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Effect of Potassium and Zinc on Soil Properties and Fraction of Potassium and Zinc in Soil

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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 carried out on Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand during *rabi* season of the year 2020-21. The experiment comprising nine treatment combinations consisted of three levels of potassium (0, 20 and 40 kg/ha) and three levels of zinc (0, 2.5 and 5.0 kg/ha). These treatments were evaluated in Randomized Block Design (factorial) with four replications. The soil of the experimental plot was loamy sand in texture, alkaline in reaction, low in organic carbon and available nitrogen, medium in available phosphorus,

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potassium and zinc. Results of the experiment revealed that the available K_2O in soil was significantly increased due to application of 40 kg K_2O/ha (K_2) and was found to be at par with application of 20 kg K_2O/ha (K1). All other chemical properties of soil (pH, EC, organic carbon, available N, P_2O_5, S, Fe, Mn, Zn and Cu) were not differ significantly due to application of different levels of potassium. Levels of zinc also failed to produce its significant effect on chemical properties of soil except available Zn in soil as it was significantly increased with the treatment of Z_2 (5.0 kg Zn/ha) than control but was found to be at par with treatment Z_1 (2.5 kg Zn/ha). Moreover, no any chemical property of soil differ due to the interaction of different levels of potassium and zinc. The water soluble K and exchangeable K fractions in soil significantly increased with the treatment of K_2 (40 kg K_2O/ha) otherwise non-exchangeable K, total K and different zinc fractions in soil did not differ significantly by the different levels of potassium. Different potassium fractions and total Zn fraction in soil were found to be non-significant under the different zinc levels but all the zinc fractions in soil (water soluble plus exchangeable Zn, carbonate bound Zn, Fe/Mn oxide bound Zn, organically bound Zn and residual Zn) significantly increased with the treatment of Z_2 (5.0 kg Zn/ha) and was remained at par with treatment Z_1 (2.5 kg Zn/ha). The interaction between potassium and zinc failed to influence significantly on potassium and zinc factions in soil.

Keywords: Potassium; zinc; protein formation; organic carbon.

1. INTRODUCTION

Potassium (K) is one of the important nutrient among 17 vital nutrients required for the growth and reproduction of crops. Potassium has a great buffering action and stabilizes various enzymes system. It acts as a major cation for the maintenance of cation-anion balance. "Its beneficial action on crop quality shows better utilization of nitrogen and increased protein formation" [1].

"Potassium application has been neglected in many countries, including India, which has resulted in soil K depletion in agricultural ecosystems and a decline in crop yields" [2]. "Among essential nutrient elements, Potassium is the third major element taken up by the plants. Plants absorb it in larger amounts as compared to other mineral elements except nitrogen. It has utmost importance for imparting drought and disease resistance and has synergistic effect on crops with nitrogen and phosphorus" [3,4]. "Higher yields and crop quality can be obtained at optimal N:K nutritional ratios. It is an essential macronutrient required for proper development of plants. Potassium has been considered as the "quality element" for crop production. Pulse growing Agroecological region of India vary widely in their K supplying capacity" [5]. Light textured alluvial soils, red and lateritic soils and shallow black soils with low levels of available K and even black cotton soil needs K supplementation to enhance the productivity. "Based on the number of field studies, it can be suggested that the application of 20-40 kg K_2O/ha and foliar application of 1-2% of KNO_3 is beneficial for higher pulse production" [6].

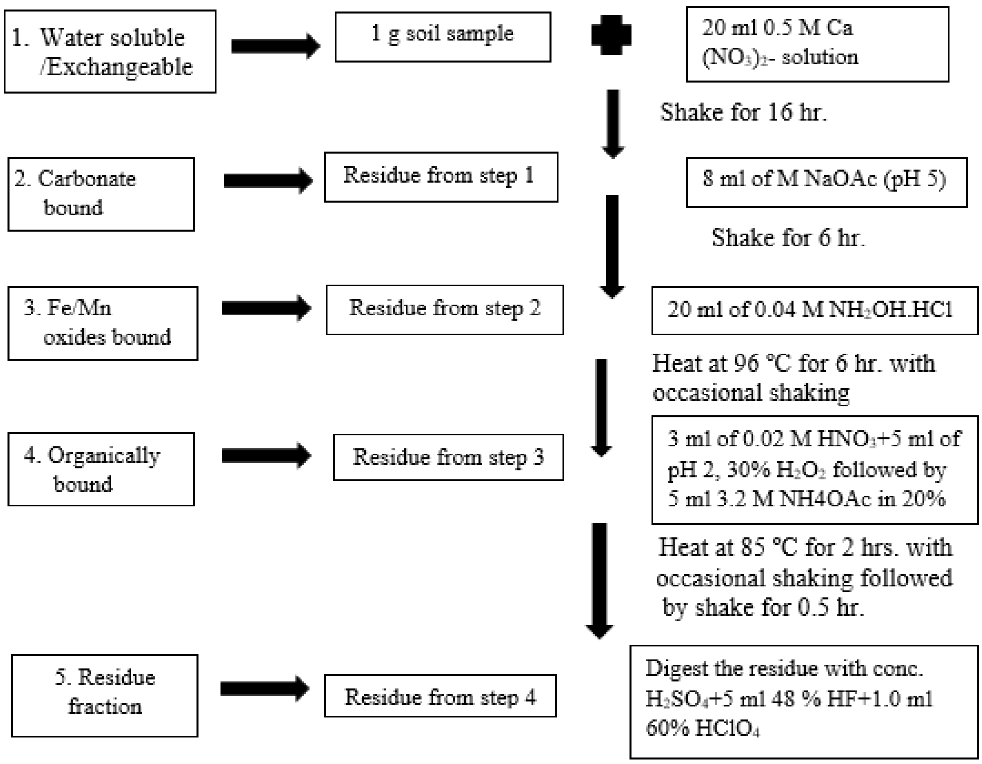
"Most of the Potassium in soil exists in various insoluble rocks, minerals and sedimentary materials. Based on its availability to plants, soil potassium can be classified into three main groups *i.e.,* unavailable, readily available and slowly available K" [7]. "The bulk of soil potassium (about 98% of total K) usually exists in unavailable form and is found in primary (micas and feldspars) and secondary (illite group) clay minerals" [8]. "The readily available K constitutes only 1-2% of total K and exists in soil in two forms, *viz*., solution and exchangeable K adsorbed on soil colloidal surface" [9]. "It is not a constituent of organic structures, but regulates enzymatic activities (over 60 enzymes require K for activation), translocation of photosynthesis and considerably improves seed yield of chickpea if applied as a fertilizer" [10,11,12].

"Among the micronutrients, zinc plays a vital role in plant growth and development. Zinc has been the micronutrient needed by crops especially pulses in sufficiently large quantity. Zinc also catalyses the biosynthesis of indole acetic acid, acting as metal activator of the enzyme, there by ultimately increasing the crop yield" [1]. Moreover, it controls the equilibrium between CO_2, water and carbonic acid in plant metabolism and helps in synthesis of nucleic acids, proteins and stimulates seed formation. Its deficiency retards photosynthesis and nitrogen metabolism.

"The plants exhibited lower rate of protein synthesis and protein accumulation under zinc deficiency. Zinc also plays important role in physiological process of plants through synthesis of hormones essential for growth and reproduction. Zinc plays an important role in metabolism both in plants as well as in animals by acting as essential component of enzyme, RNA, electron carrier *etc*., and acts as a functional, structural and regulatory cofactor of a large number of enzymes" [1]. "The proteinases, peptidases, carbonic, dehydrogenase, anhydrase *etc*., are the examples of the metallo-enzymes in which zinc is an integral part. Zinc is an essential component of RNA polymerase and provides structural integrity to ribosomes. Soil is the principal source of zinc for plants. The accumulation of zinc in edible parts of plant serves as zinc source for primary consumers. Unfortunately, about 50% of Indian soils are deficient in zinc and expected to further increase up to 63% by 2025 which imparting zinc malnutrition in population especially in children" [13]. Singh [14] reported that "one third of the world population is at the risk of zinc malnutrition due to inadequate dietary intake of zinc resulting from wide spread hidden hunger of zinc in seeds and feeds. Also, the intensive cropping systems of high yielding varieties have led to depletion of micronutrients, especially zinc".

2. MATERIALS AND METHODS

A field experiment was carried out on Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *rabi* season of the year 2020-21. The experimental plot's soil had a texture similar to loamy sand, was alkaline in response, had a low level of accessible nitrogen and organic carbon, and a medium level of potassium, zinc, and phosphorus. Three levels of potassium (0, 20, and 40 kg/ha) and three levels of zinc (0, 2.5 and 5.0 kg/ha) were used in the nine treatment combinations that made up the experiment. Four replications of the Randomized Block Design (factorial) were used to assess these treatments. A fixed dose of 20 kg/ha of nitrogen and 40 kg/ha of phosphorus were applied as fertilizer. Application of zinc and potassium was done in accordance with the therapies. Utilizing sources of urea, DAP, MOP, and zinc sulfate, respectively, the nutrients N, P, K, and Zn were applied. The experimental data that was captured for fractions and physico-chemical properties.



Flow chart 1. Flow chart of sequential fraction scheme by Miller et al. (1986)

Table 1. Methods adopted for analysis of potassium fractions in soil

Sr. No.	K fractions	Method	References
1.	Water soluble K	Flame emission spectroscopy	Richards (1954)
2.	Exchangeable K	Neutral N NH_4OAC	Hanway and Heidel (1952)
3.	Non-exchangeable K	HNO_3 extractable	Wood and De Turk (1941)
4.	Total K	HF-$HClO_4$ digestion	Page et al. (1982)

3. RESULTS AND DISCUSSION

3.1 Effect of Potassium and Zinc on Chemical Propertis of Soil

The soil properties (pH, EC and OC) analysis after harvest of chickpea were not differ significantly could be ascribed to the buffering capacity of soil. Similar results were found by Keram et al. [15] and Sutariya et al. [16].

A perusal of the data presented in Table 3 revealed that available N, P and S in soil after harvest of chickpea did not differ significantly by the different levels of potassium as well as zinc. But the treatment K_2 (40 kg K_2O/ha) and treatment Z_2 (5.0 kg Zn/ha) recorded maximum value of available N in soil (140 and 140 kg/ha, respectively). Numerically maximum available phosphorus (50.1 and 50.0 kg/ha, respectively) was found in treatment K_2 (40 kg K_2O/ha) and Z_2 (5.0 kg Zn/ha) than other treatments.

The significant increase in available potassium in soil by the application of 20 and 40 kg K_2O/ha might be attributed to solubilization of native status of potassium and such increase in available potassium status of the soil at harvest of the crop may also be due to direct addition of potassium to available pool of the soil. Similar results were also reported by Tandon [17], Gajghane et al. [18], Kadam et al. [19] and Jat et al. [20].

A perusal of the data presented in Table 3 revealed that available Fe, Mn and Cu in soil after harvest of chickpea did not differ significantly by the different levels of potassium as well as zinc. But the treatment Z_2 (5 kg K_2O/ha) and recorded maximum value of available Zn in soil (0.78 mg/ha, respectively). But numerically maximum available (Fe 1.35 and 1.34 mg/kg, 4.04 and 4.03 mg/kg, Mn 2.12 and 2.11 mg/kg and Cu 1.35 and 1.34 mg/kg respectively) was obtained under treatment of application of 40 kg K_2O/ha (K_2) and 5.0 kg Zn/ha (Z_2) than other treatments.

Table 2. Effect of potassium and zinc on available N, P_2O_5, K_2O and S in soil after harvest of chickpea crop

Treatments	Soil chemical properties		
	pH (1:25)	**EC (dS/m) (1:25)**	**OC (%)**
K levels (kg/ha)			
K_0	7.75	0.140	0.39
K_1	7.79	0.142	0.39
K_2	7.81	0.145	0.40
S. Em±	0.05	0.002	0.01
CD (P = 0.05)	NS	NS	NS
Zn levels (kg/ha)			
Z_0	7.80	0.141	0.38
Z_1	7.78	0.142	0.40
Z_2	7.77	0.144	0.40
S. Em±	0.05	0.002	0.01
CD (P = 0.05)	NS	NS	NS
K × Zn	NS	NS	NS
CV%	2.38	3.88	4.40

Table 3. Effect of potassium and zinc on available N, P_2O_5, K_2O and S in soil after harvest of chickpea crop

Treatments	Available nutrients			
	N (kg/ha)	P_2O_5	K_2O	S (mg/kg)
		K levels (kg/ha)		
K_0	135	48.8	219	15.7
K_1	138	49.5	228	16.2
K_2	140	50.1	232	16.5
S. Em±	2	0.6	3	0.2
C.D. (P = 0.05)	NS	NS	9	NS
		Zn levels (kg/ha)		
Z_0	136	49.1	225	15.7
Z_1	137	49.4	226	16.2
Z_2	140	50.0	228	16.5
S. Em±	2	0.6	3	0.2
C.D. (P = 0.05)	NS	NS	NS	NS
K × Zn	NS	NS	NS	NS
CV%	4.33	3.98	4.54	5.03

Table 4. Effect of potassium and zinc on available Fe, Mn, Zn and Cu in soil after harvest of chickpea

Treatments	DTPA extractable micronutrient (mg/kg)			
	Fe	Mn	Zn	Cu
		K levels (kg/ha)		
K_0	3.77	2.03	0.73	1.29
K_1	3.92	2.07	0.75	1.32
K_2	4.04	2.12	0.76	1.35
S. Em±	0.08	0.03	0.01	0.02
CD (P = 0.05)	NS	NS	NS	NS
		Zn levels (kg/ha)		
Z_0	3.78	2.03	0.71	1.31
Z_1	3.92	2.08	0.75	1.32
Z_2	4.03	2.11	0.78	1.34
S. Em±	0.08	0.03	0.01	0.02
CD (P = 0.05)	NS	NS	0.03	NS
K × Zn	NS	NS	NS	NS
CV%	6.65	4.66	5.33	3.95

3.2 Effect of Potassium and Zinc on Fractions of Potassium and Zinc in Soil

3.2.1 Potassium fractions in soil

The data pertaining to the different potassium fractions *viz.,* water soluble, exchangeable, non-exchangeable and total fractions in 0-15 cm depth of soil as influenced by application of potassium and zinc is presented in Table 5.

3.2.1.1 Water soluble K

Effect of potassium: The data presented in Table 5 indicated the significant effect of different levels of potassium on water soluble K in soil. The range of water soluble K was varied 25.35-27.59 mg/kg due to application of potassium. The treatment of application of 40 kg K_2O/ha recorded significantly highest water soluble K (27.59 mg/kg) than rest of the treatments.

Effect of zinc: The water soluble K did not differ significantly due to the treatment containing application of zinc (Table 5). The water soluble K was varied from 25.95 -26.66 mg/kg by the application of different levels of zinc. But maximum water soluble K (26.66 mg/kg) was found in treatment of application of 5.0 kg Zn/ha than other treatments.

Interaction effect: The interaction effect between different levels of potassium and zinc was found to be non-significant with respect to water soluble K fractions in soil after the harvest of the chickpea Table 5.

Effect of potassium: The data presented in Table 5 indicated that the exchangeable K in soil was significantly influenced with the treatment containing application of potassium. The exchangeable K was varied from 72.03-75.61 mg/kg by the application of potassium. The treatment of application of 40 kg K_2O/ha (K_2) recorded significantly highest exchangeable K (75.61 mg/kg) than rest of the treatments.

Effect of zinc: The treatment containing application of zinc did not show any significant effect on exchangeable K in soil. The exchangeable K was varied from (73.98-74.89 mg/kg) by the different levels of zinc. But maximum exchangeable K was (74.89 mg/kg) observed by treatment of application of 5.0 kg Zn/ha (Z_2) Table 6.

Interaction effect: The interaction between different levels of potassium and zinc did not show any significant effect on exchangeable K in soil (Table 6).

3.2.1.2 Non-exchangeable K (mg/kg)

Effect of potassium and zinc: The non-exchangeable K was not differ significantly by the application of potassium and zinc. But it was obtained higher non-exchangeable K (602 and 593 mg/kg, respectively) with the treatment K_2 (40 kg K_2O/ha) and treatment Z_2 (5.0 kg Zn/ha) as compared to other treatments.

Interaction effect: The interaction effect of different levels of potassium and zinc was found to be non-significant on non-exchangeable K in soil (Table 6).

3.2.1.3 Total K

Effect of potassium and zinc: Similarly, different levels of potassium and zinc fail to exert significant effect on total K fraction in soil. The higher value of total K *i.e.,* 35446 and 35011 mg/kg, respectively were recorded under treatment K_2 (40 kg K_2O/ha) and treatment Z_2 (5.0 kg Zn/ha) than other levels of potassium and zinc.

Interaction effect: The interaction effect of treatment combination of different levels of potassium and zinc was not found to be significant in relation to total K fraction in soil (Table 6).

3.2.2 Fractions of zinc in soil

The data pertaining to the different fractions of zinc *viz.,* water soluble plus exchangeable Zn, carbonate bound Zn, Fe/Mn oxide bound Zn, organically bound Zn residual Zn, and total Zn in 0-15 cm depth of soil as influenced by different levels of potassium and zinc is presented in Table 6.

Table 5. Effect of potassium and zinc on potassium fraction in 0-15 cm depth of soil

Treatments	**Water soluble K**	**Exchangeable K**	**Non-exchangeable K**	**Total K**
	(mg/kg)			
		K levels (kg/ha)		
K_0	25.35	72.03	578	32861
K_1	26.15	75.25	587	34530
K_2	27.59	75.61	602	35446
S. Em±	0.26	0.94	7.2	756
CD (P = 0.05)	0.77	2.75	NS	NS
		Zn levels (kg/ha)		
Z_0	25.95	73.98	585	33442
Z_1	26.48	74.03	590	34384
Z_2	26.66	74.89	593	35011
S. Em±	0.26	0.9	7.2	705
CD (P = 0.05)	NS	NS	NS	NS
K × Zn	NS	NS	NS	NS
CV%	3.47	4.39	4.25	7..13

Table 6. Effect of potassium and zinc on fraction of zinc 0-15 cm depth of soil

Treatments	Water soluble plus exchangeable (mg/kg)	Carbonate bound fraction	Fe/Mn oxides bound fraction	Organically bound fraction	Residual fraction	Total Zn
K levels (kg/ha)						
K_0	0.148	1.23	7.46	2.91	60.30	75.38
K_1	0.150	1.25	7.68	2.95	62.63	76.53
K_2	0.153	1.28	7.90	3.05	64.29	77.73
S. Em±	0.002	0.02	0.14	0.04	1.20	1.11
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Zn levels (kg/ha)						
Z_0	0.146	1.22	7.44	2.88	59.89	74.66
Z_1	0.150	1.26	7.70	2.98	62.44	76.75
Z_2	0.156	1.29	7.93	3.05	64.39	78.23
S. Em±	0.002	0.02	0.14	0.04	1.20	1.11
CD (P = 0.05)	0.006	0.06	0.40	0.12	3.51	NS
K × Zn	NS	NS	NS	NS	NS	NS
CV%	5.09	5.53	6.24	4.89	6.68	5.05

3.2.2.1 Water soluble plus exchangeable zinc

Effect of potassium: The result revealed that there was no significant effect on water soluble plus exchangeable Zn in soil observed with the different potassium levels. The water soluble plus exchangeable Zn ranged from 0.147 to 0.153 mg/kg observed under the application of different levels of potassium. Numerically maximum value of water soluble plus exchangeable Zn was found in treatment K_2 (40 kg K_2O/ha) than other treatments.

Effect of zinc: The perusal data presented in Table 6 indicated that different levels of zinc resulted significant increased in form of water soluble plus exchangeable Zn (0.156 mg/kg) in 0-15 cm depth of soil by the treatment of application of 5.0 kg Zn/ha (Z_2) which was found statistically at par with the treatment Z_1 (2.5 kg Zn/ha).

Interaction effect: The interaction between different levels of potassium and zinc did not show any significant effect on water soluble plus exchangeable Zn in soil Table 6.

3.2.2.2 Carbonate bound Zinc

Effect of potassium: There was no significant difference observed on carbonate bound zinc due to the treatment containing potassium application (Table 6). The carbonate bound zinc was varied from (1.23 to 1.28 mg/kg) by the potassium. But numerically maximum carbonate bound zinc was observed with treatment of application of 40 kg K_2O/ha (K_2) as compared to other potassium levels.

Effect of zinc: Results given in Table 6 revealed that treatment of application of 5.0 kg Zn/ha (Z_2) significantly increased the carbonate bound zinc in soil (1.29 mg/kg) than control (Z_0) but was remained at par with treatment Z_1 (2.5 kg Zn/ha).

Interaction effect: The non-significant interaction effect was found on carbonate bound zinc fractions in soil at harvest of chickpea with the treatment combination of different levels of potassium and zinc (Table 6).

3.2.2.3 Fe/Mn oxides bound Zinc

Effect of potassium: The treatment containing application of different levels of potassium did not show any significant effect on Fe/Mn oxides bound zinc fraction in soil. But it was observed Fe/Mn oxides bound zinc fraction range from (7.46 to 7.90 mg/kg) with the levels of potassium up to 40 kg K_2O/ha (K_2) Table 6. Moreover, maximum value of Fe/Mn oxides bound zinc (mg/kg) was found under treatment K_2 (40 kg K_2O/ha).

Effect of zinc: The data presented in Table 6 indicated the Fe/Mn oxides bound zinc fractions were influenced significantly with the different levels of zinc. Significantly higher in soil (7.93 mg/kg) was recorded under the treatment of application of 5.0 kg Zn/ha which was found to be at par with treatment Z_1 (2.5 kg Zn/ha).

Interaction effect: The interaction effect of different levels of potassium and zinc was found to be non-significant on Fe/Mn oxides bound zinc fraction in soil Table 6.

3.2.2.4 Organically bound zinc

Effect of potassium: Organically bound zinc fraction in soil was not affect significantly due to the different levels of potassium (1.5). But organically bound zinc was varied from (2.91 to 3.05 mg/kg) with the treatment of application of potassium up to 40 kg K_2O/ha. Numerically maximum organically bound zinc (3.05 mg/kg) was found under the treatment K_2 (40 kg K_2O/ha) as compared to other treatments.

Effect of zinc: Table 6 showed that the significantly increased due to application of different levels of zinc. Significantly increased organically bound zinc fraction in soil was (3.05 mg/kg) found with the treatment containing application of 5.0 kg Zn/ha (Z_2) than control but it was remained at par with treatment (Z_1) 2.5 kg Zn/ha.

Interaction effect: The non-significant interaction effect was found on organically bound zinc fraction in soil after harvest of chickpea with the treatment combination of different levels of potassium and zinc.

3.2.2.5 Residual zinc

Effect of potassium: A perusal of the data presented in Table 6 revealed that residual zinc fraction in soil did not differ significantly by different potassium levels. However, the residual zinc fraction ranged from (60.30 to 64.04 mg/kg) due to different levels of potassium up to 40 kg K_2O/ha. The higher potassium level *i.e.,* 40 kg K_2O/ha (K_2) recorded numerically maximum residual zinc in soil (64.29 mg/kg) than rest of the treatments.

Effect of zinc: Different levels of zinc had significant effect on residual zinc fraction in soil (Table 4). The treatment containing application of 5.0 kg Zn/ha recorded significant increased in in soil (64.64 mg/kg) than control but was found to be at par with treatment Z_1 (2.5 kg Zn/ha).

Interaction effect: The interaction between different levels of potassium and zinc did not show any significant effect on residual zinc fraction in soil Table 6.

3.2.2.6 Total zinc

Effect of potassium and zinc: The data indicated in Table 6 revealed that different levels of potassium and zinc fail to produce any significant effect on total zinc fraction in soil. But, total zinc fraction in soil is varied from 75.38 to 77.73 mg/kg due to different potassium levels and its maximum value was found in treatment K_2 (40 kg K_2O/ha). Whereas total zinc fraction was range from 74.66 to 78.23 mg/kg with the different levels of zinc and its maximum value was observed in treatment Z_2 (5.0 kg Zn/ha).

Interaction effect: The interaction between different levels of potassium and zinc did not show any significant difference with respect to total zinc fraction in soil after harvest of chickpea (Table 6).

4. CONCLUSION

Different potassium fractions and total Zn fraction in soil were found to be non-significant under the different zinc levels but all the zinc fractions in soil (water soluble plus exchangeable Zn, carbonate bound Zn, Fe/Mn oxide bound Zn, organically bound Zn and residual Zn) significantly increased with the treatment of Z_2 (5.0 kg Zn/ha) and was remained at par with treatment Z_1 (2.5 kg Zn/ha). The interaction between potassium and zinc failed to influence significantly on potassium and zinc factions in soil.

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 manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chauhan A, Shinde R, Shroff J, Bhuriya K. Effect of potassium and zinc on yield and nutrient content of chickpea. The Pharma Innovation Journal. 2022;11(8):1742-7.
2. Regmi A, Ladha J, Pasuquin E, Pathak H, Hobbs P, Shrestha L, Duveiller E. The role of potassium in sustaining yields in a long-term rice-wheat experiment in the Indo-Gangetic Plains of Nepal. Biology and Fertility of Soils. 2002;36(3):240-247.

3. Das PC. Plant Nutrients. In: Manures and Fertilizers (2nd Ed.). Kalyani Publishers, New Delhi, India. 1999;5-10.
4. Rathore KM, Sharma MK, Manoj, Yadav VK, Yadav RK, Meena H, Ghasil BP. Effect of Iron, Zinc and microbial inoculants on soil health and nutrient uptake of Urdbean (*Vigna mungo L.)* in Vertisols. J. Exp. Agric. Int. 2023;45(10):6-17.
Available:https://journaljeai.com/index.php/JEAI/article/view/2195
5. Sarma HH, Rajkumar A, Baro A, Das BC, Talukdar N. Impact of heavy metal contamination on soil and crop ecosystem with advanced techniques to mitigate Them. J. Adv. Biol. Biotechnol. 2024;27(6): 53-6.
Available:https://journaljabb.com/index.php/JABB/article/view/865
6. Ali M, Srinivasa Rao, Ch. Role of potassium fertilization in improving productivity of pulse crops. In Proceeding of International Symposium held in New Delhi, India. 2001;261-267.
7. Rasuli F, Owliaie H, Najafi-Ghiri M, Adhami E. Effect of biochar on potassium fractions and plant-available P, Fe, Zn, Mn and Cu concentrations of calcareous soils. Arid Land Research and Management. 2022;36(1):1-26.
8. Attoe OJ, Truog E. Exchangeable and acid soluble K as regards availability and reciprocal relationships. Soil Science Society of Soil America Proceeding. 1945; 10:81-86.
9. Brady NC, Well RR. The nature and properties of soils (13th Ed.). Personal Education Pvt. Ltd, New Delhi; 2002.
10. Samiullah, Khan NA. Physiological investigation on interactive effect of P and K on growth and yield of chickpea. Indian Journal of Plant Physiology. 2003;8(2): 165-170.
11. Singh ON, Singh RS, Singh JP. Supplementing fertilizer potassium to chickpea. Journal of Potash Research. 1994;10:83-85.
12. Verma VK. Response of irrigated chickpea (*Cicer arietinum* L.) to NPK in light soils and its economics. Advances in Plant Science. 1994;7(1):138-142.
13. Shukla AK, Tiwari PK. Progress report of AICRP on micro- and secondary nutrients and pollutant elements in soils and plants. IISS, Bhopal; 2014.
14. Singh MV. Detrimental effect of zinc deficiency on crops productivity and human health. First Global Conference on Biofortification, Harvest Plus, Washington, USA; 2010.
15. Keram KS, Sharma BL, Sawarkar SD. Impact of Zn application on yield, quality, nutrients uptake and soil fertility in a medium deep black soil (vertisol). International Journal of Science, Environment and Technology. 2012;1(5): 563-571.
16. Sutariya GS, Ramdevputra MV, Ansodaria VV, Akbari KN. Effects of potassium and zinc nutrition on yield and quality of forage sorghum. Indian Journal of Agricultural Research. 2013;47(6):540-544.
17. Tandon HLS. Phosphorus research and agricultural production in India. FDCO, New Delhi; 1987.
18. Gajghane PG, Toncher SS, Rutz MM. Effect of potassium and Sulphur levels on soils fertility status after harvest of Mustard. Plant Archives. 2015;15(1):347-351.
19. Kadam YB, Kharche VK, Borkar VS, Konde NM, Gabhne VV. Effect of sources and levels of potassium in cotton as influenced fractions of soil potassium under vertisols in Vidarbha region of Maharashtra. An Asian Journal of Soil Science. 2016;11(2):246-257.
20. Jat, Ramswaroop, Naga, Sita Ram, Choudhary, Rajsingh, Mohammad, Irfan. Effect of potassium and Sulphur on quality of Sesame (*Sesamum vindicum* L.). International Journal of Current Microbiology and Applied Sciences. 2017; 6(4):1876- 1878.

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