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Effect of Different Levels of Nitrogen and Zeolite on Soil Properties and Soil Fertility for Rice Cultivation

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Authors' contributions

This work was carried out in collaboration among all authors. Author KJR conceptualization and designing of the research work. Author MRN execution of lab experiments and data collection. Author GECVS analysis of data and interpretation. Author VBP preparation of manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The pot culture experiment was conducted to investigate effect of different levels of nitrogen and zeolite on soil properties in rice under greenhouse condition during *kharif* 2018-19. The investigation showed that soil bulk density was decrease from 1.5 to 1.02, 1.24 and 1.29 g cc^{-1} by the zeolite application at 9, 6, and 3 t ha^{-1} respectively. Water holding capacity of soil was increased from 43.53 to 55.49% with different levels of zeolites. Cation exchange capacity of soil significantly increased by 50.45, 44.54 and 29.22% with the application of zeolite at 9, 6 and 3 t ha^{-1}, respectively. Highest value of soil pH and EC were 7.6 and 1.27 dS m $^{-1}$observed in 9 t ha $^{-1}$ zeolite treatment. Fertility status of soil *i.e.* available nitrogen and available phosphorus content also improved by the application of zeolite at different rates.

Keywords: Bulk density; cation exchange capacity; nitrogen; soil fertility; zeolite.

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1. INTRODUCTION

Zeolites (clinoptilolite) are crystalline, micro porous, three dimensional aluminosilicate clay minerals with formula (Na, K) $_3$ (Al $_6$ Si $_{30}$ O $_{72}$) 24.H_2O. Zeolite was first identified by Swedish mineralogist, Alex Fredrik Cronstedt in 1756 from copper mine of Sweden. Zeolite is a Greek word and it means boiling stones. Zeolite mineral were found in volcanic rocks and its commercial production and use starts from 1960s [1]. A global level, zeolite deposits are found more extensively in western USA, Bulgaria,Hungary, Japan, Australia and Iran [2]. In India,zeolites are found in Maharashtra, Madhya Pradesh, Andhra Pradesh, Tamilnadu and Karnataka. The region of Deccan plateau in Black soil region and Indo Gangetic plain region contain the 98% and 2% of the area respectively under the zeolite in India which is approximately 2.8 million [3]. In western India particularly Pune, Nashik, Mumbai, Baroda are having zeolite deposition in Sahyandri mountains [4].

The unique properties of zeolites are more CEC, adsorption, internal surface area, water holding capacity, having more canals, cavities and micro pores. These properties of zeolite are making it a good soil amendment and slow release fertilizer in agriculture [5]. Zeolite mineral have capacity to improve CEC of soil when it is applied as soil ameliorants [6]. High CEC of zeolite and more selectivit of NH_4^+ toward zeolite can help in reduction of leaching [7], denitrification and ammonia volatisation losses in coarse texture and low rice soil. Zeolite mineral is also stored NH_4^+ in canal and cavity network. NH_4^+ ion in zeolite is released slowly which continuously uptake by plant for more yield and it also help in improving NUE in rice crop. Zeolite was applied in sandy soil increased to at least 10 – 15% of available water capacity of soil [8]. Zeolite improved lateral spread of water in root zone and limited need for re irrigation [1]. Considering all the above, the present pot culture experiment was conducted to study the effect of different levels of nitrogen and zeolite on soil properties and soil fertility in rice.

2. MATERIALS AND METHODS

The present pot culture experiment was conducted during 2018-19 in *kharif* season in the green house of Department of Soil Science and

Table 1. Characteristic of soil

Sr.No	Determination	Value	Method	Reference
A		**Physical properties**		
1	Particle size analysis		Hydrometer method	11]
	Sand (%)	74.80		
	Silt (%)	20.00		
	Clay (%)	5.20		
	Texture	Sandy loam		
2	B.D (g cc^{-1})	1.50	Cylindrical core method	[12]
3	WHC (%)	37.19	Keen box method	[12]
B.		**Physico-chemical properties**		
1	pH	6.64	Potentiometry	[13]
2	EC (dSm^{-1})	0.51	Conductimetry	[13]
3	CEC (cmol (p+) kg -1)	13.41	Sodium acetate method	[13]
C		**Chemical properties**		
1	Organic carbon (g kg^{-1})	7.50	Rapid titration method	Walkley and Black (1934)[14]
2	Available N (kg ha^{-1})	127	Alkaline $KMNO_4$	Subbiah & Asija (1956)[15]
3	Ammonium N (mg kg $^{-1}$)	4.21	Magnesium oxide	Bremmer (1965)[16]
4	Nitrate N (mg kg^{-1})	0.36	Devardas alloy	Bremmer (1965)[16]
5	Available P_2O_5 (kg ha $^{-1}$)	17.00	Olsen's method 0.5 M $NaHCO_3$ pH 8.5	Olsen *et al.*(1954)[17]
6	Available K_2O (kg ha $^{-1}$)	218	Neutral N NH_4OAc Flame Photometry method	Jackson (1973)[13]

Table 2a. Zeolite properties (sodium form)

Sr.No.		Standard value
A	**Chemical composition (%)**	
1.	SiO_2	82
2.	Al_2O_3	8
3.	Na_2O	1.5
4.	CaO	0.5
5.	TiO_2	0.3
B.	**Physical Properties**	
1.	Water holding capacity %	100
2.	Bulk density g cc^{-1}	0.4
3.	**Pore Size (micron) and Pore Volume (%)**	
	Less than 0.1 µ	23
	0.1 to 1.0 µ	33
	1.0 to 2.0 µ	23
	2.0 to 4.0 µ	13
	4.0 to 6.0 µ	01.
	20.0 50.0 µ	0.7
C.	**Chemical properties**	
1.	pH	8.5
2.	EC (dS m^{-1})	0.61
3.	CEC (cmol (p^+) kg^{-1})	130

Table 2b. Treatment combination used in this experiment

Treatment	Zeolite (t ha^{-1})	Nitrogen (Kg ha^{-1})	Phosphorus (Kg ha^{-1})	Potassium (Kg ha^{-1})
T_1	0	0	0	0
T_2	0	60	60	40
T_3	3	60	60	40
T_4	6	60	60	40
T_5	9	60	60	40
T_6	0	90	60	40
T_7	3	90	60	40
T_8	6	90	60	40
T_9	9	90	60	40
T_{10}	0	120	60	40
T_{11}	3	120	60	40
T_{12}	6	120	60	40
T_{13}	9	120	60	40

Agricultural Chemistry, College of Agriculture, Rajendra nagar, Hyderabad which is located between 78°43' E longitude and 17°31' N latitude, and at an altitude of 542.6 m above mean sea level. This experiment was conducted with the different levels of nitrogen and zeolite to study the effect of different levels of nitrogen and zeolite on soil properties and soil fertility for rice cultivation. The soil was classified as a sandy loam. Physical and chemical analyses were performed in a depth range of 0–0.15 m for the initial characterization of the area (Table 1). The experiment was laid out in completely randomized design with factorial concept, having three levels of nitrogen (60, 90 and 120 kg N ha^{-1}) and four levels of zeolite (0, 3, 6 and 9 t ha^{-1}) and replicated thrice. The experiment was undertaken with thirteen treatment combinations. Total 36 pots were used in this experiment. Nitrogen and zeolite were applied as per treatment combinations (Table 2b). Rice crop needed 120-60-40 N, P_2O_5, K_2O kg ha^{-1} respectively to achieve proper growth and highest yield in Telangana [9]. These NPK doses was converted into eight kilogram soil and applied through urea, single super phosphate and Muriate of potash respectively. In whole experiment, P and K doses remain uniform only the N doses were changed as per treatment. Zeolite (sodium form) powder used in experiment was collected from ACME chemicals, borivalli west, Mumbai. The properties of zeolite are given in Table 2a. The data emerged out from pot culture experiment was statistically analysed using fisher method of ANOVA for FCRD given by [10]. The data obtained after statistical analysis was used to evaluate the treatment effects.

3. RESULTS AND DISCUSSION

3.1 Bulk Density

Bulk density of soil was significantly affected by the different levels of zeolite but there is no significant association of nitrogen and nitrogen - zeolite interaction with soil bulk density. Soil bulk density of soil decreased with increase of zeolite levels. Highest bulk density of soil (1.42 g cc^{-1}) was observed in control followed by Z_1 level (no zeolite application) while lowest bulk density (1.02 g cc^{-1}) was recorded in Z_4 level (9 t ha^{-1}). Bulk density of soil declined from 1.5 to 1.02 g cc^{-1} by the application of 9 t ha^{-1} might be due to the increased of pore space in soil with higher application of zeolite (Table 3). Similar result related to bulk density was also obtained by Litaor *et al*. (2017)[18].

3.2 Water Holding Capacity (WHC)

Maximum water holding capacity of soil was significantly increased with the zeolite levels but non- significant effect was recorded in nitrogen levels and nitrogen- zeolite interaction based on Table 3. Highest value of water holding capacity (55.49%) has been recorded with application of zeolite at 9 t ha^{-1} (Z_4) which was significantly superior over Z_3 level at 6 t ha^{-1} (47.04%) and Z_2 level at 3 t ha^{-1} (43.53%) while lowest value of water holding capacity was recorded in Z_1 level (37.68%) as per Table 3. Water holding capacity of soil was increased with increasing zeolite level which was might be due to more pore space present in zeolite and due to decreases of bulk density of soil. Similar results were also obtained by Al-Busaidi *et al*, (2008)[19]. Ippolito *et al.* (2011)[20] reported that maximum soil water holding was found in mixed applied zeolite than band placed zeolite.

Table 3. Effect of different levels of nitrogen, zeolite and their interaction on bulk density of soil (g cc^{-1})

Levels	BD: Bulk density and WHC: Water holding capacity									
	BD	WHC	BD	WHC	BD	WHC	BD	WHC	BD	WHC
	Z_1 : 0		Z_2: 6 t ha^{-1}		Z_3: 6 t ha^{-1}		Z_4: 9 t ha^{-1}		Mean	
N_1: 60 Kg ha^{-1}	1.42	38.10	1.31	43.401	1.24	47.01	1.01	55.61	1.25	46.03
N_2: 90 Kg ha^{-1}	1.43	37.73	1.29	43.58	1.26	46.53	1.02	55.73	1.25	45.89
N_3:120 Kg ha^{-1}	1.42	37.22	1.29	43.61	1.24	47.58	1.04	55.12	1.25	45.88
Mean	1.42	37.68	1.29	43.53	1.24	47.04	1.02	55.49		
	S.Em. ±				**CD (0.05)**					
	BD	**WHC**			**BD**	**WHC**				
N	0.006	0.33			NS	NS				
Z	0.007	0.38			0.02	1.12				
N × Z	0.011	0.66			NS	NS				

** Control BD: 1.5 g cc^{-1} and WHC: 39.23 % (No nitrogen and zeolite application)*

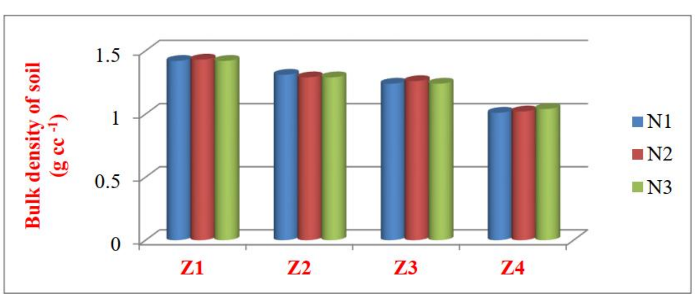

Fig. 1. Effect of different levels of nitrogen, zeolite and their interaction on bulk density of soil (g cc -1)

Table 4. Effect of different levels of nitrogen, zeolite and their interaction on cation exchange capacity of soil (cmol kg $^{-1}$)

Levels	CEC of soil (cmol (p^+) kg $^{-1}$)				
	Z_1	Z_2	Z_3	Z_4	Mean
N_1	13.45	17.17	19.32	20.28	17.55
N_2	13.34	17.22	19.33	20.32	17.55
N_3	13.36	17.49	19.39	20.34	17.65
Mean	13.38	17.29	19.34	20.13	
	S.Em. ±		CD (0.05)		
N	0.05		NS		
Z	0.06		0.16		
N × Z	0.1		NS		

Control- 13.4 cmol kg $^{-1.}$ (No nitrogen and zeolite application)

Table 5. Effect of different levels of nitrogen, zeolite and their interaction on Soil reaction (pH) and Electrical conductivity (dS m $^{-1}$)

Levels										
	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
	Z_1: 0		Z_2: 6 t ha $^{-1}$		Z_3: 6 t ha $^{-1}$		Z_4: 9 t ha $^{-1}$		Mean	
N_1: 60 Kg ha $^{-1}$	6.59	0.94	7.15	1.12	7.33	1.21	7.64	1.26	7.18	1.33
N_2: 90 Kg ha $^{-1}$	6.53	0.95	7.18	1.13	7.37	1.21	7.63	1.27	7.17	1.38
N_3: 120 Kg ha $^{-1}$	6.52	0.95	7.17	1.13	7.35	1.21	7.64	1.27	7.17	1.14
Mean	6.5	0.95	7.2	1.13	7.4	1.21	7.6	1.27		
	S.Em. ±				CD (0.05)					
	pH	EC			pH	EC				
N	0.01	0.003			NS	NS				
Z	0.01	0.004			0.03	0.011				
N × Z	0.02	0.007			NS	NS				

Control pH: 6.62 and EC: 0.92 dS m $^{-1}$ (No nitrogen and zeolite application)

Table 6. Effect of different levels of nitrogen, zeolite and their interaction on available nitrogen and available phosphorus (mg kg $^{-1}$)

Levels	A: Available Nitrogen (mg kg $^{-1}$) and B: Available Phosphorus (mg kg $^{-1}$)									
	A	B	A	B	A	B	A	B	A	B
	Z_1: 0		Z_2: 6 t ha $^{-1}$		Z_3: 6 t ha $^{-1}$		Z_4: 9 t ha $^{-1}$		Mean	
N_1: 60 Kg ha $^{-1}$	45.96	8.15	46.50	8.65	46.46	9.41	46.57	10.62	46.37	9.21
N_2: 90 Kg ha $^{-1}$	46.73	8.51	46.17	9.12	46.55	9.99	46.42	10.98	46.47	9.65
N_3:120Kg ha $^{-1}$	46.91	8.99	46.70	9.38	46.61	10.12	46.84	11.27	46.76	9.94
Mean	46.54	8.55	46.46	9.05	46.54	9.84	46.61	10.96		
	S.Em. ±				CD (0.05)					
	A	B			A	B				
N	0.09	0.03			0.19	0.07				
Z	0.07	0.03			NS	0.09				
N × Z	0.13	0.05			0.37	0.15				

Control– A: 45.94 mg kg $^{-1}$ and B: 7.89 mg kg $^{-1}$ (No nitrogen and zeolite application)

3.3 Cation Exchange Capacity (cmol (p^+) kg $^{-1}$)

According to Table 4 cation exchange capacity of soil was significantly affected by the different levels of zeolite only. Application of 9 t ha $^{-1}$ zeolite cation exchange capacity of soil was 20.31 cmol (p^+) kg $^{-1}$ which significantly higher over Z_3 level at 6 t ha $^{-1}$ zeolite (19.34 cmol (p +) kg $^{-1}$) and Z_2 level at 3 t ha $^{-1}$ zeolite (17.29 cmol (p^+) kg $^{-1}$) while lowest cation exchange capacity was recorded in Z_1 level (13.38 cmol (p^+) kg $^{-1}$). The per cent increase of cation exchange capacity by the application of 9, 6, and 3 t ha $^{-1}$ over non-zeolite was found to be 50.45, 44.54 and 29.22, respectively based on Table 4.

Table 7. Effect of different levels of nitrogen, zeolite and their interaction on available potassium content in soil at post-harvest (mg kg $^{-1}$)

Levels	Available potassium content in soil at post- harvest (mg kg $^{-1}$)				
	Z_1	Z_2	Z_3	Z_4	Mean
N_1	83.54	84.32	85.45	86.16	84.87
N_2	65.92	66.84	67.68	68.49	67.23
N_3	55.55	56.31	57.12	57.73	56.68
Mean	68.34	69.15	70.08	70.79	
	S.Em. ±		CD (0.05)		
N	0.02		0.07		
Z	0.03		0.08		
N × Z	0.05		0.14		

Control- 82.58 mg kg $^{-1}$ (No nitrogen and zeolite application

CEC of soil was improved by addition of zeolite might be due to more CEC of zeolite. Similar results were also obtained by [21]. [22] Reported that CEC of soil was increased significantly by addition zeolite. They showed that Soil CEC was increased by 22.2, 40.8, and 51.4% in 2012, and 17.9, 34.8, and 37.7% in 2013 with the application of zeolite at 5, 10, and 15 t ha^{-1}, respectively.

3.4 Soil Reaction (pH)

Soil reaction of soil was significantly influenced by different levels of zeolite and non- significantly with the application of nitrogen and nitrogen – zeolite interaction (Table 5).

Highest pH of soil (7.6) has been recorded in Z_4 level at 9 t ha $^{-1}$ which was significantly higher than Z_3 level at 6 t ha $^{-1}$ (7.4) and Z_2 level at 3 t ha $^{-1}$(7.2) while lowest soil pH was recorded in Z_1 (6.5) based on Table 4. The percentages of soil pH increase in Z_3, Z_2 and Z_1 levels were found to be 16.92, 13.85 and 10.77 respectively over Z_1. Soil pH increased with increase in zeolite levels and might be due to release of Na ion from zeolite to soil. The result of present study agrees with that of [18] who revealed that soil pH increase might be due to alkaline nature of zeolite. Similar results were also obtained by [23].

3.5 Electrical Conductivity (dS m^{-1})

The effect of different levels of nitrogen and nitrogen – zeolite interactions showed non-significant effect on EC of soil but different zeolite levels showed significant effect on EC of soil (Table 5).

EC of soil increased by the zeolite application. Highest EC of soil (1.27 dS m $^{-1}$) has been recorded with application of zeolite at 9 t ha $^{-1}$ which was significantly superior over Z_3 at 6 t ha $^{-1}$ (1.21 dS m $^{-1}$) and Z_2 level at 3 t ha $^{-1}$(1.13 dS m $^{-1}$) while lowest soil pH was recorded in Z_1 (0.95 dS m $^{-1}$). The per cent of soil EC increase in Z_4, Z_3 and Z_2 levels were found to be 34.04, 27.91 and 19.24 % respectively over Z_1 as per Table 4. Soil EC was increased with zeolite levels might be due to release of different ion from zeolite to soil. Similar result was also obtained by [23]

3.6 Available Nitrogen

There was no significant effect on available nitrogen content in soil with zeolite application but significant effect was observed in nitrogen and nitrogen – zeolite interaction (Table 6). According to Table 6 small variations was observed in available nitrogen content in soil. Highest available nitrogen content observed in N_3 level at 120 kg ha^{-1} *i.e.* 46.76 mg kg $^{-1}$ which was higher than control based on Table 6. Available nitrogen content were significantly affected, which might be due to more mineralization of organic matter that probably occurred due to immediate transformation of anaerobic condition to aerobic condition after grain filling stage. According to [24] mineralization of organic nitrogen was significantly increased with incubation period.

3.7 Available Phosphorus

Available phosphorus content in soil was affected significantly by nitrogen and zeolite application. As seen in Table 6, slight increase of available phosphorus content in soil was observed in different nitrogen doses. Its content varies from 9.21 to 9.94 mg kg^{-1}. Available phosphorus content in soil also increased due to zeolite application. Available phosphorus content in soil increased more due to zeolite than nitrogen levels and its content was varies from 8.55 to 10.96 mg kg^{-1}. Highest available phosphorus content was observed in N_3 level, Z_4 level and N_3Z_4 interaction *i.e.* 9.94, 10.96 and 11.27 respectively (Table 6). Available phosphorus content in soil increased due to nitrogen and zeolite was more than control (7.89 mg kg^{-1}). The content of available phosphorus in soil which can increases due to maintained of submerged condition in pot and solubilization effect of zeolite on soil phosphorus. In submerged condition, micronutrients like Fe, Mn, Zn and Cu are present in reduced form which is precipitated with OH^- ion and CO_3^- and decreases the affinity of micronutrient toward phosphorus, ultimately increases availability of soil phosphorus while zeolite has more CEC which can adsorb present micronutrient in soil and reduces the transformation of available form of phosphorus to unavailable form or soluble form to insoluble form [25]. This mechanism of zeolite is increases phosphorus availability in soil. Similar result was obtained by [26] ,[27] and [28].

3.8 Available Potassium

According to Table 7 available potassium content in soil was significantly influenced by zeolite and nitrogen levels. Available potassium content in soil decreased due to luxury consumption of potassium by plant. According to Table 7, available potassium content in nitrogen levels decreased from 82.58 to 56.68 mg kg^{-1} except N_1 level at 60 kg ha^{-1} contained 84.87 mg kg^{-1} due to less consumption of potassium by plant. Available potassium content in zeolite levels decreased from 82.58 to 68.34 mg kg^{-1}. Among four zeolite levels, highest available potassium content in soil was 70.79 mg kg^{-1} observed in Z_4 level at 9 t ha^{-1} because of more absorption of potassium in zeolite canal. Compared to other zeolite levels, Z_4 level at 9 t ha^{-1} increased available potassium content in soil but less than control value (82.58 mg kg^{-1}) based on Table 7. In interaction effect, highest value of available potassium content in soil was observed in N_1 with combination of four levels of zeolite followed by N_2 with combination four levels of zeolite and N_1 with combination of four levels of zeolite. Interaction of any levels of nitrogen with Z_4 was observed highest amount of available potassium because of more released of absorbed potassium from zeolite canal. At the end of experiment, it was observed that available potassium content in soil was higher in control treatment compare to other treatment due to fewer uptakes of potassium from control treatment. Similar results were also obtained by [18] and [29].

4. CONCLUSIONS

In this study, water holding capacity, cation exchange capacity, pH, electrical conductivity of soil was significantly increased with application of zeolite. The best improvement for Physical and physicochemical properties of soil at 9 t ha^{-1} zeolite application. Application of 9 t ha^{-1} zeolite caused water holding capacity, cation exchange capacity, pH and EC increased to 47.27, 50.45, 16.92 and 34.04 per cent over control respectively and bulk density of soil decreased to 39.22 per cent over control. Available nitrogen content in soil increased non-significantly by zeolite and significantly by nitrogen and zeolite interaction. Available nitrogen content in soil was more compared to initial value. Highest available nitrogen content was observed in N_3Z_4 interaction *i.e.* 11.27 mg kg^{-1}. Available phosphorus content in soil also increased significantly by the application of zeolite. Highest available phosphorus content was observed in N_3 level, Z_4 level and N_3Z_4 interaction i.e. 9.94, 10.96 and 11.27 respectively. Available potassium content in soil decreased due to more consumption of potassium in plant. Available potassium content in soil was increased by the application of zeolite compared to non-zeolite application. Available potassium content in zeolite applied soil was less than initial value of available of potassium.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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