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Effect of zeolite and potassium application on changes in soil properties after harvest of maize

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Abstract
The present investigation was undertaken to study the effect of zeolite and potassium application on Changes in soil properties after harvest of maize. The field experiment was conducted at Post Graduate Institute, Research Farm, Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri, during of summer 2022. The experimental site was medium deep black, clayey in texture, having a bulk density of 1.35 Mg m^{-3}, particle density of 2.65 Mg m^{-3}, slightly alkaline in reaction, low in electrical conductivity and medium in organic carbon and calcium carbonate content. The soil was low in available nitrogen, medium in phosphorus and very high in potassium content. However, soils were sufficient in available micronutrients *viz*., Fe, Mn, Zn and Cu.
The experiment was laid out in a randomized block design with ten treatments and three replications. The treatments were T_1: Absolute control, T_2: GRDF 120:60:40 N, P_2O_5, K_2O + 10 t FYM ha^{-1}, T_3: Zeolite @ 400 kg ha^{-1}, T_4: Zeolite @ 600 kg ha^{-1}, T_5: Zeolite @ 400 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1}), T_6: Zeolite @ 400 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1}), T_7: Zeolite @ 400 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1}), T_8: Zeolite @ 600 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1}), T_9: Zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1}), T_{10}: Zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1}). The recommended doses of N and P_2O_5 and FYM @ 10 t ha^{-1} are the same for all treatments as per RDF except T_1.
The soil physical properties *viz*., bulk density, porosity and hydraulic conductivity and chemical properties *viz*., OC, $CaCO_3$ and CEC were significantly influenced by the application of different levels of zeolite and potassium after harvest of maize.
The soil available nitrogen, phosphorous, potassium (N, P, K) and micronutrients (Fe, Mn, Zn and Cu) were significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. Significantly, the highest available N, P, K (216.77, 16.04 and 436.40 kg ha^{-1} respectively) and DTPA extractable micronutrients Fe, Mn, Zn, Cu (4.26, 6.95, 0.49 and 1.59 mg kg^{-1} respectively) were observed in treatment T_{10} i.e., zeolite @ 600 +100% K_2O of RDF (40 kg ha^{-1}) over the rest of treatments except T_9 i.e., zeolite @ 600 kg ha^{-1}+ 75% K_2O of RDF which was statistically at par. Application of zeolite and potassium influenced the soil properties and availability of nutrients in Inceptisol.

Keywords: Cauliflower, KTS, SOP, MOP

Introduction
Maize (*Zea mays* L.) is an important cereal crop which belongs to the grass family with chromosome number 2n = 20. It is the world's second most widely grown crop and India's third most important cereal crop after rice and wheat. It is cultivated as a cereal grain that has been domesticated in Central America. Globally, maize is known as the "Queen of cereal crops" because of its higher grain yield potential among all the cereals. It exhibits greater adaptability as it can be grown in a variety of agro-climatic conditions.
Potassium is the third major plant nutrient next to nitrogen and phosphorous with respect to crop production. The requirement for potassium in maize is high as it absorbs high quantities of potassium. It plays a significant role in enhancing crop quality, so it is recognized as a "quality element". It is associated with the movement of water, carbohydrates and nutrients in plants. About 80 different types of enzymes are stimulated by potassium (Kasana and Khan, 1976) [14]. It plays an important role in the stomatal functioning and helps plants to grow under drought conditions (Hsiao, 1973) [11]. Insufficient potassium in plants leads to difficulty in absorbing water, which leads to an increase in drought stress.

Generally, maize plants conserve water and reduce moisture stress by closing leaf stomata, which in terms are regulated by potassium. That's why plants with inadequate potassium supply may be slower in closing their stomata, which reduces drought stress.

Zeolites are hydrated alumino silicate minerals made up of cross-linked tetrahedra of AlO_4 and SiO_4, which consist of pores and corners of alumino silicate tetrahedra (AlO_4 and SiO_4) that are connected in three-dimensional structure of about 12 Å in diameter, connected by channels of about 8 Å diameter and made up of rings of 12 linked tetrahedron (Kaduk and Faber, 1995) [13]. Zeolites with distinct cation exchange properties, molecular sieving and adsorption (Mumpton, 1999; Glisic *et al*., 2009; Hecl and Toth, 2009) [18, 8, 10] could be used as a stabilizer, chelator and fertilizer (Loizidou and Kapetanios, 1992 and Perez-Caballero *et al*., 2008) [16, 20]. Zeolites are excellent carriers and regulators of mineral fertilizers. Besides, they also serve as a source of nutrients. As carriers of N and K fertilizers, they can increase N and K use efficiency and decrease the application rates for equal yield to be achieved (Polat *et al*., 2004) [21], zeolite enables both inorganic and organic fertilizers to slowly release their nutrients (Perez Caballero *et al*., 2008) [20].

Materials and Methods

Layout and experimental design

The field experiment was conducted at PGI Research Farm, M.P.K.V., Rahuri. The soil sample was collected and analyzed at Department of Soil Science and Agricultural Chemistry, PGI, M.P.K.V., Rahuri, Dist. Ahmednagar during *summer* 2022. The experiment was laid out in a randomized block design with 10 treatments and 3 replications. The gross plot size was 4.50 m x 3.60 m i.e. 16.2 m^2 and net plot size was 3.0 m x 3.20 m i.e. 9.60 m^2. The recommended spacing of 75 cm x 20 cm was adopted for dibbling of maize. The general recommended dose of nutrients (120:60:40 kg ha^{-1} N, P_2O_5 and K_2O respectively + FYM @ 10 t ha^{-1}) were given to maize as per treatment details except T_1 at the time of dibbling of maize.

Soils characteristic

The topography of experimental site was nearly uniform. Plots are prepared for sowing of maize; soils are medium black with good water holding capacity. Initial soil properties of soil before sowing are presented in table 1.

Table 1: Initial soil properties of experimental site

Sr. No.	Parameters	Value
I	**Physical properties**	
1.	Bulk density (Mg m^{-3})	1.35
2.	Partical density (Mg m^{-3})	2.65
3.	Porosity (%)	49.06
4.	COLE value	0.50
5.	Hydraulic conductivity (cm h^{-1})	0.24
II	**Chemical properties**	
1.	pH (1:2.5)	8.18
2.	EC (1:2.5) (dSm^{-1})	0.23
3.	Organic carbon (%)	0.54
4.	Calcium carbonate (%)	6.75
5.	CEC (cmol (p^+) kg^{-1})	47.16
6.	Available N (kg ha^{-1})	218.6
7.	Available P (kg ha^{-1})	16.32
8.	Available K (kg ha^{-1})	425.6
9.	Available Fe (mg kg^{-1})	4.46
10.	Available Mn (mg kg^{-1})	9.14
11.	Available Zn (mg kg^{-1})	0.56
12.	Available Cu (mg kg^{-1})	1.94
13.	Available B (mg kg^{-1})	0.72

Zeolite

Highly fine powdered zeolite purchased from Rudra Zeochem Pvt. Ltd., Nashik on the name Agripower- A-Z is a potential enriched zeolite and it is characterized for different chemical properties by standard methods. The chemical properties of zeolite are given in table 2.

Table 2: Characterization of zeolite

Sr. No.	Parameter	Value
1.	pH (1:10)	6.62
2.	EC (1:10) (dSm^{-1})	0.09
3.	CEC (cmol (p^+) kg^{-1})	161

Application of Zeolite and Potassium

Zeolite and Potassium as per treatment with farm yard manure @ 10 t ha^{-1} to all treatment plots except T_1.

The treatment comprised of T_1: Absolute control, T_2: GRDF 120:60:40 N, P_2O_5, K_2O + 10 t FYM ha^{-1}, T_3: Zeolite @ 400 kg ha^{-1}, T_4: Zeolite @ 600 kg ha^{-1}, T_5: Zeolite @ 400 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1}), T_6: Zeolite @ 400 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1}), T_7: Zeolite @ 400 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1}), T_8: Zeolite @ 600 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1}), T_9: Zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1}), T_{10}: Zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1}).

Soil analysis

The representative surface soil samples of the experimental plots were collected upto 22.5 cm depth at harvest stage of maize from each plot to know the fertility status of soil. The collected soil samples were dried under shade, grinded in wooden mortar and pastel, sieved through 2 mm sieve and analysed for pH, EC, $CaCO_3$, available N, P, K and DTPA extractable micronutrients Fe, Zn, Mn, Cu, B and for organic carbon determination soil was sieved through 0.5 mm sieve and analysed by using standard methods. The soil samples were analyzed at initial and at harvest of cauliflower.

Results and Discussion

Effect of Different Levels of Zeolite and Potassium Application on Physical Properties of Soil after Harvest of Maize

The data regarding the effect of different levels of zeolite and potassium application on soil physical properties after harvest of maize are shown in table 3.

The bulk density of soil was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. Significantly, the lowest bulk density (1.20 Mg m^{-3}) was observed in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF over the rest of the treatments except treatment T_9 (1.22 Mg m^{-3}) which was statistically at par where we have applied zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). However, the highest bulk density (1.33 Mg m^{-3}) was observed in treatment T_1 (Absolute control). This decrease in bulk density might be due to redistribution of soil particles by the binding action of zeolite (Hassan and Mohmoud. 2013) [9], which leads to soil aggregate formation, so the porosity gets increased and ultimately the bulk density will be reduced (Xiliang *et al*., 1991) [25].

There was no significant effect on particle density of soil by the application of different levels of zeolite and potassium after harvest of maize. However, the particle density ranged between 2.66 to 2.62 Mg m^{-3}. The highest (2.66 Mg m^{-3}) was observed in treatment T_3 i.e., zeolite @ 600 kg ha^{-1} and the lowest was observed in treatment T_2 i.e., GRDF 120:60:40 Kg ha^{-1} of N, P_2O_5 and K_2O + 10 t ha^{-1} FYM.

The porosity of soil was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. Significantly, the highest porosity (53.21%) was observed in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of treatments except T_9, T_8, T_6 and T_4 (53.04, 52.48, 52.10 and 52.66%, respectively). However, it was observed that there was an increase in the porosity in the zeolite treated plots compared to untreated plots. This might be due to an improved porous system of soil by the application of zeolite, which itself has high porosity (Georgiev *et al*., 2009) [7].

The hydraulic conductivity of soil was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize hydraulic conductivity (0.64 cm h^{-1}) was observed in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1}+ 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of the treatments except T_9 and T_8 (0.63 and 0.62 cm h^{-1} respectively) which were found to be statistically at par with $T_{10.}$ This might be due to the large pore volume of the zeolite, which effectively increases the soil water permeability and the increased porosity by addition of zeolite also increases the hydraulic conductivity. Similar results were observed by Mahabadi *et al.* (2007) [17] and Razmi and Sepaskhah. (2012) [24].

There was no significant effect on COLE value of the soil by the application of different levels of zeolite and potassium after harvest of maize. However, the COLE value is ranged between 0.22 to 0.26. The slight increase in COLE value might be because of an increase in the average particle size when the zeolite binds to soil which has high water holding capacity.

Table 3: Effect of different levels of zeolite and potassium application on soil physical properties *viz*., bulk density, particle density, porosity, hydraulic conductivity and COLE Value after harvest of maize

Tr. No.	Treatment details	BD (Mg m^{-3})	PD (Mg m^{-3})	Porosity (%)	HC (cm h^{-1})	COLE value
T_1	Absolute control	1.33	2.65	48.82	0.52	0.22
T_2	GRDF (120:60:40 N: P_2O_5: K_2O kg ha^{-1} + 10 t ha^{-1} FYM	1.30	2.62	50.39	0.54	0.22
T_3	Zeolite @ 400 kg ha^{-1}	1.26	2.66	51.54	0.58	0.24
T_4	Zeolite @ 600 kg ha^{-1}	1.24	2.64	52.66	0.60	0.25
T_5	Zeolite @ 400 kg ha^{-1} + 50% K_2O of RDF (20 K_2O kg ha^{-1})	1.28	2.63	51.34	0.59	0.26
T_6	Zeolite @ 400 kg ha^{-1} + 75% K_2O of RDF (30 K_2O kg ha^{-1})	1.26	2.63	52.10	0.61	0.24
T_7	Zeolite @ 400 kg ha^{-1} + 100% K_2O of RDF (40 K_2O kg ha^{-1})	1.25	2.64	51.90	0.60	0.25
T_8	Zeolite @ 600 kg ha^{-1} + 50% K_2O of RDF (20 K_2O kg ha^{-1})	1.23	2.63	52.48	0.63	0.24
T_9	Zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 K_2O kg ha^{-1})	1.22	2.64	53.04	0.62	0.25
T_{10}	Zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 K_2O kg ha^{-1})	1.20	2.65	53.21	0.64	0.26
SE(m)±		0.007	0.006	0.392	0.008	0.005
CD at 5%		0.02	NS	1.17	0.02	NS
Initial		1.35	2.65	49.06	0.50	0.24

Effect of Different Levels of Zeolite and Potassium on soil chemical properties *viz*., pH, EC, OC, $CaCO_3$, CEC after harvest of maize: The data regarding the effect of different levels of zeolite and potassium application on soil chemical properties after the harvest of maize are shown in table 4.

There was no significant effect on the pH of the soil by the application of different levels of zeolite and potassium after harvest of maize. However, the pH of soil ranged between 8.11 to 7.99. The higher soil pH (8.11) was recorded in treatment T_1 (Absolute control) whereas, the lowest (7.99) was observed in treatment T_{10}, i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O). The marginal decrease in soil pH might be because of the slightly acidic nature of zeolite, and the decomposition of FYM, releases some organic acids into the soil system, which reduces the soil pH.

There was no significant effect on EC of the soil with the application of different levels of zeolite and potassium after harvest of maize. However, the soil EC was ranged between 0.27 to 0.19 dSm^{-1}. The lower soil EC (0.19 dSm^{-1}) was recorded in treatment T_1 (Absolute control) and the higher EC (0.27 dSm^{-1}) was observed in treatment T_{10} i.e., zeolite @ 600 kg ha^{-1}+ 100% K_2O of RDF (40 kg ha-1 K_2O). This slight increase in EC might be because of the high exchange capacity of zeolite, which can introduce cations into the soil solution which is used to measure EC (Ramesh *et al*., 2015 and Ravali *et al*., 2020) [22, 23].

The organic carbon content of soil after harvest of maize was significantly influenced by the application of different levels of zeolite and potassium. Significantly, the highest organic carbon (0.64%) was found in the treatment $T_{10,}$ i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O), over the rest of treatments except T_9 (0.63%) and T_8 (0.62%) which were found to be statistically at par. However, the lowest (0.54%) was observed in treatment T_1 (Absolute control). The increase of organic carbon was mainly due to addition of FYM, also an increase in root biomass production by the action of zeolite. Aminiyan *et al*. (2014) [2] reported that application of zeolite at 30% and crop residues at 5% would maintain the highest amount of organic carbon in soil.

The calcium carbonate content of soil after harvest of maize was significantly influenced by the application of different levels of zeolite and potassium. Significantly, the highest $CaCO_3$ (7.77%) was observed in the treatment $T_{10,}$ i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O), over the rest of treatments except treatment T_9 and T_8 (7.67 and 7.60% respectively) which were found to be statistically at par with T_{10}. This increase in $CaCO_3$ might be due to adsorption of calcium from mono calcium phosphate by zeolite and its subsequent release during the crop growing period, which is precipitated as calcium carbonates. Thus, an increase in $CaCO_3$ was observed.

The CEC of soil after harvest of maize was significantly influenced by the application of different levels of zeolite and potassium. Significantly, the highest CEC (56.78 cmol (p^+) kg^{-1} of soil) was observed in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of treatments except treatment T_9 (55.55 cmol (p^+) kg^{-1} of soil) which was found to be statistically at par where we have applied zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). However, the lowest CEC (46.53 cmol (p^+) kg^{-1} of soil) was recorded in treatment T_1 (Absolute control).

Table 4: Effect of different levels of zeolite and potassium on soil chemical properties *viz*., pH, EC, OC, $CaCO_3$, CEC after harvest of maize

Tr. No.	Treatment details	pH (1:2.5)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC ($cmol(P^+) kg^{-1}$)
T_1	Absolute control	8.11	0.19	0.54	6.53	46.53
T_2	GRDF (120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM	8.08	0.21	0.57	6.83	48.15
T_3	Zeolite @ 400 kg ha^{-1}	8.06	0.25	0.55	7.20	50.13
T_4	Zeolite @ 600 kg ha^{-1}	8.03	0.26	0.56	7.33	51.55
T_5	Zeolite @ 400 kg ha^{-1} + 50% K_2O of RDF (20 K_2O kg ha^{-1})	8.07	0.23	0.59	7.41	52.54
T_6	Zeolite @ 400 kg ha^{-1} + 75% K_2O of RDF (30 K_2O kg ha^{-1})	8.05	0.24	0.60	7.45	53.24
T_7	Zeolite @ 400 kg ha^{-1} + 100% K_2O of RDF (40 K_2O kg ha^{-1})	8.04	0.25	0.61	7.49	53.85
T_8	Zeolite @ 600 kg ha^{-1} + 50% K_2O of RDF (20 K_2O kg ha^{-1})	8.03	0.24	0.62	7.54	54.69
T_9	Zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 K_2O kg ha^{-1})	8.01	0.26	0.63	7.57	55.55
T_{10}	Zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 K_2O kg ha^{-1})	7.99	0.27	0.64	7.77	56.78
SE(m)±		0.006	0.005	0.007	0.06	0.44
CD at 5%		NS	NS	0.02	0.19	1.32
Initial		8.18	0.23	0.54	6.75	47.16

This increase in CEC is mainly because of zeolite, with its inherent capacity of high CEC, can exchange large amounts of cations in the soil system, which increases the CEC of soil. (Dakovic *et al*., 2007) [5].

Effect of Different Levels of Zeolite and Potassium Application on Soil Available Nutrients after harvest of Maize: The data regarding soil available N, P and K as influenced by different levels of zeolite and potassium after harvest of maize are shown are shown in table 5.

The available nitrogen content in the soil was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. Significantly, the highest (216.77 kg ha^{-1}) available nitrogen was found in treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of treatments except treatment T_9 (213.62 kg ha^{-1}) which is found to be statistically at par where we have used zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). However, the lowest nitrogen was observed in the absolute control (164.52 kg ha^{-1}). The increase in the available status of nitrogen is because of reduced losses of NH_4^+ and NO_3^- by the application of zeolite, where the pore size of the zeolite is large enough for the ammonium ion to enter, but it is small enough for the nitrifying bacteria, so the nitrification process can be prevented and the ammonia is not converted in to nitrate, eventually leaching of NO_3^- is also prevented (Aiyuk *et al*., 2004 and Englert *et al*., 2005) [1, 6]. The absorbed NH_4^+ is released slowly into soil. Also demonstrated that a 40-50% improvement in soil exchangeable ammonium retention in zeolite-treated soil.

Available phosphorous content in the soil was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. Significantly, the highest (16.04 kg ha^{-1}) phosphorous was observed in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O), over the rest of treatments except treatment T_9 (15.45 kg ha^{-1}) which was statistically at par where we have applied zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). Zheng *et al.* (2019) [26] and Lathifa *et al.* (2017) [15] also reported an increase of available phosphorous in the zeolite treated soils. The increase in available status of phosphorous might be due to reduced P fixation in the soil, because the zeolite which create very slightly alkaline conditions where the phosphorous fixation due to calcium was reduced.

The available potassium status of soil was significantly influenced by the application of different levels of potassium and zeolite after harvest of maize. Significantly, the highest available potassium (436.40 kg ha^{-1}) was observed in the treatment $T_{10,}$ i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of treatments except treatment T_9 (431.47 kg ha^{-1}) which was found to be statistically at par where we have applied zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). This might be because of zeolite, which has strong affinity for K^+ compared to other cations like Ca^{+2}, Na^+ and Mg^{+2}, so it is difficult to remove K^+ from zeolite exchange sites (Barrer and Colella. 1996) [4], so the leaching loses of potassium will be reduced and availability status will be increased in soil.

Table 5: Effect of Different levels of zeolite and potassium application on available nitrogen, phosphorous and potassium status in soil after harvest of maize

Tr. No.	Treatment details	Soil available nutrients (kg ha^{-1})		
		N	P	K
T_1	Absolute control	164.52	9.03	403.20
T_2	GRDF (120:60:40 N: P_2O_5: K_2O kg ha^{-1} +10 t ha^{-1} FYM	188.04	10.11	418.33
T_3	Zeolite @ 400 kg ha^{-1}	204.85	12.89	408.80
T_4	Zeolite @ 600 kg ha^{-1}	210.73	14.28	411.33
T_5	Zeolite @ 400 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1} K_2O)	206.12	13.47	415.20
T_6	Zeolite @ 400 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O)	207.21	13.78	419.93
T_7	Zeolite @ 400 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O)	210.68	14.54	424.00
T_8	Zeolite @ 600 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1} K_2O)	211.46	15.17	427.20
T_9	Zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O)	213.62	15.45	431.47
T_{10}	Zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O)	216.77	16.04	436.40
SE(m)±		1.758	0.453	3.071
CD at 5%		5.22	1.34	9.12
Initial		218.6	16.32	425.6

Effect of Different of Zeolite and Potassium Application on DTPA Micronutrients and Available Boron in Soil after Harvest of Maize

The DTPA-Fe was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. Significantly, the highest DTPA-Fe (4.26 mg kg^{-1}) was found in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of treatments except treatment T_9 (4.24 mg kg^{-1}) which was found to be statistically at par, where we have applied zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). The increase in DTPA-Fe might be due to adsorption of iron by zeolite and its subsequent release by ion exchange phenomenon during the crop growth period. An increase of 19% DTPA- Fe is also observed by Suhayda *et al.* (1982) through the application of zeolite.

The DTPA-Mn was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. Significantly, the highest DTPA-Mn (6.95 mg kg^{-1}) was observed in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of treatments except treatment T_9 (6.92 mg kg^{-1}) which was found to be statistically at par, where we have applied zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). This increase of DTPA-Mn might be because of the great potential of zeolite to hold manganese and act as a slow-release fertilizer in its release as reported by (Iskander *et al.*, 2011) [12].

The DTPA-Zn was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. The highest (0.49 mg kg^{-1}) DTPA-Zn was observed in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of treatments except treatment T_9 (0.47 mg kg^{-1}) which was statistically at par where we have applied zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). This is because of the great affinity of zeolite towards zinc sorption and its subsequent release (Oren and Kaya, 2006) [19].

The DTPA-Cu was significantly influenced by the application of zeolite after harvest of maize. The significantly highest (1.59 mg kg^{-1}) DTPA-Cu is observed in the treatment T_{10} i.e., zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O) over the rest of treatments except treatment T_9 (1.56 mg kg^{-1}) which was statistically at par where we have applied zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O). This might be because of zeolite, which has a strong affinity towards Cu sorption and its subsequent release during the growth period as reported by (Oren and Kaya, 2006) [19].

There is no significant effect on the available boron content of soil with the application of different levels of potassium and zeolite after harvest of the maize. However, available boron was ranged between 0.64 to 0.68 mg kg^{-1}.

Table 6: Effect of different levels of zeolite and potassium on DTPA extractable micronutrients (Fe, Mn, Cu, Zn) and available boron in soil after harvest of maize

Tr. No.	Treatment details	DTPA micronutrients (mg kg^{-1} soil)				Hot water extractant
		Fe	Mn	Zn	Cu	B
T_1	Absolute control	4.11	6.17	0.31	1.35	0.64
T_2	GRDF (120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM	4.22	6.45	0.38	1.52	0.69
T_3	Zeolite @ 400 kg ha^{-1}	4.15	6.32	0.35	1.43	0.67
T_4	Zeolite @ 600 kg ha^{-1}	4.17	6.37	0.37	1.44	0.68
T_5	Zeolite @ 400 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1} K_2O)	4.20	6.57	0.42	1.42	0.69
T_6	Zeolite @ 400 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O)	4.22	6.64	0.44	1.45	0.67
T_7	Zeolite @ 400 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O)	4.24	6.71	0.45	1.48	0.65
T_8	Zeolite @ 600 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1} K_2O)	4.21	6.83	0.46	1.53	0.65
T_9	Zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O)	4.24	6.92	0.47	1.56	0.66
T_{10}	Zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O)	4.26	6.95	0.49	1.59	0.68
SE(m)±		0.012	0.012	0.008	0.011	0.001
CD at 5%		0.03	0.03	0.02	0.03	NS
Initial		4.46	9.14	0.56	1.94	0.72

Conclusion

In conclusion, the study evaluated the impact of various levels of zeolite and potassium application on soil physical properties post-maize harvest. Zeolite application, especially at higher rates combined with potassium, significantly reduced bulk density, enhanced porosity, and increased hydraulic conductivity compared to untreated plots. These improvements are attributed to the binding action of zeolite, promoting soil aggregate formation and enhancing water permeability. While no significant effect was observed on particle density or COLE value, the findings suggest the potential of zeolite as a soil amendment to improve soil structure and water movement, thus contributing to enhanced soil health and crop productivity.

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