Current Journal of Applied Science and Technology

39(38): 1-13, 2020; Article no.CJAST.63376
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Response of Maize to Different Levels of Zeolite and Nitrogen and Evaluation of Soil Chemical Properties as Influenced by Different Levels of Zeolite and Nitrogen

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Authors' contributions

This work was carried out in collaboration among all authors. Author CHR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KJR and TA managed the analyses of the study. Author KS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i3831090
Editor(s):
(1) Dr. Alessandro Buccolieri, Università del Salento, Italy.
Reviewers:
(1) Fabrício Marinho Lisbôa, Federal Institute of Education, Science and Technology of Rondonia, Brazil.
(2) Sharise Beatriz Roberto Berton, State University of Maringa (UEM), Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/63376

Original Research Article

Received 25 September 2020
Accepted 01 December 2020
Published 11 December 2020

ABSTRACT

A pot study was conducted during *kharif*, 2018-19 in College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, with the aim to evaluate the response of maize to different levels of zeolite and nitrogen and to know the influence of zeolite on selected soil properties. The treatments consists of combinations of 3 levels of nitrogen (100, 150, 200 kg ha^{-1}) and 4 levels of zeolite (0, 2.5, 5, 7.5 t ha^{-1}) along with a control in which only P and K were applied and they were replicated thrice in a factorial completely randomized design. Results indicated that application of zeolite (7.5 t ha^{-1}) and nitrogen (200 kg ha^{-1}) individually had significant effect on N, P, K contents in maize at 30, 60, 90 DAS and at harvest. N and P contents in maize was significantly higher in $N_{200}Z_{7.5}$

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(Nitrogen @ 200 kg ha^{-1} + Zeolite @ 7.5 t ha^{-1}) however, there was no significant interaction with respect to K content. At harvest, the available P and K were significantly higher in the treatment receiving $N_{100}Z_{7.5}$.

Keywords: Zeolite; nitrogen; maize; available nutrient status; N,P,K contents.

1. INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in India after rice and wheat [1]. In India, the crop is cultivated in an area of 96.63 lakh hectares with a production of 25899.87 metric tonnes with productivity of 2689 kg ha^{-1} [2]. In Telangana state, the crop is grown in an area of 8.02 lakh hectares with a production of 2663.19 metric tonnes and with productivity of 3321 kg ha^{-1} during 2016-2017 [2]. Zeolites were first introduced by a Swedish mineralogist, A.F. Cronstedt in the year 1756, with the discovery of the mineral Stilbite [3]. Zeolites are alumino-silicate minerals which have a molecular sieve action due to their open channel network and are composed of tetrahedral linked with oxygen TO_4 sharing the negative charge created by the presence of AlO_2^- which is balanced by cations that neutralize the charge deficiency. These cations include: the alkaline (Na^+, K^+, Rb^+, Cs^+), the alkaline earth (Mg^{2+}, Ca^{2+}) cations, NH_4^+, H_3O^+, TMA^+ (Tetra methyl ammonium) and other nitrogen containing organic cation and the rare earth and noble metal ions [4]. Clinoptilolite promote better plant growth by improving the value of fertilizers due to its relatively high adsorption rate, cation exchange, catalysis and dehydration capacities. It has a very high CEC (from 100 to 230 cmol(p+)kg^{-1}). Therefore, its application to the soil increases the CEC of soils 2-3 times greater than other types of minerals found in soils. The mix of zeolite (Z) and nitrogen (N) has been investigated to enhance soil fertility and improve crop production. Accordingly, the aim of this study is to evaluate whether the soil, when amended with zeolite along with nitrogen might improve selected soil properties and also to evaluate the response of maize crop to different levels of zeolite and nitrogen.

2. MATERIALS AND METHODS

This study was carried out at Professor Jayashankar Telangana State Agricultural University, College of Agriculture, Rajendranagar, which is located in Ranga Reddy district of Telangana state at an altitude of 542.6 m above mean sea level, 78.4237°E longitude and 17.3142°N latitude. The mean maximum and mean minimum temperatures of the location are 28.0°C to 32.6°C and 10.1°C to 23.9°C respectively. The normal annual rainfall of the location is 816.7 mm. The treatments consisted of 4 levels of zeolite (4 zeolite levels (0, 2.5 t ha^{-1}, 5 t ha^{-1} and 7 t ha^{-1}), 3 levels of nitrogen (100 kg ha^{-1}, 150 kg ha^{-1} and 200 kg ha^{-1}), replicated thrice and the design was Factorial Completely Randomized Design.

The treatments were fixed at the initiation of the experiment (*kharif 2018-19*). The details of treatments are given in Table 2.

2.1 Plant Analysis

Plant samples collected at 30, 60, 90 days after sowing and were shade dried and kept in the hot air oven at 60ºC - 80ºC until constant weight is attained. The maize plants were harvested at 105 days after sowing by removing the plants along with their roots. The cobs were then separated from the plants and grains were separated from cobs. These harvested plant samples (plant and grains separately) were shade dried, after recording dry weight and kept

Table 1. Properties of zeolite used in the study

S. No.	Property	Values
1.	Moisture at 105°C	0-10%
2.	Water Absorption	90-100%
3.	Bulk Density (Mg m^{-3})	0.35-0.45
4.	pH	8.0 - 9.0
5.	EC (dS m^{-1})	5.5
6.	CEC (cmol(p+)kg^{-1})	130-135
7.	Silica (SiO_2)	78-82%
8.	Alumina (Al_2O_3)	6-8%

Table 2. Treatment details

Particulars	Abbreviated as
No Nitrogen and No Zeolite	N_0Z_0
Nitrogen @100 kg ha^{-1} + No Zeolite	$N_{100}Z_0$
Nitrogen @100 kg ha^{-1} + Zeolite @ 2.5 t ha^{-1}	$N_{100}Z_{2.5}$
Nitrogen @100 kg ha^{-1} + Zeolite @ 5 t ha^{-1}	$N_{100}Z_5$
Nitrogen @100 kg ha^{-1} + Zeolite @ 7.5 t ha^{-1}	$N_{100}Z_{7.5}$
Nitrogen @150 kg ha^{-1} + No Zeolite	N_{150} Z_0
Nitrogen @150 kg ha^{-1} + Zeolite @ 2.5 t ha^{-1}	N_{150} $Z_{2.5}$
Nitrogen @150 kg ha^{-1} + Zeolite @ 5 t ha^{-1}	N_{150} Z_5
Nitrogen @150 kg ha^{-1} + Zeolite @ 7.5 t ha^{-1}	N_{150} $Z_{7.5}$
Nitrogen @ 200 kg ha^{-1}+ No Zeolite	N_{200} Z_0
Nitrogen @200 kg ha^{-1} + Zeolite @ 2.5 t ha^{-1}	N_{200} $Z_{2.5}$
Nitrogen @200 kg ha^{-1} + Zeolite @ 5 t ha^{-1}	N_{200} Z_5
Nitrogen @200 kg ha^{-1} + Zeolite @ 7.5 t ha^{-1}	N_{200} $Z_{7.5}$

Note: 1. Recommended dose of P and K were applied @ 60-60 kg ha^{-1} (24.29 - 24.29 mg pot^{-1}) uniformly to all the treatments.

2. Zeolite – Zeolite was mixed with soil before filling the pots according to the zeolite doses in the treatments.

in the hot air oven followed by grinding of the samples. These were further used for analyzing the nutrient contents (plant and grains separately). The dried plant samples were then powdered separately using grinding mill and this is used for analyzing the nutrient contents [5]. The Nitrogen content in the plant samples was determined by micro Kjeldal distillation using automatic nitrogen distillation unit, after digesting the plant sample in conc. H_2SO_4 and H_2O_2 [5]. The P concentration in plant samples was determined by pre-digestion in diacid mixture (HNO_3 and $HClO_4$ in 9:4 ratio), followed by determination of P content in Spectrophotometer (Shimadeu UV-1800 double beam spectrophotometer) at 420 nm by vanado-molybdo phosphate yellow colour method as described by Piper [5]. For determination of K content in plant samples, the samples were first digested in diacid mixture (HNO_3 and $HClO_4$ in 9:4 ratio), then potassium content was determined by Flame photometer (Elico CL 378) [5].

2.2 Analysis

Initial soil samples (before initiation of experiment) and treatment wise soil samples were collected at 30, 60, 90 DAS and at harvest and were shade dried , pounded and passed through 2 mm sieve and preserved in polythene bags and used for the analysis of chemical properties of soil. Available nitrogen in the soil samples was determined by alkaline potassium permanganate method as described by Subbiah and Asija [6] by using Kjeldal distillation unit. Available phosphorous was determined by Olsen's extractant (0.5*N* $NaHCO_3$, pH 8.5) described by Olsen et al. (1954). The colour development (blue colour) was done by ascorbic acid method given by Watanabe and Olsen [7]. After the colour development, the intensity of the blue colour was determined using Spectrophotometer (Shimadeu UV-1800 double beam spectrophotometer) at 660 nm wavelength. The available potassium in soil was extracted using neutral normal ammonium acetate and the extracted potassium was determined by flame photometer (Elico CL 378) as described by Jackson [8] and expressed as kg ha^{-1}.

2.3 Methods for Initial Sample Analysis

Soil reaction (pH) was determined in 1:2.5 Soil water suspension using pH meter (Elico CM 180) by Potentiometric method after shaking of soil sample for 20 - 30 minutes intermittently [9]. Total soluble salts (EC) were determined in 1:2.5 soil water suspension by Conductometric (Elico CM 180) method using EC meter [9]. Organic Carbon content was determined in 0.5 mm sieved soil by wet digestion method [10]. Soil texture of initial (before initiation of experiment) soil sample was determined by Bouyoucos hydrometer method [5]. Bulk density of initial (before initiation of experiment) soil samples was determined by Core method. Bulk density (Mg m^{-3}) of the soil is determined from the ratio of dry weight of the soil to the internal volume of metallic core [11]. Cation Exchange Capacity of initial (before initiation of experiment) and final (after harvest) soil samples was determined by sodium acetate method. Water Holding Capacity (WHC) initial (before initiation of experiment) and final (after harvest) soil samples was determined using Keen cup method [12]. The determination of exchangeable Na^+ and K^+ were done by extracting the soil with 1 N neutral (pH 7.0) ammonium acetate [13]. The exchangeable Ca^{2+} and Mg^{2+} were determined by displacement with 1 N sodium acetate of pH 8.2. The soil was extracted and the leachate was analysed for Ca^{2+} and Mg^{2+} as per the method of Richards [13].

Ammoniacal nitrogen and Nitrate nitrogen: Ten grams of soil was shaken with 20 ml of 2 M KCl for an hour and filtered. Then the filtrate was steam distilled with 2.5% NaOH in presence of 0.2 g MgO (ammoniacal nitrogen) / 0.2 g Devarda's alloy (NO_3^- - N). The distillate was collected in 4% boric acid containing mixed indicator was titrated with standard sulphuric acid (0.02 *N*) as described by Bremner (1965) and expressed in mg kg^{-1}. The available N,P,K were analyzed using the methods described above.

3. RESULTS AND DISCUSSION

The soil was sieved through 2 mm sieve and was analyzed for initial physical, physico-chemical and chemical properties which are presented in the Table 3.

3.1 Available Nutrient Status (mg kg^{-1}) in Soil

The data regarding available N, P, K at harvest was presented in Table 4. There was no significant difference in the available nitrogen status in soil at harvest among the zeolite levels, nitrogen levels and there was no significant interaction between nitrogen and zeolite was observed with respect to available N. The zeolite addition have not significant role in the improvement of available nitrogen status in the soil. The results are consistent with results of Litaor et al. [14] who concluded that when zeolite and compost were combinely added to soil, compost has significantly improved the availability of soil N whereas zeolites had no impact on availability of N. At harvest, significantly higher available P was recorded in $Z_{7.5}$ (mean value - 19.76) and the lowest available P among the four zeolite levels was observed in Z_0 (mean value - 11.20). There was significant interaction observed between nitrogen and zeolite levels. Among all the treatments, available P was significantly higher in $N_{100}Z_{7.5}$ (24.43) compared to all other treatments. The lowest available P was recorded in $N_{100}Z_0$ (7.26). Irrespective of nitrogen levels, increase in the zeolite levels increased available P in the soil. The reason might be that, Clinoptilolite zeolite might favoured the release of soluble P when Ca^{2+} ions in zeolite are exchanged with NH_4^+ or K^+ ions. These results were in confirmity with the findings of Weaks [15] where available P was significantly improved with zeolite addition. Soil total P and available P differed significantly with zeolite application [16].

Application of different zeolite levels significantly altered available K at harvest. Significantly higher available K was recorded in $Z_{7.5}$ (mean value - 136.24 mg kg^{-1}), followed by Z_5 (mean value - 131.02 mg kg^{-1}). The lowest available K was recorded in control (86.58 mg kg^{-1}). Among nitrogen levels, highest available K was observed in N_{200} (mean value - 152.43 mg kg^{-1}) which differed significantly with N_{150} (mean value - 129.77 mg kg^{-1}) and N_{100} (mean value - 102.76 mg kg^{-1}). The interaction between nitrogen and zeolite was significant. Among all the treatments, highest available K was recorded in $N_{100}Z_{7.5}$ (159.79 mg kg^{-1}), this treatment was significantly different compared to all other treatments and control (86.58 mg kg^{-1}).

Higher doses of zeolite showed higher amounts of available K in the soil. This is because zeolite has the potential to absorb K^+ from chemical fertilizers, hence reducing K leaching. These results were in accordance with the findings of Kavoosi [17] and Caballero et al. (2008) who observed that increasing the zeolite dosage increased available K in the soil.

3.2 Nitrogen Content (%) in Plant

N content in maize at 30, 60, 90 DAS (Table 5) and at harvest (Table 6) were analyzed. Application of various levels of zeolite and nitrogen tend to significantly increase nitrogen content in maize at 30, 60, 90 DAS and at harvest over control. At 30 DAS the zeolite level, $Z_{7.5}$ has recorded highest nitrogen content (mean value - 1.17) and it was on par with Z_5 (mean value - 1.16) and they differed significantly with the nitrogen content in Z_0 level (1.12) and control (1.01). The increase in the nitrogen content as compared to control was 15.84 % with the application of 7.5 t ha^{-1} of zeolite. The nitrogen level N_{200} produced higher nitrogen (mean value - 1.21) content which had shown significant difference with other levels of nitrogen *i.e.*, N_{150} (mean value - 1.15) and N_{100} (mean value -

1.09), while the lowest nitrogen content among all the treatments was observed in control (1.01). The similar trend was followed at 60 DAS where the zeolite level, $Z_{7.5}$ produced higher nitrogen content (mean value - 1.10) which was on par with Z_5 (mean value - 1.09), followed by $Z_{2.5}$ (mean value - 1.06) and Z_0 recorded lowest nitrogen content among all the zeolite levels (mean value - 1.03). Among three nitrogen levels highest nitrogen content was observed in N_{200} (mean value - 1.13), which differed significantly with N_{150} (mean value - 1.08), N_{100} (mean value - 1.00) and control (0.88). Interaction between nitrogen and zeolite was found to be significant. Among all the treatments, higher N content was recorded from $N_{200}Z_{7.5}$ treatment (1.16) which was on par with $N_{200}Z_5$ (1.14) and $N_{200}Z_{2.5}$ (1.12) and they were significantly superior over $N_{200}Z_0$ (1.11) and control (0.88). The increase in the nitrogen content was 31.81 over control in $N_{200}Z_{7.5}$ treatment. At 90 DAS $Z_{7.5}$ recorded significantly higher N content (mean value - 1.03), followed by Z_5 (mean value - 1.01), while the lowest N content was recorded in Z_0 (mean value - 0.93) and among nitrogen levels, highest nitrogen content was observed in N_{200} (mean value - 1.10) which differed significantly with N_{150} (mean value - 0.99), N_{100} (mean value - 0.87) and control (0.75). Interaction between nitrogen and zeolite was found to be significant. Among all the treatments, higher N content was recorded from $N_{200}Z_{7.5}$ treatment (1.14) recorded significantly highest N content compared to all other treatments. The lowest N content was recorded in control (0.75).

The nitrogen content in maize grain and straw was given in Table 6. At harvest, in maize grain among four zeolite levels, $Z_{7.5}$ produced higher nitrogen content (mean value - 0.82), followed by Z_5 (mean value - 0.80) and they were significantly superior to control (0.45). Among nitrogen levels, highest nitrogen content was observed in N_{200} (mean value - 1.13) which differed statistically with N_{150} (mean value - 1.08) and N_{100} (mean value - 1.00) and control (0.45). Interaction between nitrogen and zeolite was found to be significant. Among all the treatments, highest nitrogen content in grain was recorded from $N_{200}Z_{7.5}$ treatment (0.91) which was on par with $N_{200}Z_5$ (0.90) they were significantly superior over control (0.45). The zeolite level $Z_{7.5}$ recorded significantly higher N content in maize straw (mean value - 0.43), whereas Z_0 recorded lower N content (mean value - 0.33) compared to all other zeolite levels and among nitrogen levels, highest N content was recorded in N_{200} (mean value - 0.53) which differed statistically with N_{150} (mean value -0.38) and N_{100} (mean value - 0.23) and control (0.16). Interaction between nitrogen and zeolite was found to be significant. Among all the treatments, highest nitrogen content in straw was recorded from $N_{200}Z_{7.5}$ treatment (0.56) which was on par with $N_{200}Z_5$ (0.55) they. The lowest N content was recorded in control (0.16).

Table 3. a, b and c initial soil properties

a) Physical Properties:			**b) Physico-chemical Properties**		
S. No.	**Property**	**Values**	**S. No.**	**Property**	**Values**
1.	Soil type	Red soil	1.	pH	7.08
2.	Sand (%)	87.36	2.	EC (dSm^{-1})	0.45
3.	Silt (%)	4.40	3.	Organic Carbon (%)	0.57
4.	Clay (%)	8.24	4.	CEC (cmol(p+)kg^{-1})	13.02
5.	Soil Texture	Loamy sand			
6.	Bulk Density ($Mg\ m^{-3}$)	1.18			
7.	Water Holding Capacity (%)	28			

c) Chemical Properties		
S. No.	**Property**	**Values**
1	Available N ($kg\ ha^{-1}$)	177
2	Available P ($kg\ ha^{-1}$)	15
3	Available K ($kg\ ha^{-1}$)	380
4	Exchangeable Ca^{+2} ($cmol\ kg^{-1}$)	1.45
5	Exchangeable Mg^{+2} ($cmol\ kg^{-1}$)	0.82
6	Exchangeable Na^{+} ($cmol\ kg^{-1}$)	0.22
7	Exchangeable K^{+} ($cmol\ kg^{-1}$)	0.53
8	Exchangeable NH_4^{+} ($mg\ kg^{-1}$)	10.44
9	Exchangeable NO_3^{-} ($mg\ kg^{-1}$)	2.80

Table 4. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on available nutrient status (mg kg^{-1}) status at harvest

Levels	Available N					Available P					Available K				
	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)
N_{100}	65.00	64.90	64.79	64.77	**64.87**	16.19	23.30	23.08	24.43	**21.75**	145.94	149.85	154.14	159.79	**152.43**
N_{150}	64.82	64.93	65.16	64.70	**64.90**	11.48	18.00	19.33	21.45	**17.56**	123.48	126.87	130.66	138.10	**129.77**
N_{200}	64.77	64.56	64.72	64.81	**64.72**	7.26	12.52	13.02	13.39	**11.55**	93.77	98.15	108.26	110.84	**102.76**
Mean (Z)	**64.86**	**64.80**	**64.89**	**64.76**		**11.64**	**17.94**	**18.48**	**19.76**		**121.06**	**124.96**	**131.02**	**136.24**	
*Control (No nitrogen, no zeolite) – 64.63 mg kg^{-1}						*Control (No nitrogen, no zeolite) – 7.04 mg kg^{-1}					*Control (No nitrogen, no zeolite) – 86.58 mg kg^{-1}				

	S.Em. (±)				**CD (p=0.05)**		
	Avail. N	**Avail. P**	**Avail. K**		**Avail. N**	**Avail. P**	**Avail. K**
N	0.29	0.16	0.46	N	NS	0.47	1.35
Z	0.33	0.19	0.53	Z	NS	0.55	1.56
N X Z	0.58	0.33	0.92	N X Z	NS	0.94	2.71

Table 5. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on nitrogen content (%) in maize at 30, 60, 90 DAS

Levels	30 DAS					60 DAS									
	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)
N_{100}	1.05	1.08	1.10	1.12	**1.09**	0.93	1.00	1.03	1.05	**1.00**	0.79	0.86	0.90	0.93	**0.87**
N_{150}	1.13	1.15	1.16	1.18	**1.15**	1.05	1.06	1.09	1.10	**1.08**	0.94	0.97	1.01	1.03	**0.99**
N_{200}	1.18	1.20	1.21	1.22	**1.21**	1.11	1.12	1.14	1.16	**1.13**	1.05	1.08	1.11	1.14	**1.10**
Mean (Z)	**1.12**	**1.14**	**1.16**	**1.17**		**1.03**	**1.06**	**1.09**	**1.10**		**0.93**	**0.97**	**1.01**	**1.03**	
*Control (No nitrogen, no zeolite) – 1.01%						*Control (No nitrogen, no zeolite) – 0.88%					*Control (No nitrogen, no zeolite) – 0.75%				

	S.Em. (±)	**CD (p=0.05)**		**S.Em. (±)**	**CD (p=0.05)**		**S.Em. (±)**	**CD (p=0.05)**
N	0.01	0.02	N	0.01	0.02	N	0.004	0.01
Z	0.01	0.02	Z	0.01	0.02	Z	0.01	0.01
N X Z	0.01	NS	N X Z	0.01	0.04	N X Z	0.01	0.02

Table 6. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on nitrogen content (%) in maize grain and stover

Levels	Grain					Stover				
	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)
N_{100}	0.60	0.66	0.70	0.73	**1.00**	0.18	0.21	0.25	0.29	**0.23**
N_{150}	0.74	0.78	0.81	0.83	**1.08**	0.32	0.35	0.39	0.46	**0.38**
N_{200}	0.84	0.86	0.90	0.91	**1.13**	0.48	0.51	0.55	0.56	**0.53**
Mean (Z)	**0.73**	**0.77**	**0.80**	**0.82**		**0.33**	**0.36**	**0.40**	**0.43**	
*Control (No nitrogen, no zeolite) – 0.45%						*Control (No nitrogen, no zeolite) – 0.16%				
	S.Em. (±)	**CD (p=0.05)**					**S.Em. (±)**	**CD (p=0.05)**		
N	0.004	0.01				N	0.004	0.01		
Z	0.004	0.01				Z	0.01	0.01		
N X Z	0.01	0.02				N X Z	0.01	0.02		

The increase in the nitrogen content of maize was likely due to effect of increased proportion of NH_4^+ and NO_3^- in the soil solution which is a result of adsorption of NH_4^+ in the zeolite lattice and become slowly available to plants thus gave better response to added fertilizer with the addition of zeolite and so there was increase in the N content throughout the growth period. The results obtained in this study were consistent with the results obtained by Rabai et al. [16] who noticed that there was significant effect of zeolite on N content of maize. According to Manikandan and Subramanian [18] the maize plants grown in soil treated with zeourea showed higher N concentration in plant and grain.

3.3 Phosphorous Content (%) in Plant

The phosphorous content of maize was significantly improved by application of different combinations of nitrogen and zeolite levels. The data pertaining to P content at 30, 60, 90 DAS was presented in Table 7. At 30 DAS, the data indicates that among the three nitrogen levels, N_{200} recorded significantly higher phosphorous content (mean value - 0.28), followed by N_{150} (mean value - 0.25) and N_{100} (mean value - 0.22) and among four zeolite levels, $Z_{7.5}$ recorded highest phosphorous content (mean value - 0.27), which is on par with Z_5 (mean value - 0.26), while the lowest P content among four zeolite levels was recorded in Z_0 (mean value - 0.21). There was significant interaction between nitrogen and zeolite on P content. Among different treatments, $N_{200}Z_{7.5}$ recorded highest phosphorous content at 30 DAS (0.30), which is on par with $N_{200}Z_5$ (0.30). These treatments were statistically different compared to rest of the treatments. The lowest phosphorous content at 30 DAS was obtained from control (0.20). The similar trend was followed at 60 DAS. The zeolite level, $Z_{7.5}$ produced higher P content (mean value - 0.23) which is on par with Z_5 (mean value - 0.22) and Z_0 recorded lowest P content (mean value - 0.17) among all the zeolite levels. Among three nitrogen levels highest nitrogen content was observed in N_{200} (mean value - 0.24), which differed significantly with N_{150} (mean value - 0.20) and N_{100} (mean value - 0.17) There was significant interaction observed between nitrogen and zeolite. Among all treatments, the highest P content was recorded from $N_{200}Z_{7.5}$ treatment (0.27) and $N_{200}Z_5$ (0.27) they were significantly superior other treatments. The lowest P content was recorded in control (0.14). The increase in the P content in $N_{200}Z_{7.5}$ treatment was 92.85 % over control. At 90 DAS, among the three nitrogen levels, N_{200} recorded significantly higher phosphorous content (mean value - 0.18), followed by N_{150} (mean value - 0.16) and N_{100} (mean value - 0.14) and among four zeolite levels, $Z_{7.5}$ recorded highest phosphorous content (mean value - 0.17), which is on par with Z_5 (mean value - 0.17). The lowest phosphorous content at 90 DAS was obtained from control (0.12). The interaction effect between zeolite and nitrogen with respect to P content at 90 DAS was not significant.

The data pertaining to P content in maize grain and straw was presented in Table 8. In grains, the P content increased from 0.18 (mean value) in control to 0.23 in $Z_{7.5}$ and Z_5 (mean value - 0.23) which was on par with $Z_{2.5}$ (mean value - 0.22). The lowest P content was recorded in control (0.18). Among nitrogen levels, highest P content was observed in N_{200} (mean value - 0.24) which differed significantly with N_{150} (mean value - 0.22), N_{100} (mean value - 0.21) and control (0.18). However N_{150} and N_{100} were on par with each other with respect to P content in grains. In maize stover, the zeolite level, $Z_{7.5}$ has recorded highest P content (mean value - 0.15) and it is on par with Z_5 (mean value - 0.14) which is in turn on par with $Z_{2.5}$ (mean value - 0.13). The nitrogen level N_{200} produced higher nitrogen (mean value - 0.16) content which had shown significant difference with other levels of nitrogen *i.e.*, N_{150} (mean value - 0.13) and N_{100} (mean value - 0.09), while the lowest nitrogen content was observed in control (0.07). There was significant interaction observed between nitrogen and zeolite levels on P content in stover. The treatment $N_{200}Z_{7.5}$ recorded highest P content (0.19), which is on par with $N_{200}Z_5$ (0.18), which is in turn on par with $N_{200}Z_{2.5}$ (0.17) and they were significantly superior over control (0.07).

P content was significantly improved by addition of zeolite. Theoretically, Zeolite properties, such as it being alkaline and having negative charges, can be used to improve P availability through amelioration of soil pH, reduction of soil acidity, soil exchangeable Al and soil exchangeable Fe. This will result in less P being fixed by metal oxyhydroxides.

In addition, zeolite incorporation into crop fertilization programs may trigger induce-exchange dissolution mechanisms that release P through uptake of nutrients by the plant. Isomorphous substitution of Al for Si in Zeolite framework provides exchange sites onto which cations are held. Plant uptake of cations from Zeolite leads to vacant exchange sites onto which cations are attracted. This process lowers the activity of exchangeable bases such as Ca^{2+} from soil solution thereby inducing further dissolution of phosphate [19]. These results were contrary to the findings of Ahmed et al. [20] where zeolite has shown non-significant effect on P concentration in maize at harvest.

3.4 Potassium Content (%) in Plant

The data pertaining to K content at 30, 60, 90 DAS was presented in Table 9. Zeolite has significantly increased the potassium content in maize. Among the three nitrogen levels, N_{200} recorded significantly higher potassium content at 30 DAS (mean value - 1.40) compared to all other levels of nitrogen N_{150} (mean value - 1.33), N_{100} (mean value - 1.26) and among four zeolite levels, $Z_{7.5}$ recorded highest potassium content at (mean value - 1.36), which is on par with Z_5 (mean value - 1.34), while lowest in control (1.20). The interaction between zeolite and nitrogen was not significant. At 60 DAS, the K content in maize followed the same trend. The highest K content was observed in $Z_{7.5}$ (mean value - 1.28), followed by Z_5 (mean value - 1.25) which are significantly superior over $Z_{2.5}$ (mean value - 1.23), Z_0 (mean value - 1.21) and control (1.10). The nitrogen level, N_{200} recorded significantly higher potassium content (mean value - 1.33) which is significantly superior over other nitrogen levels *i.e.*, N_{150} (mean value - 1.24) and N_{100} (mean value - 1.15). The lowest K content was recorded in control (1.10). The interaction between zeolite and nitrogen was also found to be non significant with respect to K content at 60 DAS. At 90 DAS, $Z_{7.5}$ recorded significantly higher K content (mean value - 0.76), followed by Z_5 (mean value - 0.74), $Z_{2.5}$ (mean value - 0.72), Z_0 (mean value - 0.70) and among nitrogen levels, highest K content was observed in N_{200} (mean value - 0.79) which differed significantly with N_{150} (mean value - 0.73) and N_{100} (mean value - 0.66). The lowest K content was recorded in control (0.61). The interaction between zeolite and nitrogen was also found to be not significant with respect to K content at 90 DAS.

The data pertaining to K content in maize grain and straw was presented in Table 10. In grains, the K content increased from 0.18 in control to 0.36 (mean value) in $Z_{7.5}$. The lowest K content was recorded in control (0.18). Application of different zeolite levels significantly increased K content in grains from 0.29 (mean value) in Z_0 to 0.36 (mean value) in $Z_{7.5}$. However in zeolite levels Z_5 and $Z_{2.5}$, K content in grains was found to be 0.34 (mean value) and 0.32 (mean value) respectively. Among nitrogen levels, highest K content was observed in N_{200} (mean value - 0.42) which differed significantly with N_{150} (mean value - 0.32), N_{100} (mean value - 0.24) and control (0.18). There was no significant interaction between zeolite and nitrogen on K content in maize grain. In maize stover, the zeolite level, $Z_{7.5}$ has recorded highest K content (mean value - 1.12) and it is on par with Z_5 (mean value - 1.11) and they differed significantly with the K content in $Z_{2.5}$ (mean value - 1.09) and Z_0 level (mean value - 1.07) and control (0.98). The increase in the K content as compared to control was 14.28 with the application of 7.5 t ha^{-1} of zeolite. The nitrogen level N_{200} produced higher nitrogen (mean value - 1.17) content which had shown significant difference with other levels of nitrogen *i.e.*, N_{150} (mean value - 1.09) and N_{100} (mean value - 1.03), while the lowest nitrogen content was observed in control (0.98). There was no significant interaction between nitrogen and zeolite levels.

Table 7. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on phosphorous content (%) in maize at 30, 60, 90 DAS

Levels	30 DAS					60 DAS					90 DAS				
	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)
N_{100}	0.21	0.22	0.22	0.23	**0.22**	0.16	0.17	0.17	0.20	**0.17**	0.13	0.14	0.14	0.15	**0.14**
N_{150}	0.21	0.25	0.26	0.28	**0.25**	0.17	0.21	0.21	0.22	**0.20**	0.14	0.16	0.17	0.17	**0.16**
N_{200}	0.23	0.29	0.30	0.30	**0.28**	0.19	0.25	0.27	0.27	**0.24**	0.16	0.18	0.19	0.19	**0.18**
Mean (Z)	**0.21**	**0.25**	**0.26**	**0.27**		**0.17**	**0.21**	**0.22**	**0.23**		**0.15**	**0.16**	**0.17**	**0.17**	
*Control (No nitrogen, no zeolite) – 0.20%						*Control (No nitrogen, no zeolite) – 0.14%					*Control (No nitrogen, no zeolite) – 0.12%				
	S.Em. (±)	**CD (p=0.05)**					**S.Em. (±)**	**CD (p=0.05)**				**S.Em. (±)**	**CD (p=0.05)**		
N	0.003	0.01				N	0.002	0.01			N	0.002	0.01		
Z	0.003	0.01				Z	0.002	0.01			Z	0.003	0.01		
N X Z	0.006	0.02				N X Z	0.003	0.01			N X Z	0.005	NS		

Table 8. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on phosphorous content (%) in maize grain and stover

Levels	Grain					Stover				
	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)
N_{100}	0.20	0.20	0.21	0.21	**0.21**	0.08	0.09	0.10	0.10	**0.09**
N_{150}	0.20	0.22	0.22	0.23	**0.22**	0.09	0.13	0.14	0.15	**0.13**
N_{200}	0.22	0.24	0.25	0.25	**0.24**	0.12	0.17	0.18	0.19	**0.16**
Mean (Z)	**0.21**	**0.22**	**0.23**	**0.23**		**0.10**	**0.13**	**0.14**	**0.15**	
*Control (No nitrogen, no zeolite) – 0.18%						*Control (No nitrogen, no zeolite) – 0.07%				
	S.Em. (±)	**CD (p=0.05)**					**S.Em. (±)**	**CD (p=0.05)**		
N	0.003	0.01				N	0.002	0.01		
Z	0.003	0.01				Z	0.002	0.01		
N X Z	0.005	NS				N X Z	0.003	0.01		

Table 9. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on potassium content (%) in maize at 30, 60, 90 DAS

Levels	30 DAS					60 DAS					90 DAS				
	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)
N_{100}	1.23	1.26	1.27	1.29	**1.26**	1.13	1.14	1.16	1.18	**1.15**	0.64	0.66	0.67	0.69	**0.66**
N_{150}	1.30	1.32	1.34	1.35	**1.33**	1.20	1.23	1.25	1.28	**1.24**	0.70	0.72	0.74	0.75	**0.73**
N_{200}	1.37	1.39	1.41	1.43	**1.40**	1.29	1.32	1.35	1.37	**1.33**	0.76	0.78	0.81	0.83	**0.79**
Mean (Z)	**1.30**	**1.32**	**1.34**	**1.36**		**1.21**	**1.23**	**1.25**	**1.28**		**0.70**	**0.72**	**0.74**	**0.76**	
*Control (No nitrogen, no zeolite) – 1.20%						*Control (No nitrogen, no zeolite) – 1.10%					*Control (No nitrogen, no zeolite) – 0.61%				
	S.Em. (±)	**CD (p=0.05)**					**S.Em. (±)**	**CD (p=0.05)**				**S.Em. (±)**	**CD (p=0.05)**		
N	0.003	0.01				N	0.004	0.01			N	0.002	0.01		
Z	0.003	0.01				Z	0.004	0.012			Z	0.003	0.01		
N X Z	0.006	NS				N X Z	0.007	NS			N X Z	0.005	NS		

Table 10. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on potassium content (%) in maize grain and stover

Levels	Grain					Stover				
	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)
N_{100}	0.20	0.23	0.25	0.27	**0.24**	1.00	1.02	1.04	1.04	**1.03**
N_{150}	0.28	0.31	0.33	0.36	**0.32**	1.06	1.09	1.11	1.12	**1.09**
N_{200}	0.38	0.41	0.42	0.45	**0.42**	1.14	1.16	1.18	1.19	**1.17**
Mean (Z)	**0.29**	**0.32**	**0.34**	**0.36**		**1.07**	**1.09**	**1.11**	**1.12**	
*Control (No nitrogen, no zeolite) – 0.18%						*Control (No nitrogen, no zeolite) – 0.98%				
	S.Em. (±)	**CD (p=0.05)**					**S.Em. (±)**	**CD (p=0.05)**		
N	0.002	0.004				N	0.003	0.01		
Z	0.002	0.005				Z	0.003	0.01		
N X Z	0.003	NS				N X Z	0.006	NS		

The close perusal of data indicates that the zeolite has significantly improved K content in 30, 60, 90 DAS and at harvest. These results are in conformity with the results obtained by Rabai et al. [16] who reported that all treatments with zeolite significantly improved K content in maize. The K concentration in maize stems was higher in the treatments receiving zeolite [21].

3.5 Grain Yield (g pot^{-1})

The data pertaining to grain yield of maize was presented in Table 11 and Fig. 1. The grain yield of maize ranged from 14.86 to 46.80 g pot^{-1}.

The grain yield of maize was significantly improved by application of different combinations of zeolite and nitrogen levels. Among the three nitrogen levels, N_{200} produced significantly higher grain yield (mean value - 42.79) compared to other levels of nitrogen. The N_{150} produced grain yield of 33.39 (mean value) and N_{100} produced the lowest grain yield (mean value - 23.73). Among four zeolite levels, $Z_{7.5}$ produced highest grain yield (mean value - 36.62) which was significantly superior over other zeolite levels. This is followed by Z_5 where the grain yield was 35.12 (mean value). The next best grain yield of maize was observed in $Z_{2.5}$ (mean value - 32.36), while the treatment Z_0 produced lowest grain yield (mean value - 29.11). These treatments were statistically different compared to control which showed lowest grain yield (14.86) among all the treatments. Among different combination of zeolite and nitrogen, $N_{200}Z_{7.5}$ (Nitrogen @ 200 kg ha^{-1} + Zeolite @ 7.5 t ha^{-1}) resulted in higher grain yield (46.80) which is on par with $N_{200}Z_5$ (Nitrogen @ 200 kg ha^{-1} + Zeolite @ 5 t ha^{-1}) where the grain yield recorded was 45.35. The lowest grain yield was observed in control (14.86).

Table 11. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on grain yield (g pot^{-1}) of maize

Levels	Grain yield of maize (g pot^{-1})				
	Z_0	$Z_{2.5}$	Z_5	$Z_{7.5}$	Mean (N)
N_{100}	19.50	22.87	25.35	27.20	**23.73**
N_{150}	29.73	33.30	34.67	35.86	**33.39**
N_{200}	38.10	40.89	45.35	46.80	**42.79**
Mean (Z)	**29.11**	**32.36**	**35.12**	**36.62**	
	S.Em. (±)	**CD (p=0.05)**			
N	0.26	0.78			
Z	0.31	0.90			
N X Z	0.53	1.55			

**Control (No nitrogen, no zeolite) – 14.86 g pot-1*

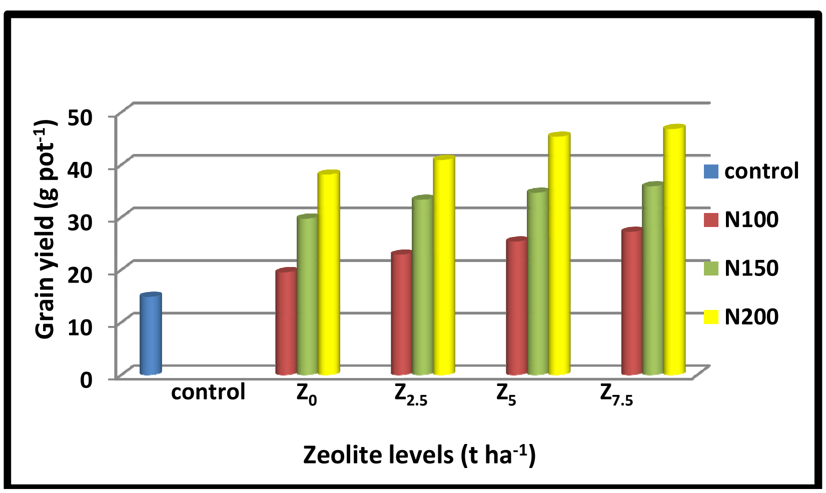

Fig. 1. Effect of different levels of nitrogen (kg ha^{-1}) and zeolite (t ha^{-1}) application on grain yield (g pot^{-1}) of maize

The increase in the grain yield of maize may be due to the availability of nutrients for timely utilization by the maize crop which may be due to the temporary retention of soil exchangeable NH_4^+, Ca, Mg, K, Na, and available N, P, K in the treatments with zeolite compared with the use of chemical fertilizers alone. The zeolite serves as stabilizer and regulator of mineral fertilizers besides being source of nutrients which and ultimately lead to increase in the grain yield. These results were comparable to results obtained by Manikandan and Subramanian [18] where the grain yield of maize in alfisols was increased in zeourea treatment. There was enhancement of maize yield with application of zeolite @ 200 kg ha^{-1} compared to without application of Zeolite, Weaks [15].

4. CONCLUSION

The available nutrient status at harvest was significantly higher in the treatment receiving 7.5 t ha^{-1} zeolite along with 100 kg ha^{-1} nitrogen. Application of nitrogen @ 200 kg ha^{-1} + zeolite @ 7.5 t ha^{-1} resulted in higher N, P, K contents in maize and also improved grain yield which was on par with the treatment receiving nitrogen @ 200 kg ha^{-1} + zeolite @ 5 t ha^{-1}. From the results of investigation, it can be concluded that zeolite addition to soil in combination with nitrogen increased the availability of nutrients for timely utilization by the maize crop which resulted in increased nutrient contents and grain yield of maize. Hence zeolite can be considered as slow release fertilizer and can also be called as one of the exchange fertilizers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/63376