Zeolite Effects On Nitrogen and Phosphorus Availability in Soil

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Abstract

Zeolites are naturally occurring alumino-silicate minerals with a large reactive surface area. A field study based on randomized complete block design was established in 2011 to evaluate the effects of Zeolite as a soil amendment to improve the N and P-use efficiency of crops. Mined Ca-Zeolite (Clinoptilolite) was applied at 0, 25, 50, 100 and 200 kg/ha, respectively in winter-killed Cowpea and radish cover crop plots in April, 2012. Composite soil samples were collected weekly from each replicated plot at 0-15-cm depth, processed, and analyzed for nitrate, ammonium and available P after extracting the field-moist soil with deionized water and 1-M KCl solution. Results showed that N and P availability to plants was improved. Lesser amount of nitrate was extracted by both water and 1-M KCL solution. Most of the N was extracted as ammonium by 1-M KCL solution. Corn yield was responded to Zeolite application.

Introduction

Off-site movement of N and P from agroecosystems is associated with reduced fertilizer-use efficiency and water quality degradation (Diaz and Rosenberg, 2008). Thus, agricultural systems research leading to management practices that improve N and P utilization efficiency and decrease N and P losses is essential (Powlson et al., 2008). Adoption of new management techniques that improve N and P availability yet limit N and P loss may help improve agroecosystem services.

Zeolite is a nanoporous natural secondary mineral with large surface contact area making it ideal for adsorption and desorption of nutrients (***Photo 1***). Zeolite is not susceptible to biological degradation and is expected to have long-term benefits for nutrient recycling. Zeolites are not susceptible to biological degradation.

Several researchers have reported that Zeolite (such as Clinoptilolite) incorporation significantly decreased N leaching from sand media (Huang and Petrovic 1994). Ferguson and Pepper (1987) attributed the lower leaching losses to the high NH_4 retention of Zeolite. MacKown and Tucker (1985) also reported lower NH_4 losses with Zeolites and found that as incorporation rate increased, N loss decreased significantly. Penn et al. (2010) performed batch experiments with zeolite alone, noting that NH_4 sorption was mostly exchangeable as 81% to 87% of zeolite-bound NH_4 was removed with 1-M KCl. After 6 weeks of corn growth in amended sandy soil, zeolite increased corn yields compared with control. The objectives of the study were to evaluate the effects of Zeolite as a soil amendment to improve the (1) reactive N (NO_3 and NH_4) and P retention and availability, and (2) growth and yield of corn.

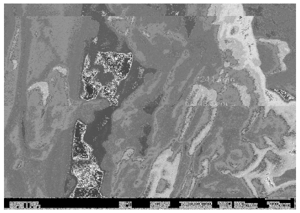


Photo 1: Scanning microscopy of Clinoptilolite

Photo 2: Cowpea and radish as cover crop

Materials and Methods

The study was conducted at the Ohio State University South Centers at Piketon, Ohio in 2011 and 2012. The soil is a Omulga silt loam (Fine-silty, mixed, mesic Typic Fragiudalfs) and has pH 5.3, electrical conductivity 53.2 µS/cm, total carbon 1.51%, total nitrogen 0.13%, bulk density 1.36 g/cm³ at 0 to 15-cm depth. A randomized complete block design with 5 levels of powdered Clinoptilolite (0, 25, 50, 100 and 200 kg/ha, respectively) was laid-out in 2011. The treatments were replicated 4 times in 20-m x 30-m plots. Prior to establish the experimental design, the field was chisel-plowed in early July, 2011 followed by planting of Cowpea (30 kg/ha) and oilseed radish (kg/ha) together as cover crops (***Photo 2***). The cover crops were winter-killed and Zeolite was surface applied in the fall. Corn was planted within cover crop residues in the spring.

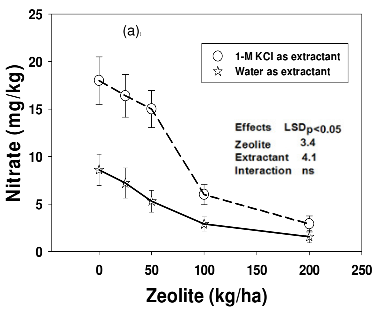
Geo-referenced composite soil samples were collected weekly at 0 to 15-cm depth from each plot from March 16, 2012 until July 6, 2012. Field-moist soil samples were processed, extracted with deionized water and 1-M KCL, and analyzed for NH_4, NO_3 and available P. SPAD meter was used to measure leaf chlorophyll content of the growing corn. At harvest, a random grain sample was collected from each plot, oven-dried and used for calculation of crop yields.

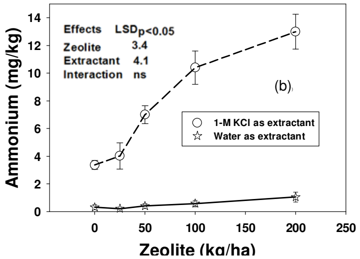
Significant differences in reactive N and P concentration, leaf chlorophyll, and crop yields attributed to the effects of Zeolite over time were assessed in a factorial arrangement of the randomized complete block design using analysis of variance procedure of the SAS (SAS 2008). The time and block were considered as random factors. Zeolite and extractant were considered as fixed factors. For all statistical analyses, significant main and interactive effects of predictors on dependent variables were evaluated using the SAS General Linear Model procedure and separated by the F-protected least significant different (LSD) test at $p \leq 0.05$ unless otherwise mentioned.

Results and Discussion

Results showed that Zeolite as a soil amendment significantly influenced the adsorption and release of NH_4, NO_3 and available P (**Fig. 1**). While incorporation of Zeolite significantly decreased NO_3 concentration in soil (**Fig. 1a**), the NH_4 concentration significantly increased with Zeolite application (**Fig. 1b**). Likewise, available P in soil increased with Zeolite levels (**Fig. 1c**).

The NO_3 , NH_4 and available P concentration have shown a non-linear increase over time when extracted with 1-M KCl or water (**Fig. 2a, b and c**). On average, the 1-M KCl extracted significantly higher concentration of NO_3, NH_4 and available P compared with water. The temporal increase in NH_4 concentration was for longer time than NO_3 and available P.





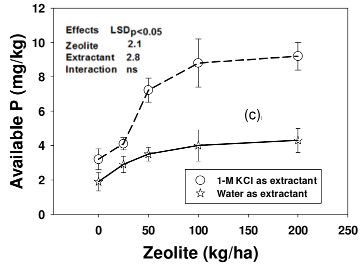


Fig. 1: Zeolite effects on (a) nitrate, (b) ammonium, and (3) available phosphorus concentration in soil

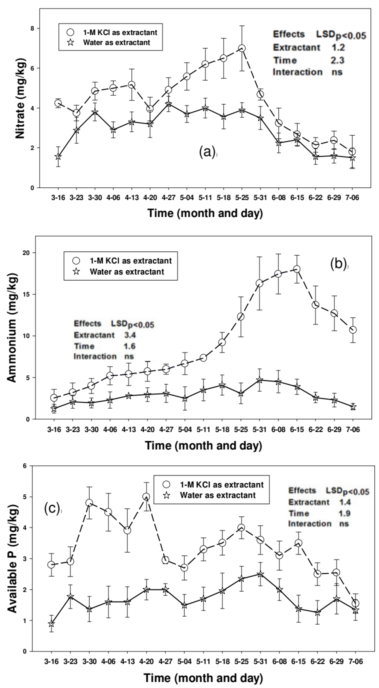


Fig. 2: Release of soil (a) nitrate, (b) ammonium, and (c) available P over time as measured by 1-M KCl and deionized water extraction.

The result is expected to be short-term, as the NH_4 concentration decreased significantly after July 15. Most of the NH_4 adsorbed onto zeolite surface is likely released and quickly absorbed by growing corn to meet its demand for N. Moreover, the increase in NH_4 by Zeolite and at these time steps could have been caused by sorption in the zeolite lattice. This finding supports that of others who showed that zeolite can help retain NH_4 in soils (Ferguson and Pepper, 1987; MacKown and Tucker, 1985; Weber et al., 1983).

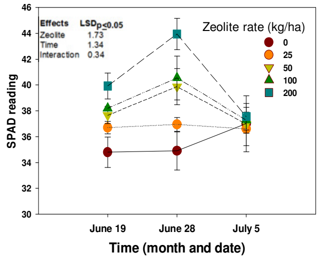


Fig. 3: Zeolite effects on corn leaf chlorophyll content (SPAD reading)

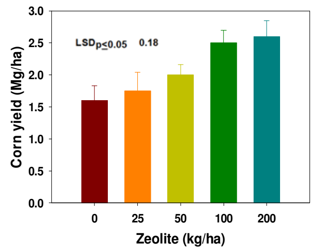


Fig. 4: Zeolite effects on corn yields

Conclusions

Results showed that Zeolite significantly adsorb NH_4 and P and minimize reactive NO_3 formation. Nitrogen released as NH4 after dissolution of applied chemical fertilizers or decomposition of manures and cover crops is adsorbed by Zeolite. Higher concentration of NH_4 extracted by 1-M KCl than by water suggested that NH_4 is adsorbed by Zeolite and is not removable by water erosion. N mixed with Zeolite could be used as a controlled release fertilizer.

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