Soil Application of Zeolite Affects Inorganic Nitrogen, Water Soluble and Exchangeable Potassium

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

An incubation study was conducted at college of agriculture, rajendranagar, PJTSAU to evaluate the influence of zeolite application on inorganic nitrogen, water soluble and exchangeable potassium in soil. Clinoptilolite Zeolite was fully mixed with soil (7.5 t ha^{-1}) at the start of the experiment. Nitrogen was applied to soil through urea (200 kg ha^{-1}). The experiment was conducted for 35 days and soil was analyzed for inorganic nitrogen, water soluble and exchangeable potassium at weekly intervals *i.e.*, 1, 7, 14, 21, 28, 35 days of incubation. The results indicated that the treatment with zeolite application showed significantly higher ammoniacal nitrogen from day 1 (136.54 mg kg^{-1}) to day 35 (38.71 mg kg^{-1}) as well as nitrate nitrogen (day 1 – 59.13 mg kg^{-1}; day 35 – 130.13 mg kg^{-1}). Similarly water soluble (day 1 – 92.21 kg ha^{-1}; day 35 – 103.13 kg ha^{-1}) and

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exchangeable potassium (day 1 – 363.69 kg ha^{-1}; day 35 – 393.94 kg ha^{-1}) was also significantly higher in zeolite applied treatments. Thus, mixing of zeolite into soil improves inorganic nitrogen through reducing leaching losses and also improves water soluble and exchangeable potassium.

1. INTRODUCTION

Nitrogenous fertilizers are often overused by farmers in intensive crop production, with large variation in application rates. Though affected by the green revolution, most farmers still believe that more fertilizer and higher grain yield are synonymous. High off-farm incomes and relatively low retail prices for nitrogenous fertilizers have also encouraged farmers to continuously increase their application of nitrogenous fertilizers. In typical farm practices, fertilizer applications are often based on experience rather than real-time nutrient requirements of crops and/or site-specific knowledge of soil nutrient status.

Zeolites were first introduced by a Swedish mineralogist, A.F. Cronstedt in the year 1756, with the discovery of the mineral Stilbite [1]. By heating with a blowpipe flames this mineral lost water. He called this mineral "zeolite" from the Greek 'zeo', to boil and 'lithos', stone. Since their discovery, zeolites are one of the most abundant minerals on earth which have been recognized as a separate group of minerals. 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, 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 [2].

Clinoptilolite zeolite, which maximizes N use efficiency and water use efficiency, may decrease environmental degradation through the use of balanced fertilizers in agriculture [3]. Slow release of N fertilizers can be produced by amending N fertilizers, such as urea with clinoptilolite zeolite [4]. The mechanism for slow release of K may be similar to the reactions shown for PO_3^- and NH_4^+. This is possible because of the sequestering effect of the exchanger of clinoptilolite zeolite [5,6].

Amendment of clinoptilolite zeolite to sandy soils has been reported to lower nitrogen concentration in the leachate and to increase moisture and nutrients in the soil due to increased soil surface area and cation-exchange capacity [7]). So, in order to improve nitrogen uptake in maize, zeolite can be used along with inorganic fertilizers.

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.

Clinoptilolite zeolite is a hydrated aluminosilicate of alkali and alkaline earth metals consist of infinite three-dimensional crystal structure, a polyhedral shape, and a great open cavity [8]. Clinoptilolite zeolite is widely used in cultivating different crops such as cereals, forage, vegetables, vine and fruit crops due to their exceptionally high ion-exchange capacity [9].

2. MATERIALS AND METHODS

An incubation study was conducted at college of agriculture, Rajendranagar, PJTSAU to evaluate the influence of zeolite application on inorganic nitrogen, water soluble and exchangeable potassium in soil. The red soil required for the experiment was collected from B-Block of Student farm, College of Agriculture, Rajendranagar. The clods in the soil were broken down and the soil was sieved through 2 mm sieve. After sieving, the soil was mixed with zeolite as per the treatments (7.5 t ha^{-1}) at the start of experiment and the soil was transferred to trays @ 1 kg soil per tray. Urea was applied as per the treatments (200 kg ha^{-1}) by dissolving in distilled water. The soil was maintained at field capacity throughout the incubation period by regularly adding distilled water. Incubation was

Table 1. Initial soil properties

S.No.	Property	Values	S.No.	Property	Values
1.	Soil type	Red soil	11.	Available K (kg ha^{-1})	380
2.	Sand (%)	87.36	12.	CEC (cmol(p+)kg^{-1})	13.02
3.	Silt (%)	4.40	13.	Exchangeable Ca^{+2} (cmol kg^{-1})	1.45
4.	Clay (%)	8.24	14.	Exchangeable Mg^{+2} (cmol kg^{-1})	0.82
5.	Soil Texture	Loamy sand	15.	Exchangeable Na^{+} (cmol kg^{-1})	0.22
6.	pH	7.08	16.	Bulk Density (Mg m^{-3})	1.18
7.	EC (dS m^{-1})	0.45	17.	Water Holding Capacity (%)	28
8.	Organic Carbon (%)	0.57			
9.	Available N (kg ha^{-1})	177			
10.	Available P (kg ha^{-1})	15			

carried out for 5 weeks at room temperature. Sampling is done at weekly intervals and was analyzed for ammoniacal nitrogen, nitrate nitrogen, water soluble potassium and exchangeable potassium. Initial soil properties of the soil were analyzed (Table 1).

Table 2. 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$_2$O$_3$) (%)	6-8

2.1 Treatment Details

T1: Only soil (control); T2: Soil + Nitrogen ; T3: Soil + Phosphorous + Potassium : T4: Soil + Nitrogen + Phosphorous + Potassium + Zeolite. Commercial grade Urea (46% N), Single Super Phosphate (16% P$_2$O$_5$), Muriate of Potash (60% K$_2$O) were used as the source of N, P, K respectively.

2.1.1 Ammoniacal nitrogen

Ten grams of soil was shaken with 100 ml of 2 M KCl for an hour and filtered. Then the filtrate was steam distilled in presence of 0.2 g MgO. The distillate was collected in 2 % boric acid containing mixed indicator was titrated with standard Sulphuric acid (0.02 *N*) as described by Bremner [10] and expressed in mg kg^{-1}.

2.1.2 Nitrate nitrogen

After the distillation of ammoniacal nitrogen, immediately 0.2 g Devarda's alloy was added

and distillation was done to obtain NO$_3$-- N. The distillate was collected in 2 % boric acid containing mixed indicator was titrated with standard Sulphuric acid (0.02 *N*) as described by Bremner [10] and expressed in mg kg^{-1}.

2.1.3 Water soluble K

The water soluble K in soil was extracted using soil and distilled water in the ratio of 1:5 and filtered. The extracted potassium was determined by flame photometer (Elico CL 378).

2.1.4 Exchangeable K

The exchangeable 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 [11] and expressed as kg ha^{-1}.

3. RESULTS AND DISCUSSION

3.1 Ammoniacal Nitrogen

The ammoniacal nitrogen increased from day 1 to day 7 (Table 3 and Fig. 1) and later there was a decrease in ammoniacal nitrogen upto day 35. On day 1, the ammoniacal nitrogen was highest in SNZPK treatment (136.54 mg kg^{-1}) followed by SN (61.41 mg kg^{-1}). Lowest ammoniacal nitrogen was recorded in the control (only soil – 30.08 mg kg^{-1}). On day 7, the ammoniacal nitrogen was highest in SNZPK treatment (155.20 mg kg^{-1}) followed by SN (74.08 mg kg^{-1}), while the lowest was in control (41.75 mg kg^{-1}). Similar trend was observed on day 14, 21, 28 and 35 where the significantly higher ammoniacal nitrogen was recorded in SNZPK treatment (107.03, 70.34, 66.56, 38.71 mg kg^{-1} respectively) and control treatment recorded lower ammoniacal nitrogen among all the treatments on day 14, 21, 28, 35

(14.96, 9.42, 5.64, 2.86 mg kg^{-1} respectively). Among all the treatments, the treatment where zeolite is mixed with soil showed significantly higher ammoniacal nitrogen than other treatments. A short time after zeolite application, the ammoniacal nitrogen content was reduced due to NH_4^+ fixation by zeolite, but later on opposite was true. The increase in NH_4^+- N in the treatment with zeolite application could have been caused by sorption in the zeolite lattice and release of adsorbed nitrogen from the zeolite crystal lattice. Increasing zeolite application rate irrespective of method of application had increased NH_4^+- N [12]. Similar results were obtained by Torma *et al*. [13] who found that, at the end of the field experiment, treatments with zeolite showed 24 % - 59 % higher ammoniacal nitrogen than control. There was decrease in NH4-N upto day 35 this is because most of the NH_4^+- N adsorbed onto zeolite inner channels was likely released and nitrified, a mechanism suggested by Perrin et al. [14].

3.2 Nitrate Nitrogen

Nitrate nitrogen showed an increasing trend from day 1 to day 35 (Table 4 and Fig. 2) in the treatment with zeolite. On day 1, the NO_3-N was significantly higher in SNZPK (59.13 mg kg^{-1}), followed by SN (53.22 mg kg^{-1}), while the lowest NO_3-N was recorded in control (35.27 mg kg^{-1}). Similar trend was noticed on day 7 where SNZPK treatment recorded significantly higher NO_3-N (81.78 mg kg^{-1}) among all the treatments and the lowest NO_3-N was recorded in control (27.24 mg kg^{-1}). SNZPK treatment showed significantly higher NO_3-N on day 14, 21, 28 and 35 among all the treatments which was 93.45, 101.91, 111.66, 130.13 mg kg^{-1} respectively, while the control treatment recorded lowest NO_3-N on day 14, 21, 28 and 35 (23.48, 19.36, 17.91 and 20.36 mg kg^{-1} respectively). The higher NO_3-N in zeolite treatment among all the treatments may be due to the presence of zeolite in the soil which inhibits nitrification process to a certain extent, so that nitrate leaching into deeper soil horizons is not so intensive. These results were comparable to the results obtained by Lija et al. [15], who found that treatment with compound fertilizer combined with zeolite showed highest NO_3-N while in compared to all other treatments. Mixing of an acid soil with clinoptilolite zeolite under waterlogged conditions significantly increased NO_3^- [16].
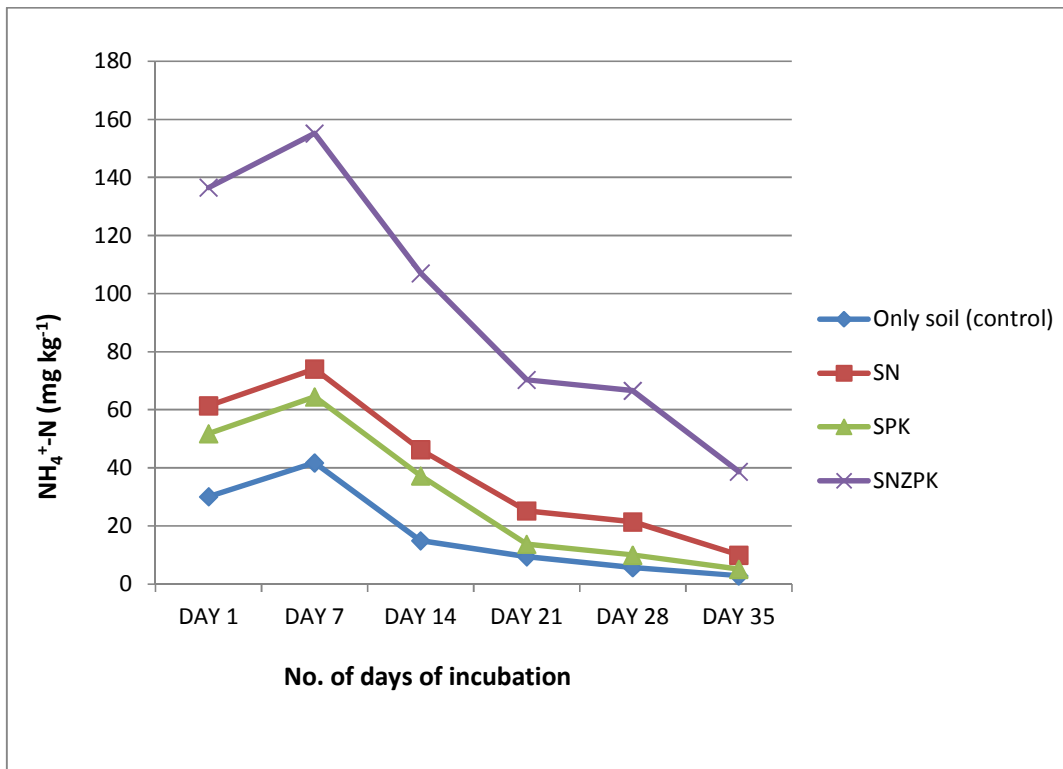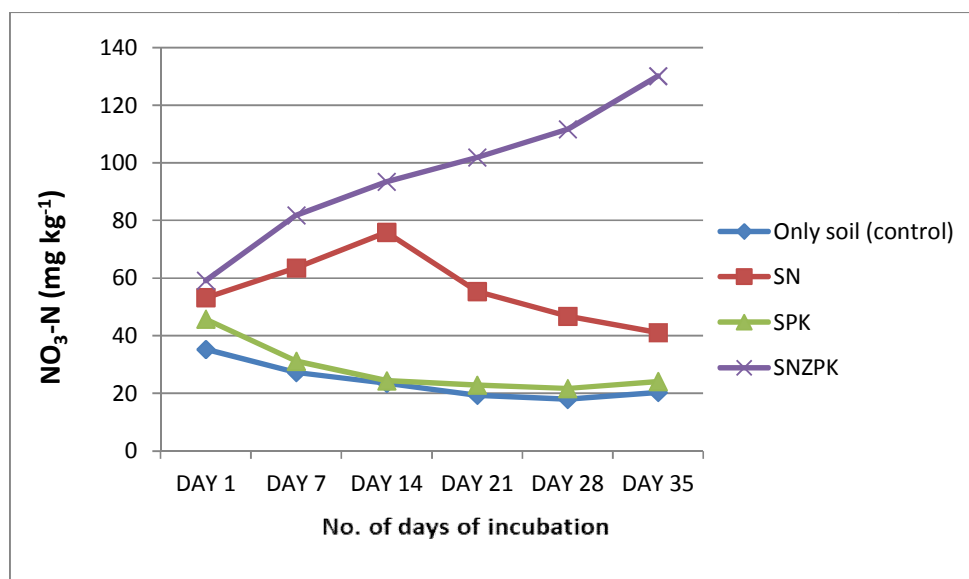

Fig. 1. Effect of addition of zeolite to soil on release of NH_4^+-N (mg kg^{-1})

Table 3. Effect of addition of zeolite to soil on release of NH_4^+- N (mg kg^{-1})

	Day 1	Day 7	Day 14	Day 21	Day 28	Day 35
Only soil (control)	30.08	41.75	14.96	9.42	5.638	2.858
SN	61.41	74.08	46.29	25.23	21.448	9.988
SPK	51.83	64.50	37.31	13.77	9.988	5.148
SNZPK	136.54	155.20	107.03	70.34	66.560	38.710
C.D.	1.38	1.47	0.72	0.67	0.667	0.667
SE(m)	0.46	0.49	0.24	0.22	0.221	0.221

Table 4. Effect of addition of zeolite to soil on release of NO_3-N (mg kg^{-1})

	Day 1	Day 7	Day 14	Day 21	Day 28	Day 35
Only soil (control)	35.27	27.24	23.48	19.36	17.91	20.36
SN	53.22	63.53	75.89	55.36	46.77	41.10
SPK	45.79	31.20	24.40	22.90	21.72	24.17
SNZPK	59.13	81.78	93.45	101.91	111.66	130.13
C.D.	0.58	0.55	0.55	0.88	0.55	0.55
SE(m)	0.19	0.18	0.18	0.29	0.18	0.18

Fig. 2. Effect of addition of zeolite to soil on release of NO_3-N (mg kg^{-1})

3.3 Exchangeable and Water Soluble K

The exchangeable K was significantly higher in SNZPK (363.69 kg ha^{-1}) on day 1 (Table 5), followed by SPK (351 kg ha^{-1}) and the lowest exchangeable K was observed in control treatment (307.28 kg ha^{-1}). After day 1, there was decrease in the exchangeable K up to day 7 in SNZPK treatment (336.18 kg ha^{-1}). On day 7, SPK treatment had recorded significantly higher exchangeable K (357.98 kg ha^{-1}) and the lowest was observed in control (311.85 kg ha^{-1}). On day 14, exchangeable K was significantly higher in SNZPK (365.78 kg ha^{-1}), followed by SPK

(361.70 kg ha^{-1}) and the lowest was observed in control (301.49 kg ha^{-1}). Similar trend was observed on day 21, 28 and 35 where SNZPK showed significantly higher exchangeable K (376.04, 384.50, and 393.94 kg ha^{-1} respectively) and the lowest was observed in control (296.83, 289.42, 283.78 kg ha^{-1} respectively).

Water soluble K increased from day 1 to day 7 (Table 6). Later there was a slight decrease in water soluble K content up to day 35 in SPK and SNZPK treatments. In control and SN treatments, there was decrease in the water soluble K from day 1 to day 35. On day 1,

Table 5. Effect of addition of zeolite to soil on Exchangeable K (Kg ha^{-1})

	Day 1	Day 7	Day 14	Day 21	Day 28	Day 35
Only soil (control)	307.28	311.85	301.49	296.83	289.42	283.78
SN	320.21	315.80	307.13	303.22	297.56	293.21
SPK	351.00	357.98	361.70	331.40	322.65	312.24
SNZPK	363.69	336.18	365.78	376.04	384.50	393.94
C.D.	9.29	0.90	1.00	3.00	3.00	3.00
SE(m)	3.07	0.30	0.33	0.99	0.99	0.99

Table 6. Effect of addition of zeolite to soil on Water soluble K (Kg ha^{-1})

	Day 1	Day 7	Day 14	Day 21	Day 28	Day 35
Only soil (control)	84.15	77.13	67.10	54.00	51.49	42.82
SN	96.67	90.24	81.77	71.49	66.44	67.36
SPK	87.35	112.64	106.68	98.31	94.52	92.36
SNZPK	92.21	126.06	119.12	111.53	108.02	103.13
C.D.	1.31	1.68	1.27	1.23	1.18	1.49
SE(m)	0.43	0.56	0.42	0.41	0.39	0.49

the water soluble K was significantly higher in SN (96.67 kg ha^{-1}), followed by SNZPK (92.21 kg ha^{-1}) and the lowest was observed in control (84.15 kg ha^{-1}).). On day 7, SNZPK treatment had recorded significantly higher water soluble K (126.06 kg ha^{-1}) and the lowest was observed in control (77.13 kg ha^{-1}). On day 14, water soluble K was significantly higher in SNZPK (119.12 kg ha^{-1}), followed by SPK (106.68 kg ha^{-1}) and the lowest was observed in control (67.10 kg ha^{-1}). Similar trend was observed on day 21, 28 and 35 where SNZPK showed significantly higher water soluble K (111.53, 108.02, 103.13kg ha^{-1} respectively) and the lowest was observed in control (54.00, 51.49, 42.82 kg ha^{-1} respectively).

From day 1 to day 7 there was decrease in exchangeable K due to adsorption by zeolite. Later there was higher exchangeable K in zeolite applied treatment due to release of K from zeolite. Addition of zeolite showed higher amounts of exchangeable K in the soil. This is because zeolite has the potential to absorb K$^+$ from chemical fertilizers, hence reducing K leaching. The water soluble K increased immediately after application of K fertilizer in SPK and SNZPK treatments and later there was a decrease. But in zeolite applied treatment there was higher water soluble K compared to all other treatments.These results were in accordance with the findings of Kavoosi [17] and Caballero *et al*. [18] who observed that increasing the zeolite dosage increased available K in the soil.

4. CONCLUSION

Our study aimed to evaluate the effect of zeolite application to soil on inorganic nitrogen and water soluble and exchangeable K. It was concluded that in zeolite applied treatment, a short term decline in NH$_4$-N was observed due to adsorption on zeolite lattice, but however later the zeolite applied treatment showed highest NH$_4$-N and NO3-N among all the treatments. Zeolite also tends to absorb K from commercial fertilizers which will be released later on, preventing leaching losses and increasing K availability. Thus we can conclude that application of zeolite to soil reduced leaching losses and improved availability of N and K in soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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