Impact of Zeolite and Soil Moisture on P Uptake

Amirhossein Shokouhi, Masoud Parsinejad and Hamideh Noory
University of Tehran, Iran.
shokoohi.amir@ut.ac.ir

1. ABSTRACT

Importance of phosphorus as an essential nutrient for plant growth, limitations on sources of phosphate rock and inherent characteristics of phosphorus fixation and immobility, demonstrate the need of study on strategies to increase phosphorus plant uptake and reduce leaching. In this study, effect of NH4-exchanged Zeolite (Clinoptilolite) to reduce the fixation time and increase availability of phosphorus due to its chemical characteristic in combination with two levels of soil moisture control (40 and 50 percent depletion) was evaluated. In addition, macro pores were artificially introduced in soil to observe the effect of the management strategies under a condition prone to leaching. Results demonstrated that addition of Zeolite at 2 percent level could nominally increase rate of phosphorus uptake, but a significant increase in phosphorus uptake is not achieved unless a higher rate of Zeolite/soil is introduced. This latter option may not necessarily be economically justified. Also, the results show that increased average soil moisture could increase rate of phosphorus uptake quantitatively. Finally, artificial macro pores facilitated redistribution of moisture in soil which was resulted in a better root growth which improved phosphorus uptake.

2. INTRODUCTION

Phosphorus is the second most important nutrient for plants growth after nitrogen. The great importance of phosphorus is because of the role it plays in the biochemical and physiological processes. On the other hand, phosphorus due to its limited resources is highly important. Due to the limited resources of phosphate rock, optimal and proper utilization to prolong the cycle of using this element is essential. Phosphorus uptake by plants depends on factors such as soil pH, soil texture, and systems of root development. Phosphorus uptake has some problems due to the high rate of fixation, low dissolution, and absence of dynamicity of this element in the soil. Thus, farmers to solve this problem, generally use high amounts of phosphate fertilizer in agricultural land. Excessive use of phosphate fertilizer creates problems such as the extraction of phosphorus into surface waters and creation of a phenomenon of the enrichment of surface waters (Eutrophication).

The most suitable soils for absorption of phosphorus have been reported to be the kinds with pH values of 6.5 to 7.5. Another important factor in the absorption of phosphorus is moisture. With increasing soil moisture, phosphorus uptake by plants generally increases, the reason of which is higher solubility of phosphorus and further development of the root caused by moisture (Misra, 2003). Zeolite is a mineral component which is mainly composed of Aluminosilicate, and is used as surface adsorbent in industry. Zeolite is also used as a nutrient in agriculture because of its ion exchange ability (Ramesh et al. 2011). More than 50 different kinds of this element have been identified up to now, among which the natural Zeolite of Clinoptilolite is the most frequent. The conducted studies on this kind of Zeolite have indicated effects of moderating soil and conserving nitrogen in soil, high exchange ability of , increasing phosphorus uptake, and reducing pollution load of this element (Ramesh et al. 2011). Other applications of Zeolite in agriculture include preventing the occurrence of environmental problems through increasing nitrogen, phosphorus, and water use efficiency. One way of increasing phosphorus uptake by plants and reducing its load of pollution, is using natural Zeolite. Clinoptilolite as an ammonium exchanger, reacts with phosphate rock, extracts Calcium from phosphate rock, and increases the solubility of phosphate rock.

Price of Zeolites is determined based on the kind and usage of it. Natural Catalysts cost 3 to 4 dollars per kg, natural Zeolites for extensive usages cost 0.25 to 0.4 dollars per kg, and natural Zeolites with adsorbent usage cost 1.5 to 3.5 dollars per kg in the United States (Kulprathipanja, 2010). Therefore, the economic justification is important in the use of Zeolites.

Several studies have been conducted to evaluate the effect of Clinoptilolite on the absorption of phosphorous and plant yield. Investigating the effect of Zeolite on the absorption of phosphorus (source of phosphate rock), nitrogen and potassium in planting corn in acid soils demonstrated that the absorption of phosphorus, nitrogen and potassium increase in the presence of Zeolite (Ahmed et al. 2010). Investigating the effect of Zeolite on the absorption of phosphorus from phosphate rock by sunflower indicated that the absorption of phosphorus from phosphate rock increases in the presence of Zeolite (Pickering et al. 2002).

The aim of this study was to investigate the effect of Clinoptilolite at the level of 2% weight of soil on phosphorus uptake in planting corn with regard to the economic justification, and the integration with other managements. Managements included 60two allowable depletion levels of humidity (40% and 50%) and the use of artificial macro pore parts in order to accelerate the creation of preferential flow and drainage in soil.

3. METHODS AND MATERIALS

This study was conducted at 2013 in a growing season in the research field of soil and water research center in the irrigation & reclamation engineering department at the University of Tehran, located in Karaj, Iran. The pot experiment was done in pots with diameter of 35, and a height of 60 cm and a density of two plants of corn per pot. The corn used in this study was SC 704 which was planted with forage crop sowing aim. The study was conducted in a randomized complete design with three factors of presence and absence of Zeolite, allowable 40% and 50% depletion levels of humidity, and presence and absence of artificial macro pore parts, and with three replications.

Table1. Soil Profile Properties

Physico-Chemical Properties	Values
pH	7.8
Ece (dS/m)	1.5
Texture	Loam
Clay (%)	25
Silt (%)	35
Sand (%)	40
Available P (mg/kg)	22.7
K (mg/kg)	410
Total N (%)	0.12
Organic Carbon (%)	1.37

A pit with the dimensions of 0.5×4×4 was dug-out and the pots were placed inside it. Around the pit, and in order to eliminate marginal effect, four rows of corn were planted. Triple Super Phosphate fertilizer (TSP) with the amount of 500 mg per kg of soil as the source of phosphorus (30 g of fertilizer in a pot containing 60 kg of soil), 40 pieces of five-centimeter long thin plastic tube as parts of artificial macro pore, and Zeolite with particle size of 1 mm at the level of 2% weight of soil, and with taking into account its economic justification on a large scale, each corresponding to the desired treatment, was combined with soil uniformly. Table 2 shows composition of the used Zeolite. The control groups in the present study were treatments P40 and P50 including phosphate fertilizer at two moisture levels. Based on soil test results, the same amount of urea fertilizer was given to each of the pots. A view of position of the pots can be seen in Figure 1. The required drainage was placed in each pot to enable the removal of drainage.

Table2. Composition of Zeolite

SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	Na_2O	K_2O	Cl^-
67.83	11.64	0.54	0.84	0.2	4.5	4.32	0.98

Surface irrigation was applied for each pot according to the moisture depletion and in order to prevent soil moisture from reaching the tension level. Drip irrigation was applied for the marginal plants with regard to the need for irrigation calculated by the software AGWAT. The moisture of pots was read on a daily basis using TDR device and 30-cm probes. Taking the soil sample of the pots was conducted before the flowering stage. Soil samples were taken from the bottom of each pot with a depth of 20 and 40 cm using Auger drilling. Olsen method was used to measure the concentration of residual phosphorus in soil. Extraction was performed on soil samples and reading phosphorus concentration of soil extraction was carried out by 6705 UV/VIS spectrophotometer (colorimetric method). Extraction was performed on plant samples to determine the amount of phosphorus uptake by the plant, and phosphorus concentration of plant extraction was determined by spectrophotometer. With regard to the weight of aerial plant organ, phosphorus concentration (mg to kg) was converted into adsorbed phosphorus in mg. The amount of phosphorus uptake by the root was also obtained from the phosphorus balance. In order to investigate the created density of root, at the end of the study, soil was washed off the roots. Analysis of variance for the measured traits was performed with SAS, and means of the targeted features were compared using Duncan's test for comparison of means at level of 5%.

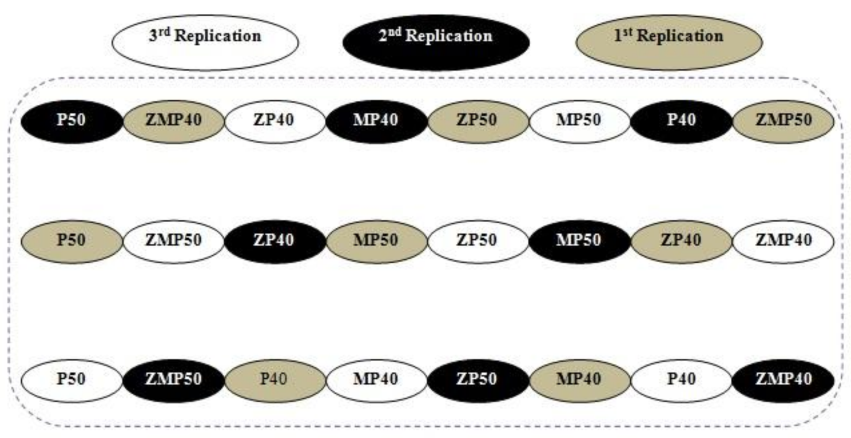

Fig1. Position of Pots in the Pit (Z: Zeolite, P: P Fertilizer, M: Macro pores)

4. RESULTS & DISCUTIONS

By examining the volume of irrigation water, it can be seen that the treatments with 40% moisture depletion level, received more water in terms of volume compared to the treatments with 50% moisture depletion level. However, analysis of variance of the volume of irrigation water, due to the limited size of the studied soil and non-significant difference of applied moisture levels in two depletion levels of 40% and 50%, did not show any statistically significant difference between the treatments. Comparing means of the treatment in Duncan test at 5% level, indicated a reduction in the volume of the irrigation water in the presence of Zeolite, but such a difference was not significant compared to the absence of Zeolite (Figure 2).

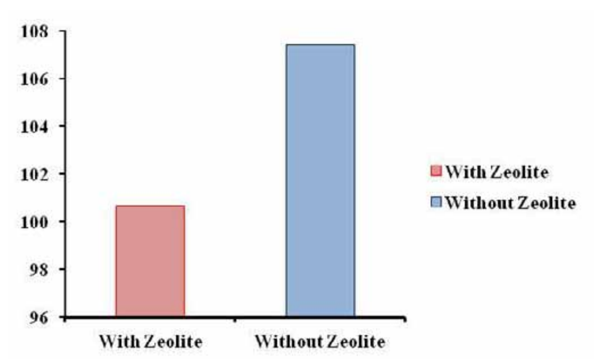

Fig2. Duncan Comparison of Mean Irrigation Amount

Duncan's test for comparison of means at level of 5 percent demonstated that the concentration of phosphorus absorbed by plant increased in the presence of Clinoptilolite, however, this amount of increase had not resulted in a statistically significant difference compared to the absence of Clinoptilolite (Figure 3). This may be due to inadequate portion of used Zeolite at a level of 2% weight of soil, considering the alkalinity of the soil under cultivation.

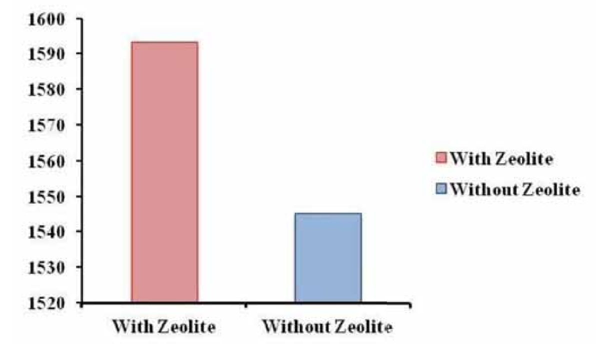

Fig3. Mean Plant P Concentration Duncan Comparison

Comparison of the means of the treatments containing macro pores and different levels of moisture depletion did not show any statistically significant difference in the concentration of phosphorus absorbed by plant compared to the control groups (Figure 4).

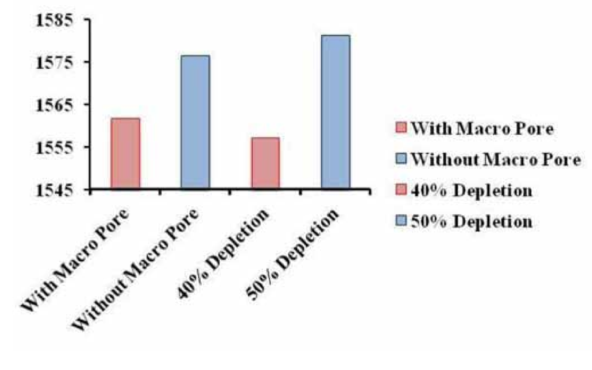

Fig4. Mean Plant P Concentration Duncan Comparison

In general, by decreasing humidity, phosphorus uptake was reduced with a gentle slope. The presence of artificial macro pore, due to the high-density cultivation which leads to consume all irrigation water by plant, could not behave as expected in accelerating preferential flow and forming drainage, and the effects of artificial macro pores could have only led to the redistribution of moisture in soil. The washed roots form the pots were equal to 60 to 65 cm, and based on the 40-cm height of soil in the pots, and two corn plants being placed in a pot with a diameter of 35 cm, these values totally point out the high density of planting that prevented the drainage to be formed and phosphorus deposits to be leached by the output drainage.

5. CONCLUSION

Low transferability, low solubility of Phosphorus, as much as it is needed, will result in limited plant uptake. Although concerns about environmental pollution of phosphorus is much lower compared to nitrate, studies on management strategies to increase its plant uptake is still important, specially where potential risk of P-loss and environmental pollution is high. In this study field treatments were designed to examine the role of: 1. Clinoptilolite on increasing phosphorus plant uptake, 2. irrigation managements to keep the average soil moisture to increase solubility and phosphorus uptake and finally, reproduction and implementation of artificial macro pores to provide preferential flow in soil (in order to imitate favorable conditions for phosphorus loss). The results showed that because of the high natural alkalinity of the soil, the proportion of Clinoptilolite used, was inadequate (at a level of 2% weight of soil), phosphorus uptake was not significantly increased (at the level of 5%). The amount of Clinoptilolite used, were based on the economic justification of large-scale implementation of the project. However, a higher amounts of Zeolite, is expected to increase the uptake of phosphorus. Justifiability of using high proportions of Zeolite in large scales needs to be further investigated. Furthermore, time management of irrigation in order to maintain a higher average soil moisture as well as reproduction of artificial macro pore, despite their theoretical justifications to increase plant uptake of phosphorus was ineffective. These results can also be attributed to soil disturbances to prepare the pots, and as a result, destruction of soil structure in addition to other conditions such as high crop density per area, which resulted in higher rate of water consumption which prevented deep percolation loss.

6. REFRENCES

❖ Ahmed, O. H., Majid, N., & Muhamad, N. (2010). Use of Zeolite in maize (Zea mays) cultivation on nitrogen, potassium, and phosphorus uptake and use efficiency. International Journal of the Physical Sciences, 5(15), 2393-2401.

❖ Kulprathipanja, S. Ed. (2010). Zeolites in industrial separation and catalysis. Weinheim, Germany: Wiley-Vch.

❖ Misra, A. (2003). Influence of water conditions on growth and mineral nutrient uptake of native plants on calcareous soil (Doctoral dissertation, Lund University).

❖ Pickering, H. W., Menzies, N. W., & Hunter, M. N. (2002). Zeolite/phosphate rock—a novel slow release phosphorus fertiliser for potted plant production. Scientia Horticulturae, 94(3), 333-343.

❖ Ramesh, K., Damodar Reddy, D., Kumar Biswas, A., & Subba Rao, A. (2011). 4 Zeolites and Their Potential Uses in Agriculture. Advances in agronomy, 113-215.

2nd European Sustainable Phosphorus Conference (ESPC2)