15
T_4	279.09	276.86	23.88	22.87	179.06	178.67
T_5	280.28	279.10	24.60	23.42	180.55	179.93
T_6	283.01	282.12	25.48	24.52	182.94	182.18
T_7	285.42	284.21	25.98	25.29	185.73	185.08
T_8	287.05	285.60	28.41	27.18	188.35	187.24
T_9	288.14	287.68	29.60	28.85	192.41	191.54

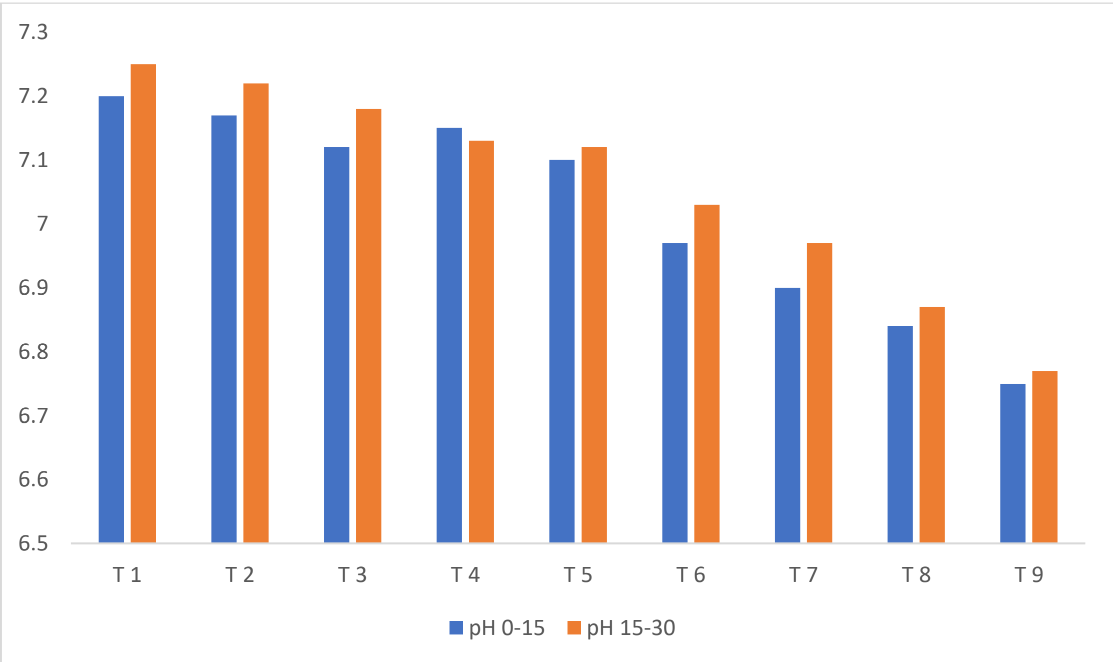

Fig. 3. The influence of phosphorus and zinc on pH of soil after crop harvest

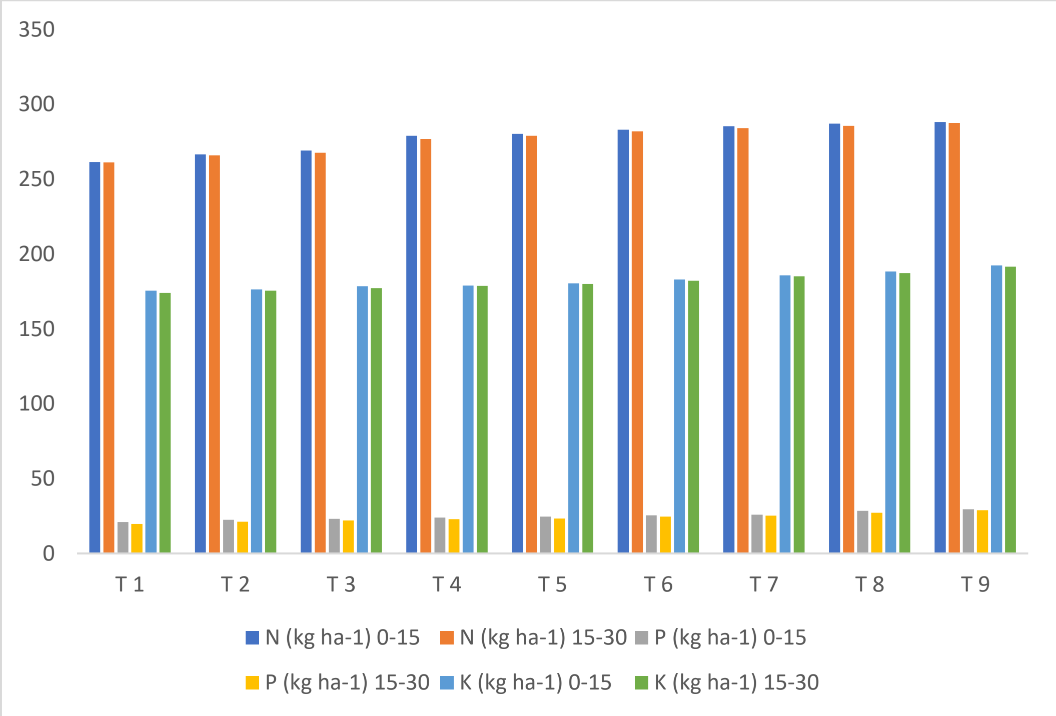

Fig. 4. The effect of phosphorus and zinc on available NPK of soil after crop harvest

4. CONCLUSION

The results of the experiment concluded as the application of Phosphorus and Zinc in treatment T_9 [P_2O_5 @ 100% + Zn @ 100%] was found sample most effective in improving physicochemical properties of soil as a decrease in bulk density, particle density, and pH an increase in electrical conductivity, Pore space, Water retaining capacity, organic carbon, and Available Nitrogen, Phosphorus, and Potassium. Similarly, the maximum plant height, number of Branches per plant, Pod Per Plant, Length of Pod, Seed and Straw yield, and Harvesting index was found in treatment T_9 [P_2O_5 @ 100% + Zn @ 100%]. The economically of different treatments concerned, the treatment T_9 [P_2O_5 @ 100% + Zn @ 100%] provides a maximum Gross Return ₹ 129340.00 ha^{-1}, a Net Return of ₹ 91211.00 ha^{-1} with Cost benefit ratio is 1:3.39.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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