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SHORT NOTE [NOTA CORTA]

TWO SOURCES OF ZEOLITE AS SUBSTITUTES OF NITROGEN FERTILIZER FOR WHEAT (*Triticum aestivum*) PRODUCTION IN TLAXCALA, MEXICO

[DOS FUENTES DE ZEOLITA COMO SUBSTITUTOS DEL FERTILIZANTE NITROGENADO PARA PRODUCCIÓN DE TRIGO (*Triticum aestivum*) EN TLAXCALA, MÉXICO]

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SUMMARY

Nitrogen is the main nutrient added to the soil for wheat production, but its application increases production costs. Urea is the most used nitrogen fertilizer (NF) in Mexico, however only 10 to 60 % is absorbed by crops. To improve this efficiency, the use of slow-release fertilizers has been promoted, although their cost is high compared with traditional nitrogen sources. One alternative to increase the efficiency of NF is the use of minerals such as zeolite. One type of zeolite is the “clinoptilolite”, an aluminum-silicate mineral. The objective of the study was to evaluate two sources of clinoptilolite (Chinobampo and Tehuacán). In four locations, six treatments were established: 1) 100 % NF; 2) 20 % zeoilte + 80 % NF; 3) 40 % zeolite + 60 % NF; 4) 60 % zeolite + 40 % NF; 5) 80 % zeolite + 20 % NF; and 6) 100 % zeolite. In treatments 2, 4 and 6 the seeds were mycorrhized before sowing. On average, treatment 3 yielded 2.9 ton ha^{-1}, followed by treatment 2 with 2.6 ton ha^{-1}, which yielded 2.3 and 3.0 ton ha^{-1} with zeolite Chinobampo and Tehuacán, respectively.

Key words: Nitrogen; slow-release fertilizers; clinoptilolite; wheat.

RESUMEN

El nitrógeno es el principal nutriente adicionado al suelo para la producción de trigo, pero su aplicación aumenta los costos de producción. La urea es el fertilizante nitrogenado (FN) más usado en México, pero sólo 10 a 60 % de ésta es absorbida por los cultivos. Para mejorar esta eficiencia se ha fomentado el uso de fertilizantes de liberación lenta, aunque su costo es alto comparado con fuentes tradicionales de nitrógeno. Una alternativa para aumentar la eficiencia de FN es el uso de minerales como la zeolita. Una zeolita es la clinoptilolita, un mineral alumino-silicatado. El objetivo del estudio fue evaluar dos fuentes de clinoptilolita (Chinobampo y Tehuacán). En cuatro localidades se establecieron seis tratamientos: 1) 100 % FN; 2) 20 % zeolita + 80 % FN; 3) 40 % zeolita + 60 % FN; 4) 60 % zeolita + 40 % FN; 5) 80 % zeolita + 20 % FN; y 6) 100 % zeolita. En los tratamientos 2, 4 y 6 se micorrizó la semilla antes de la siembra. En promedio, el tratamiento 3 rindió 2.9 t ha^{-1}, seguido del 2 con 2.6 t ha^{-1}, el cual rindió 2.3 y 3.0 t ha^{-1} con la zeolita Chinobampo y Tehuacán, respectivamente.

Palabras clave: Nitrógeno; fertilizantes de liberación lenta; clinoptilolita; trigo.

INTRODUCTION

In last decades, nitrogen (N) fertilization has been an important tool to improve yield and quality of crops, particularly cereals, and to ensure maximum economic benefits (Giambalvo *et al*., 2010). However, due to its high mobility in the soil-plant-atmosphere system, N contributes significantly to agriculture pollution through its leaching, volatilization and denitrification. It is estimated that 50% or less of N fertilizer (NF) applied to the soil is absorbed by cereal crops, and this percentage decreases as the dose of N is increased. Ammonia (NH_3) losses significantly reduce efficiency of urea N in crop production. This reduced efficiency has generally been associated with surface application of urea, due to ammonia volatilization; thus, it is necessary to generate technologies that help reduce N losses and increase crop uptake. According to Ahmed *et al*. (2009), urea mixed with calcium triple superphosphate and zeolite has the potential to reduce ammonia losses occurring from surface application of urea. Zeolites are aluminosilicates with high cation exchange capacity (CEC), and capable to reduce N losses from ammonium (NH_4^+) fertilizers. Zeolites also improve potassium (K^+) availability.

Research has been conducted to determine the effect of zeolite addition to fertilizers for crop production (Huang and Petrovic, 1994); some results indicate that N efficiency was improved by 63 % in rice, and by 13 to 15 % in wheat, attributing this positive effect to an improvement in N efficiency or to a reduction in ammonium phytotoxicity. According to Lewis *et al.* (1984), ammonium-loaded clinoptilolite acted as a slow-release fertilizer in soils of medium texture, and in coarser texture soils, it decreased N losses due to leaching; these authors also demonstrated that clinoptilolite can reduce NH_3 volatilization when mixed with urea and added in a coarse-texture alkaline soil. Ferguson and Pepper (1987) studied N retention as NH_4 in sand added with clinoptilolite, concluding that it reduced NH_4 losses from the soil, and might increase NF efficiency. Zeolite clinoptilolite is used together with fertilizer, adding 25 % zeolite and 75% fertilizer. A well homogenized mixture of zeolite and fertilizer is achieved by manually mixing for 5 min soil, fertilizer and zeolite (Flores *et al*., 2007).

Crop fertilization is one of the most expensive components of crop production. For example, in the State of Tlaxcala, Mexico, the most common fertilizers used for wheat production are urea, calcium triple superphosphate and diammonium phosphate, accounting for 25 % of the total production cost (AMSDA, 2004). Therefore, the objective of this study was to evaluate the yield response of wheat to the substitution of five levels of NF by two Mexican sources of zeolite (Chinobampo and Tehuacán).

MATERIALS AND METHODS

The study was conducted in four locations in the municipality of Zacatelco, in the Southern area of the State of Tlaxcala, Mexico. In this area wheat is planted mostly during the autumn-winter cycle (October to March), due to availability of irrigation and lower incidence of frosts; the type of soil is sandy loam.

Experimental plots sown was made in October and November 2009, using seed varieties NANA F2008, Altiplano F2008, Rebeca F2000 and Nahuatl F2000, at a seeding rate of 130 kg ha^{-1}. Seeds were sown by broadcasting and covered with soil using a disk harrow. Plot size was 5 x 16.7 m, with six treatments for each of the two types of zeolite (Nerea Chinobampo and Tehuacán). Six treatments were: 1) 100 % NF; 2) 20 % zeolite + 80 % NF; 3) 40% zeolite + 60 % NF; 4) 60 % zeolite + 40 % NF; 5) 80 % zeolite + 20 % NF; and 6) 100 % zeolite. Additionally, seed was inoculated with mycorrhizal fungi before sowing in treatments 2, 4 and 6, to take advantage of the validation plots design of the dose 25 % zeolite + 75% NF with and without mycorrhiza, in comparison with the recommended fertilization and the absolute control, both also with and without mycorrhiza. Fertilization formula used was 40-40-00, with urea as N source and calcium triple superphosphate as P source. In the study area, flooding irrigation is commonly practiced during the fall-winter cycle; however, during this study and due to problems with a dam that supplies water to the municipality, a drought period was present in most of the crop cycle, except in one plot.

Grain yield was evaluated by harvesting one square meter by treatment in each plot; the sample was cut and weighed with stems and ears, and 50 spikes per sample were separated and weighed (Sayre, N / D). Crop yield was calculated using the formula Y = dry biomass * (harvest index / 100). Only results for grain yield are presented. The analysis of variance was made with the SAS 9.0 software, using a split-split plot design, with sites (5) being the large plots, types of zeolite (2) being medium-sized plots, and treatments (6) being subplots.

RESULTS AND DISCUSSION

Table 1 shows the physical-chemical characteristics of the soil in the studied sites. Soil texture was loam and sandy loam, with low content of organic matter (< 1.1 %), moderate content of inorganic N (NO_3 + NH_4), fairly low to medium P content, and low K content. At the Xoxtla site, two varieties of wheat were planted.

Table 2 shows results from the plot at Zopilocalco site. On average, treatment 3 exceeded the control (treatment 1) with the recommended NF dose by 686 kg ha^{-1} of grain. Grain yield with zeolite Tehuacán was

182 kg ha^{-1} higher than with zeolite Chinobampo. Control was the recommended fertilization formula (40-40-00) with both types of zeolite, and the average yield was 2587 kg ha^{-1}; the third column in Table 2 shows the average yield of both types of zeolite.

Table 1. Physical-chemical characteristics of soils in sites studied in Tlaxcala, Mexico. Fall-winter 2009-2010 cycle.

Site	Sand (%)	Clay (%)	Silt (%)	Texture	BD* gcm^{-3}	Organic matter (%)	Inorganic N ppm	P-Bray ppm	K ppm	Na ppm
Cuacualoya	50.2	19.1	30.7	Loam	1.30	1.24	12.6	19.0	96.0	88.6
Zopilocalco	64.2	13.1	22.7	Sandy loam	1.39	1.20	14.1	27.4	85.7	1.2
Xoxtla	52.2	15.1	32.7	Sandy loam	1.34	0.99	19.3	10.4	195	14.6
Las Lamas	66.2	9.1	24.7	Sandy loam	1.39	0.89	13.3	13.5	65.3	83.5

BD = bulk density; N = nitrogen; P = phosphorus; K = potassium; Na = sodium; ppm = parts per million.

Table 2. Wheat grain yield obtained with two types of zeolite (Tehuacán and Chinobampo) at the Zopilocalco site in Zacatelco, Tlaxcala, Mexico.

T	N/O	Average yield kg ha^{-1}	Zeolite Tehuacan kg ha^{-1}	Zeolite Chinobampo kg ha^{-1}
1	2	2587	1748	3427
2	2	2427	2804	2051
3	2	3273	3364	3182
4	2	2000	2634	1367
5	2	2139	2531	1746
6	2	1891	2329	1454

T = treatments; N/O = number of observations. *Average yield for both types of zeolite

Table 3 summarizes results at the four locations and using both types of zeolite. On average, treatment 3 exceeded the control with the recommended fertilization (T 1) by 303 kg ha^{-1}. Figure 1 shows grain yield with the two types of zeolite. The quadratic model shows a positive response to the application of 20 to 40 % zeolite added to the fertilizer. In the other treatments, the response was similar or lower to yield in the control, which used 100 % NF. The coefficient of regression (R^2) for zeolite Tehuacán was 0.71 and 0.50 for Chinobampo.

Grain yield in treatment 3 was 2878 kg ha^{-1}, and in treatment 2 was 2631 kg ha^{-1}, showing that when zeolite was increased from 20 to 40 % of NF, grain yield increased by 247 kg ha^{-1}. This is in agreement with the results obtained in maize by Ahmed *et al.* (2009), who increased zeolite from 12.3 to 17.7 % in treatments with urea + calcium triple superphosphate + zeolite + potassium chloride, obtaining 258 and 289 g plant^{-1} of dry stems and leaves biomass, respectively.

The average yield of zeolite treatments in this study was 2451 kg ha^{-1}, whereas the average yield in the control treatment with no zeolite added (40-40-00) was 2575 kg ha^{-1}.

Table 3. Average wheat grain yield obtained using two types of zeolite, in four localities of the municipality of Zacatelco, in Tlaxcala, Mexico.

Treatment	No. of observations	Yield (kg ha^{-1})
1	10	2575
2	10	2631
3	10	2878
4	10	2383
5	10	2321
6	10	2041

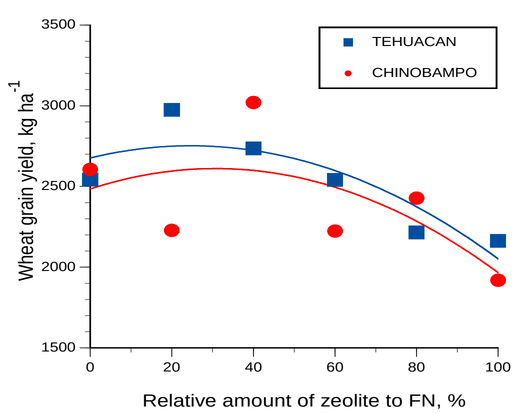

Figure 1. Wheat grain yield response to two types of zeolite (Tehuacan and Chinobampo), substituting 20 to 100 % of the nitrogen fertilizer (FN).

CONCLUSION

The full recommended nitrogen fertilizer (NF) produced greater grain yield than 60, 80 and 100 % of zeolite substituting NF, respectively. However, control had similar grain yield than 20 and 40 % NF. Considering irrigation availability and weather during the fall-winter 2009-2010 cycle in the Southern region of Tlaxcala, Mexico, it is possible to substitute 20 to 40 % of NF with zeolites Chinobampo or Tehuacan, for wheat production.

REFERENCES

Ahmed, O. H., Hussin, A., Ahmad. H, M. H., Jalloh, M. B., Rahim, A. A., Majid, N. M. A. 2009. Enhancing the urea-N use efficiency in maize (*Zea mays*) cultivation on acid soils using urea amended with zeolite and tsp. American Journal of Applied Sciences. 6(5): 829-833.

AMSDA. 2004. Diagnóstico del Sistema Producto-Trigo. Asociación Mexicana de Secretarios de Desarrollo Agropecuario, A.C. Estado de Tlaxcala, México.

Ferguson, G. A., Pepper, I. L. 1987. Ammonium retention in sand amended with clinoptilolite. Soil Science Society of America Journal. 51: 231-234.

Flores, M. A., Galvis, S. A., Hernández, M. T. M., De León, G. F., Payán Z. F. 2007. Efecto de la adición de zeolita (clinoptilolita y mordenita) en un andosol sobre el ambiente químico-edáfico y el crecimiento de avena. Interciencia. 32(10): 692-696.

Giambalvo, D., Ruisi, P., Di Miceli, G., Salvatore, A., Amato, G.. 2010. Nitrogen use efficiency and nitrogen fertilizer recovery of durum wheat genotypes as affected by interspecific competition. American Society of Agronomy. 102(2): 707-715.

Huang, Z. T., Petrovic, A. M. 1994. Clinoptilolite zeolite influence on nitrate leaching and nitrogen use efficiency in simulated sand based golf greens. Journal of Environmental Quality. 23: 1190-1194.

Lewis, M. D., Moore, F. D., Goldsberry, K. L. 1984. Ammonium-exchanged clinoptilolite and granulated clinoptilolite with urea as nitrogen fertilizers. In: Pond, W. G., Mumpton, F. A. (eds.). Zeo-Agriculture: Use of Natural Zeolites in Agriculture and Aquaculture. Weistview Press, Boulder, CO, USA.

Sayre, K.D. (No date). A method to reduce the grain threshing requirement (especially for synthetic wheats), to estimate grain yield and other related factors. CIMMYT, Mexico.

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