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

C. H. Ravali†, K. Jeevan Rao2, T. Anjaiah1 and K. Suresh3

1Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, 500030, India.
2International Programmes, PJTSAU, Hyderabad, India (Retd.).
3Department of Agronomy, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, 500030, India.

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

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\(_{200Z7.5}\).

*Corresponding author: E-mail: ravalireddych96@gmail.com;
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 25899.87 metric tonnes 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 aluminosilicate 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\(_2\)O\(^+\), 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, catalystsis and dehydrogen 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\(^\circ\)E longitude and 17.3142\(^\circ\)N latitude. The mean maximum and mean minimum temperatures of the location are 28.0\\(^\circ\)C to 32.6\\(^\circ\)C and 10.1\\(^\circ\)C to 23.9\\(^\circ\)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 60\(^{\circ}\)C - 80\(^{\circ}\)C 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

---

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

Available phosphorous was determined by and Asija properties of soil. Available nitrogen in the soil through 2 mm sieve and preserved in polythene and were shade dried, pounded and passed were collected at 30, 60, 90 DAS and at harvest experiment) and treatment wise soil samples. Initial soil samples (before initiation of experiment) were determined by Flame photometer (Elico CL 378) digested in diacid mixture (HNO$_3$ and HClO$_4$ in 9:4 ratio), then potassium content 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 vanadomolybdo 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 (0.5N 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

| Particulars | Abbreviated as |
|-------------|----------------|
| No Nitrogen and No Zeolite | N$_0$Z$_0$ |
| 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.
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 Ca²⁺ and Mg²⁺ were determined by displacement with 1 N sodium acetate of pH 8.2. The soil was extracted and the leachate was analysed for Ca²⁺ and Mg²⁺ 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 (NO₃⁻ - 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 combinelly 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 Z₇.₅ (mean value - 19.76) and the lowest available P among the four zeolite levels was observed in Z₀ (mean value - 11.20). There was significant interaction observed between nitrogen and zeolite levels. Among all the treatments, available P was significantly higher in N₁₀₀Z₇.₅ (24.43) compared to all other treatments. The lowest available P was recorded in N₁₀₀Z₀ (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⁺⁺ ions in zeolite are exchanged with NH₄⁺ or K⁺ ions. These results were in conformity with the findings of Weak [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 Z₇.₅ (mean value - 136.24 mg kg⁻¹), followed by Z₅ (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 N₂₀₀ (mean value - 152.43 mg kg⁻¹) which differed significantly with N₁₅₀ (mean value - 129.77 mg kg⁻¹) and N₁₀₀ (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 N₁₀₀Z₇.₅ (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, Z₇.₅ has recorded highest nitrogen content (mean value - 1.17) and it was on par with Z₅ (mean value - 1.16) and they differed significantly with the nitrogen content in Z₀ 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 N₂₀₀ produced higher nitrogen (mean value - 1.21) content which had shown significant difference with other levels of nitrogen i.e., N₁₅₀ (mean value - 1.15) and N₁₀₀ (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\textsubscript{7.5} produced higher nitrogen content (mean value - 1.10) which was on par with Z\textsubscript{5} (mean value - 1.09), followed by Z\textsubscript{2.5} (mean value - 1.06) and Z\textsubscript{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\textsubscript{200} (mean value - 1.13), which differed significantly with N\textsubscript{150} (mean value - 1.08), N\textsubscript{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\textsubscript{200}Z\textsubscript{7.5} treatment (1.16) which was on par with N\textsubscript{200}Z\textsubscript{5} (1.14) and N\textsubscript{200}Z\textsubscript{2.5} (1.12) and they were significantly superior over N\textsubscript{200}Z\textsubscript{0} (1.11) and control (0.88). The increase in the nitrogen content was 31.81 over control in N\textsubscript{200}Z\textsubscript{7.5} treatment. At 90 DAS Z\textsubscript{7.5} recorded significantly higher N content (mean value - 1.03), followed by Z\textsubscript{5} (mean value - 1.01), while the lowest N content was recorded in Z\textsubscript{0} (mean value - 0.93) and among nitrogen levels, highest nitrogen content was observed in N\textsubscript{200} (mean value - 1.10) which differed significantly with N\textsubscript{150} (mean value - 0.99), N\textsubscript{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\textsubscript{200}Z\textsubscript{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\textsubscript{7.5} produced higher nitrogen content (mean value - 0.82), followed by Z\textsubscript{5} (mean value - 0.80) and they were significantly superior to control (0.45). Among nitrogen levels, highest nitrogen content was observed in N\textsubscript{200} (mean value - 1.13) which differed statistically with N\textsubscript{150} (mean value - 1.08) and N\textsubscript{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\textsubscript{200}Z\textsubscript{7.5} treatment (0.91) which was on par with N\textsubscript{200}Z\textsubscript{5} (0.90) they were significantly superior over control (0.45). The zeolite level Z\textsubscript{7.5} recorded significantly higher N content in maize straw (mean value - 0.43), whereas Z\textsubscript{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\textsubscript{200} (mean value - 0.53) which differed statistically with N\textsubscript{150} (mean value -0.38) and N\textsubscript{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\textsubscript{200}Z\textsubscript{7.5} treatment (0.56) which was on par with N\textsubscript{200}Z\textsubscript{5} (0.55) they. The lowest N content was recorded in control (0.16).

### Table 3. a, b and c initial soil 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\textsuperscript{-1}) | 0.45            |
| 3.    | Silt (%)          | 4.40            | 3.    | Organic Carbon (%)        | 0.57            |
| 4.    | Clay (%)                  | 8.24            | 4.    | CEC (cmol(p+)kg\textsuperscript{-1}) | 13.02            |
| 5.    | Soil Texture              | Loamy sand      | 6.    | Bulk Density (Mg m\textsuperscript{-3}) | 1.18            |
| 7.    | Water Holding Capacity (%)| 28              |       |                           |                 |

### c) Chemical Properties

| S. No. | Property                  | Values          |
|-------|---------------------------|-----------------|
| 1.    | Available N (kg ha\textsuperscript{-1}) | 177             |
| 2.    | Available P (kg ha\textsuperscript{-1}) | 15              |
| 3.    | Available K (kg ha\textsuperscript{-1}) | 380             |
| 4.    | Exchangeable Ca\textsuperscript{2+} (cmol kg\textsuperscript{-1}) | 1.45            |
| 5.    | Exchangeable Mg\textsuperscript{2+} (cmol kg\textsuperscript{-1}) | 0.82            |
| 6.    | Exchangeable Na\textsuperscript{+} (cmol kg\textsuperscript{-1}) | 0.22            |
| 7.    | Exchangeable K\textsuperscript{+} (cmol kg\textsuperscript{-1}) | 0.53            |
| 8.    | Exchangeable NH\textsubscript{4\textsuperscript{+}} (mg kg\textsuperscript{-1}) | 10.44           |
| 9.    | Exchangeable NO\textsubscript{3} (mg kg\textsuperscript{-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) |
| N$_{100}$ | 65.00     | 64.90   | 64.79       | 64.77  | 64.87        | 16.19 | 23.08     | 24.43 | 21.75     | 145.94   |
| N$_{150}$ | 64.82     | 64.93   | 65.16       | 64.70  | 64.90        | 11.48 | 18.00     | 21.45 | 17.56     | 123.48   |
| N$_{200}$ | 64.77     | 64.56   | 64.72       | 64.81  | 64.72        | 7.26  | 12.52     | 13.39 | 11.55     | 93.77    |
| Mean (Z) | 64.86     | 64.80   | 64.89       | 64.76  | 11.64        | 17.94 | 18.48     | 19.76 | 121.06    | 124.96   |

*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  | 0.29 0.16   | 0.46 0.53 | N NS |
| Avail. P  | 0.33 0.34   | 0.46 0.53 | Z NS |
| Avail. K  | 0.58 0.33   | 0.92 N X Z | NS |

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) |
| 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  | 1.10    | 0.93    | 0.97  | 1.01    | 1.01    | 1.03    | 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) |
|-----------|-------------|
| 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 | N X Z 0.01 0.02 |
The increase in the nitrogen content of maize was likely due to effect of increased proportion of NH₄⁺ and NO₃⁻ in the soil solution which is a result of adsorption of NH₄⁺ 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, N₂₀₀ recorded significantly higher phosphorous content (mean value - 0.28), followed by N₁₅₀ (mean value - 0.25) and N₁₀₀ (mean value - 0.22) and among four zeolite levels, Z₇.₅ recorded highest phosphorous content (mean value - 0.27), which is on par with Z₅ (mean value - 0.26), while the lowest P content among four zeolite levels was recorded in Z₀ (mean value - 0.21). There was significant interaction between nitrogen and zeolite on P content. Among different treatments, N₂₀₀Z₇.₅ recorded highest phosphorous content at 30 DAS (0.30), which is on par with N₂₀₀Z₅ (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, Z₇.₅ produced higher P content (mean value - 0.23) which is on par with Z₅ (mean value - 0.22) and Z₀ recorded lowest P content (mean value - 0.17) among all the zeolite levels. Among three nitrogen levels highest nitrogen content was observed in N₂₀₀ (mean value - 0.24), which differed significantly with N₁₅₀ (mean value - 0.20) and N₁₀₀ (mean value - 0.17). There was significant interaction observed between nitrogen and zeolite. Among all treatments, the highest P content was recorded from N₂₀₀Z₇.₅ treatment (0.27) and N₂₀₀Z₅ (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 N₁₀₀Z₇.₅ treatment was 92.85 % over control. At 90 DAS, among the three nitrogen levels, N₂₀₀ recorded significantly higher phosphorous content (mean value - 0.18), followed by N₁₅₀ (mean value - 0.16) and N₁₀₀ (mean value - 0.14) and among four zeolite levels, Z₇.₅ recorded highest phosphorous content (mean value - 0.17), which is on par with Z₅ (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 Z₇.₅ and Z₅ (mean value - 0.23) which was on par with Z₂.₅ (mean value - 0.22). The lowest P content was recorded in control (0.18). Among nitrogen levels, highest P content was observed in N₂₀₀ (mean value - 0.24) which differed significantly with N₁₀₀ (mean value - 0.22), N₁₀₀ (mean value - 0.21) and control (0.18). However N₁₅₀ and N₁₀₀ were on par with

### 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 | |
|--------|-------|-------|-------|-------|-------|-------|
|        | Z₀    | Z₂.₅  | Z₅    | Z₇.₅  | Mean | Z₀    | Z₂.₅  | Z₅    | Z₇.₅  | Mean |
| N₁₀₀   | 0.60  | 0.66  | 0.70  | 0.73  | 1.00 | 0.18 | 0.21 | 0.25 | 0.29 | 0.23 |
| N₁₅₀   | 0.74  | 0.78  | 0.81  | 0.83  | 1.08 | 0.32 | 0.35 | 0.39 | 0.46 | 0.38 |
| N₂₀₀   | 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  S.Em CD
(-)  (±)  (±)  (±)
(p=0.05)  (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
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 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_{5} 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\textsuperscript{-1}) and zeolite (t ha\textsuperscript{-1}) application on phosphorous content (%) in maize at 30, 60, 90 DAS

| Levels | 30 DAS |          |          |          |          | 60 DAS |          |          |          | 90 DAS |          |          |          |
|--------|--------|----------|----------|----------|----------|--------|----------|----------|----------|--------|----------|----------|----------|
|        | Z\textsubscript{0} | Z\textsubscript{2.5} | Z\textsubscript{5} | Z\textsubscript{7.5} | Mean (N) | Z\textsubscript{0} | Z\textsubscript{2.5} | Z\textsubscript{5} | Z\textsubscript{7.5} | Mean (N) | Z\textsubscript{0} | Z\textsubscript{2.5} | Z\textsubscript{5} | Z\textsubscript{7.5} | Mean (N) |
| N\textsubscript{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\textsubscript{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\textsubscript{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 | 0.23 | 0.15 | 0.16 | 0.17 | 0.17 | 0.17 | 0.17 |

*Control (No nitrogen, no zeolite) – 0.20%

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

| Levels | Grain |          |          |          |          |          | Stover |          |          |          |          |          |          |          |
|--------|-------|----------|----------|----------|----------|----------|--------|----------|----------|----------|----------|----------|----------|----------|
|        | Z\textsubscript{0} | Z\textsubscript{2.5} | Z\textsubscript{5} | Z\textsubscript{7.5} | Mean (N) | Z\textsubscript{0} | Z\textsubscript{2.5} | Z\textsubscript{5} | Z\textsubscript{7.5} | Mean (N) |
| N\textsubscript{100} | 0.20 | 0.20 | 0.21 | 0.21 | 0.21 | 0.08 | 0.09 | 0.10 | 0.10 | 0.09 |
| N\textsubscript{150} | 0.20 | 0.22 | 0.22 | 0.23 | 0.22 | 0.09 | 0.13 | 0.14 | 0.15 | 0.13 |
| N\textsubscript{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 | 0.14 | 0.15 | 0.15 |

*Control (No nitrogen, no zeolite) – 0.18%

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

*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
### 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 | 1.31 | 1.34 | 1.36 | 1.39 | 1.42 | 1.45 | 1.48 | 1.51 | 1.54 | 1.57 | 1.60 |
| \(N_{150}\) | 1.30 | 1.32 | 1.34 | 1.35 | 1.33 | 1.38 | 1.41 | 1.44 | 1.47 | 1.50 | 1.53 | 1.56 | 1.59 | 1.62 | 1.65 | 1.68 |
| \(N_{200}\) | 1.37 | 1.39 | 1.41 | 1.43 | 1.40 | 1.45 | 1.48 | 1.51 | 1.54 | 1.57 | 1.60 | 1.63 | 1.66 | 1.69 | 1.72 | 1.75 |
| Mean (Z) | 1.30 | 1.32 | 1.34 | 1.36 | 1.33 | 1.38 | 1.41 | 1.44 | 1.47 | 1.50 | 1.53 | 1.56 | 1.59 | 1.62 | 1.65 | 1.68 |

*Control (No nitrogen, no zeolite) – 1.20%  
S.E.m. (±) CD (p=0.05)  
N 0.003 0.01  
Z 0.003 0.01  
N X Z 0.006 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) | \(Z_0\) | \(Z_{2.5}\) | \(Z_5\) | \(Z_{7.5}\) | 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 | 0.34 | 1.07 | 1.09 | 1.11 | 1.12 |

*Control (No nitrogen, no zeolite) – 0.18%  
S.E.m. (±) CD (p=0.05)  
N 0.002 0.004  
Z 0.002 0.005  
N X Z 0.003 NS

*Control (No nitrogen, no zeolite) – 0.98%  
S.E.m. (±) CD (p=0.05)  
N 0.002 0.004  
Z 0.002 0.005  
N X Z 0.003 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, 

| Levels   | Grain yield of maize (g pot⁻¹) | Mean (N) |
|----------|-------------------------------|----------|
|          | Z₀   | Z₂₅  | Z₅   | Z₇₅  |          |
| N₁₀₀     | 19.50 | 22.87 | 25.35 | 27.20 | 23.73    |
| N₁₅₀     | 29.73 | 33.30 | 34.67 | 35.86 | 33.39    |
| N₂₀₀     | 38.10 | 40.89 | 45.35 | 46.80 | 42.79    |
| Mean (Z) | 29.11 | 32.36 | 35.12 | 36.62 |          |

S.E.m. (±) CD (p=0.05)

|          | CD (p=0.05) | S.E.m. (±) |
|----------|-------------|------------|
| 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.

REFERENCES

1. Food and Agriculture Organization (FAO). Maize: International market profile; 2006.
2. Available: https://www.indiastats.com/2016-17.
3. Nguyen ML, Tanner CC. Ammonium removal from wastewater using natural New Zealand zeolites. New Zealand Journal of Agricultural Research. 1986; 41:427-46.
4. Gruener JE, Ming DW, Henderson KE. 003. Common ion effects in zeoponic substrates: Wheat plant growth experiment. Microporous and Mesoporous Materials. 2003;61:223-30.
5. Piper CS. Soil and plant analysis. Hans publishers, Bombay. 1966;137-153.
6. Subbiah BV, Asija GL. A rapid procedure for determination of available nitrogen in soils. Current Science. 1956;25:259-260.
7. Watanabe, Olsen P. Methods of soil analysis-chemical and microbiological properties. Soil Science Society of America Incorporation, Madison, Wisconsin, USA; 1965.
8. Jackson ML. Soil chemical analysis. Prentice Hall of India, Pvt. Ltd. New Delhi. 1973;498.
9. Jackson ML. Soil chemical analysis. Prentis Hall of India Pvt. Ltd., New Delhi. 1967;111-203.
10. Walkley A, Black CA. Estimation of Organic Carbon by chromic acid titration method. Soil Science. 1934;37: 29-38.
11. Klute A. Porosity. In Methods of soil analysis - part 1(ed. C.A. Black). Physical and mineralogical methods. American Society of Agronomy inc., SSSA, IC, Madison/Wisconsin, USA; 1986.
12. Dane JH, Hopmans JW. Water retention and storage. Methods of Soil Analysis. Part. 4. SSSA Book Ser. 5. Soil Science Society of America, Madison, WI. 2002; 671–796.
13. Richards LA. (ed.). Diagnosis and improvement of saline and alkali soils. Handbook no. 60 USDA, Washington, D. C; 1954.
14. Litaor MI, Katz L, Shenker M. The influence of compost and zeolite co-addition on the nutrients status and plant growth in intensively cultivated Mediterranean soils. Soil Use and Management. 2017;33:72–80.
15. Weaks EN, Raut Y, Jahan H, Islam HR. Zeolite effects on nitrogen and phosphorus availability in soil; 2013. Available:http://scisoc.confex.com/crops/2013am/webprogram/Handout/Paper79339/Zeolite%2C%20Nitrogen%20and%20Phosphorous.pdf
16. Rabai KA, Ahmed OH, Kasim S. Use of formulated nitrogen, phosphorus, and potassium compound fertilizer using clinoptilolite zeolite in maize (Zea mays L.) cultivation. Emirates Journal of Food and Agriculture. 2013;25(9):713-722.
17. Kavoosi M. Effects of Zeolite application on rice yield, nitrogen recovery and nitrogen use efficiency. Communications in Soil
Science and Plant Analysis. 2007;38(1-2): 69-76.
18. Manikandan A, Subramanian KS. Evaluation of Zeolite based nitrogen Nano-fertilizers on Maize growth, yield and quality on inceptisols and alfisols. International Journal of Plant & Soil Science. 2016;9(4):1-9.
19. Allen E, Hossner L., Ming D, Henninger D. Solubility and cation exchange in phosphate rock and saturated clinoptilolite mixtures. Soil Science Society American Journal. 1993;57:1368-1374.
20. Ahmed OH, Sumalatha G, Majid NMA. Use of zeolite in maize (Zea mays) cultivation on nitrogen, potassium and phosphorus uptake and use efficiency. International Journal of the Physical Sciences. 2010; 5(15):2393-2401.
21. Lija M, Ahmed OH, Kasim S. Maize (Zea mays L.) nutrient use efficiency as affected by formulated fertilizer with Clinoptilolite Zeolite. Emirates Journal of Food Agriculture. 2014;26(3):284-292.