Zeolite as a Soil Amendment for Vegetable Production in the Lower Rio Grande Valley[1]

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ABSTRACT

Zeolites are a naturally occurring group of minerals containing a cage-like structure which may promote plant growth by enhancing nutrient availability, soil conditioning, and improving soil moisture holding capacity. Abundant natural deposits are available in some regions of the world which could be mined for use as a soil amendment. This study was conducted to evaluate the effect of additions of a zeolite material to soils in South Texas on vegetable production. The zeolite material was applied at rates up to 4.2 Mg/ha and cabbage and bell peppers were grown. Soil moisture content was not affected by application of the zeolite material, but early cabbage growth was slowed; however, this effect later disappeared. Cabbage yields were not affected, but pepper yields showed a quadratic response to zeolite application rate, primarily as an initial decrease then an increase in fruit size as rate increased. NH_4^+-N may initially be immobilized by zeolite application reducing N availability to the crop. South Texas has excellent growing conditions for vegetables including fertile soils and water for irrigation. The slight effect of zeolite application observed in this study suggests that it's potential benefit might be realized only under poorer conditions where the needs for improvement in nutrient retention and moisture holding capacity are greater. The more ideal the growing environment, the less likely a response to zeolite application is to occur.

RESUMEN

Los zeolitos son un grupo de minerales de origen natural, que contienen estructuras similares a cavidades, y que pueden promover el crecimiento vegetal mediante el mejoramiento de la disponibilidad de nutrientes, el acondicionamiento del suelo, y el mejoramiento de la capacidad de retención de humedad del suelo. Existen abundantes depósitos naturales de zeolitos en algunas regiones del mundo los cuales pueden explotarse para su uso como agentes mejoradores de suelo. Este estudio se realizó para evaluar el efecto sobre la producción vegetal de la adición de material zeolítico a suelos en el sur de Texas. El material zeolítico se aplicó en concentraciones de hasta 4.2 Mg/ha en parcelas donde se cultivaron repollo y chile pimiento. La aplicación del material zeolítico no afectó el contenido de humedad del suelo pero volvió mas lento el crecimiento del repollo durante las fases tempranas; sin embargo, este efecto desapareció más tarde. El rendimiento del repollo no fue afectado, pero el del chile presentó una respuesta cuadrática a la cantidad de zeolito aplicado, primariamente como una disminución inicial en el tamaño del fruto y después en un incremento en el tamaño de la fruta a medida que se incrementaron las dosis. El NH_4^+-N probablemente sea inmovilizado inicialmente por la aplicación de zeolito reduciendo así la disponibilidad de N para el cultivo. El Sur de Texas presenta excelente condiciones para el crecimiento de hortalizas incluyendo suelos fértiles y agua para riego. El ligero efecto de la aplicación de zeolito observada en este estudio sugiere que su aplicación puede tener un beneficio potencial solo bajo condiciones mas pobres donde las necesidades para el mejoramiento de la retención de nutrientes y de humedad son mayores. A medida que un medio ambiente es mas ideal para el cultivo de vegetales, es menos probable que se presente una respuesta a la adición de zeolito.

Additional index words: cabbage, bell peppers, soil water content, yield

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[2]Mention of a trade name does not constitute an endorsement by the Texas Agricultural Experiment Station to the exclusion of other materials that may also be suitable.

Zeolites are a naturally occurring group of minerals consisting of cage-like polyhedral units with a high cation exchange capacity and internal pores in crystal latices that result in high water adsorption and nutrient retention (Zelazny and Calhoun, 1977). Zeolites have many industrial uses such as municipal water purification; and have been tested for use as a soil amendment on

Table 1. Chemical and mineral properties of the Agriboost[z] zeolite material used.

Chemical analysis (oxide form)		Mineral composition	
Non exchangeable	%		%
SiO_2	42	Phillipsite	20
Al_2O_3	14	Chabazite	2
Fe_2O_3	9	Altered basaltic glass (palagonite)	58
MgO	6	Calcite	5
CaO	6	Olivine and altered olivine	5
Na_2O	1.9	Gypsum	1
K_2O	1.9	Water	8
P_2O_5	0.5		
MnO	0.1		
SO_3	1.0		
H_2O	9		
exchangeable bases			
K_2O	1.3		
MgO	4.8		
CaO	4.5		
P_2O_5	0.2		

[z]"AgriBoost", ASI Europe GmbH, Wendelsweg 34, D-60599 Frankfurt.

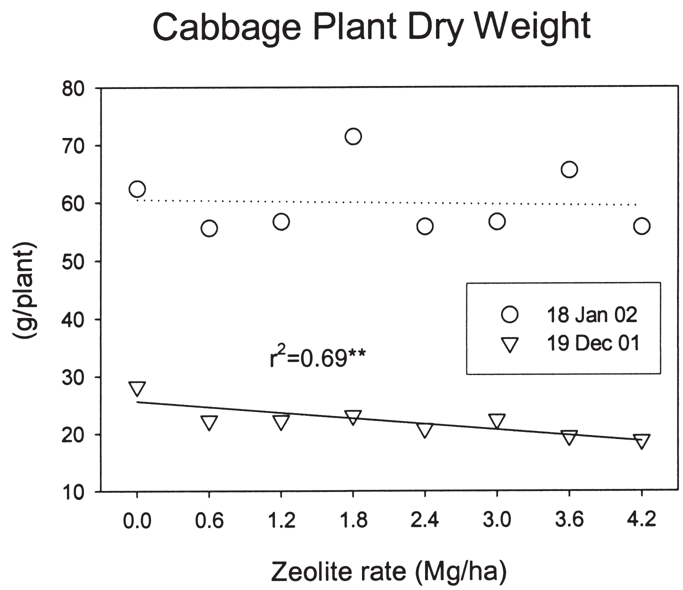

Fig. 1. Cabbage dry weight on two sampling dates as affected by zeolite application rate. Dry weight showed a statistically significant linear decline with increasing zeolite application rate on 19 Dec 02, but no significant response was observed on 18 Jan 03. Each point is the mean of 18 samples.

various crops including vegetables and in greenhouses in Russia, field crops in Japan, as constituents of golf course greens and tees in order to improve drainage and aeration, improve compaction resistance, and reduce leaching of pesticides and fertilizers from the soil (Wallace, 1998). Several reports have suggested that increased N use efficiency occurs on zeolite amended soils (Ferguson et al. 1986; Ferguson and Pepper, 1987; MacKown and Tucker, 1985). Other possible uses being investigated include applications as a carrier of slow-release fertilizers, insecticides, fungicides and herbicides, and as a trap for heavy metals in soils (Ming and Dixon, 1986). Zeolite deposits occur naturally in many areas globally including South Texas (Ming and Dixon, 1986). The availability of high quality deposits justify mining and make zeolites attractive as a potential soil and potting mix amendment.

The objective of this study was to evaluate the effect of a zeolite material as a soil amendment on cabbage and pepper production in the Lower Rio Grande Valley of Texas.

MATERIALS AND METHODS

Two field studies were conducted at the Texas A&M Research & Extension Center at Weslaco, an area with a subtropical, semiarid climate, on a Hidalgo sandy clay loam soil (Fine-loamy, mixed, hyperthermic Typic Calciustolls). The first study was conducted using cabbage (*Brassica oleracea* cv. Capitata) in the fall of 2001 and the second study was conducted using bell peppers (*Capsicum annuum*) in the spring of 2002.

Treatments consisted of variable application rates of AgriBoost[z] (ASI, Frankfurt, Germany) a zeolite material with a CEC of 100-150 meq/100 g (Table 1). The application rates were 0, 0.6, 1.2, 1.8, 2.4, 3.0, 3.6, or 4.2 Mg/ha. Treatments were applied in plots 9.1 m in length by 6.1 m wide (6 rows), and were replicated 6 times in randomized block designs. The zeolite was broadcast applied to the top of the bed and incorporated to a depth of 5 cm immediately prior to planting.

Both crops were direct-seeded in double rows on 1.02 m (40 in.) raised beds, with subsurface drip tubing installed at 15 cm depth in the center of each bed. Cabbage (cv. Blue Vantage) was seeded on 4 Oct 2001 and bell peppers (cv. Lucky Green Giant) on 14 Feb 2002. Herbicide bensulide (Prefar 4-E, Gowan) was applied preplant and incorporated, and again at pre-emergence. The crops were irrigated as needed based on visual observation using subsurface drip irrigation. Additional weed control consisted of hand hoeing as needed.

Table 2. Soil fertility status prior to treatment application in each field study.

pH	NO_3^--N	P	K	Ca	Mg	salinity	Na	S
	mg • kg^{-1}							
				Fall 2001 Cabbage				
8.2	31 M	120 VH	447 VH	8,030 VH	378 H	465 N	324 L	52 H
				Spring 2002 Peppers				
7.9	38 VH	121 VH	591 VH	11,501 VH	486 H	489 N	357 L	54 H

VH - very high, H - high, M - medium, L - low, N - none.

Table 3. Soil water content at 20 cm depth for the different rates of zeolite applied in the cabbage study on various sampling dates, and averaged across sampling dates.

	Date						
Zeolite rate	15 Jan	8 Feb	25 Feb	4 Mar	11 Mar	18 Mar	Avg
Mg/ha				%			
0	11.4[z]	15.6	11.9	10.2	9.0	8.1	11.0
0.6	12.4	15.3	10.6	10.8	10.1	8.0	11.2
1.2	10.3	15.4	10.2	11.9	9.8	8.0	10.9
1.8	10.2	13.8	10.3	12.1	9.6	8.7	10.8
2.4	10.4	14.6	11.1	11.0	9.6	8.1	10.8
3.0	11.3	14.5	11.8	10.7	8.8	7.9	10.8
3.6	10.7	16.2	10.5	11.1	9.3	7.7	10.9
4.2	11.4	15.7	11.2	11.6	10.5	8.3	11.5
Avg	11.0	15.1	11.0	11.2	9.6	8.1	11.0

[z]No statistically significant differences were found in soil water content due to zeolite application on any sampling date, or when averaged across sampling dates.

Soil subsamples were taken prior to treatment application from throughout both study sites to a depth of 15 cm, and were pooled by block. These samples were analyzed for routine fertility status by the Texas Cooperative Extension Soil, Water and Forage Testing Laboratory in College Station. Soil water levels were monitored periodically to a depth of approximately 20 cm in the cabbage study using time-domain reflectometry (TDR 300, Spectrum Technologies, Inc.). Three readings were taken in each plot and averaged on each sampling date. Plant biomass was determined in the cabbage study on 2 dates by taking 3 plants in each plot, drying at 70º C and weighing. Yields were determined for both crops by harvesting mature cabbage or bell peppers from the middle 2 rows in each plot on several dates, counting and weighing. Total fresh weight, average size and earliness were calculated. Data were analyzed statistically using the GLM procedure of the PC SAS system (Release 8.02).

RESULTS

Preplant soil sampling at both sites indicated moderately alkaline pH, medium to very high residual NO_3^--N levels, high or very high levels of other nutrients, and no salinity hazard (Table 2). These conditions are fairly typical for alluvial soils throughout the Lower Rio Grande Valley of Texas.

In the cabbage study, few effects due to zeolite application were observed. Soil water contents measured six times between Jan and Mar were between 9% and 15%, with the highest moisture occurring in Feb and the lowest at harvest. Soil water content was not affected by zeolite application rate on any date (Table 3). While rainfall was low, adequate irrigation was applied for this crop (Table 4), therefore water was never limiting. Cabbage plant dry weights showed a slight but significant linear decline with increasing zeolite application rate on 19 Dec 01, but showed no effect to zeolite application on 18 Jan 02 (Fig. 1). Cabbage total yield, average size and earliness (% in the first picking) were not affected by zeolite application (Fig. 2).

Bell pepper yields showed a slight but significant quadratic decline in yield, reflecting a decrease in size rather than fruit number, to increasing rate of zeolite application (Fig. 3). Fruit size declined up to 2.4 Mg/ha zeolite application, then increased with increasing zeolite application thereafter.

DISCUSSION

Ferguson and Pepper (1987) suggested that the effects of zeolite on N uptake and plant growth would vary with soil type, and that maximum benefit would be expected on course-textured low cation exchange capacity soils. The soils used for vegetable production in the Lower Rio Grande Valley are fertile loams and clay loams having excellent physical properties including CEC and water holding capacity. The potential benefits offered by zeolite amendment including improved nutrient retention, availability, and improved water holding capacity in South Texas are therefore probably slight.

Where zeolite application affected crop growth in this study, responses were generally negative. MacKown and Tucker (1985) found that zeolite applications decrease nitrification and leaching losses. Pierla et al. (1984) found that in the field the zeolite clinoptilolite reduced corn yields, while in the greenhouse this material appeared to act as a slow release fertilizer increasing the growth of radish after three successive

Table 4. Monthly rainfall and irrigation received by the cabbage and bell pepper crops.

	Cabbage		Bell Peppers	
Month	Rainfall	Irrigation	Rainfall	Irrigation
		mm		
Oct	6	174		
Nov	57	51		
Dec	17	0		
Jan	2	80		
Feb	9	64	5	158
Mar	1	0	8	74
Apr			7	51
May			59	24
Jun			6	47
TOTAL	92	369	85	354

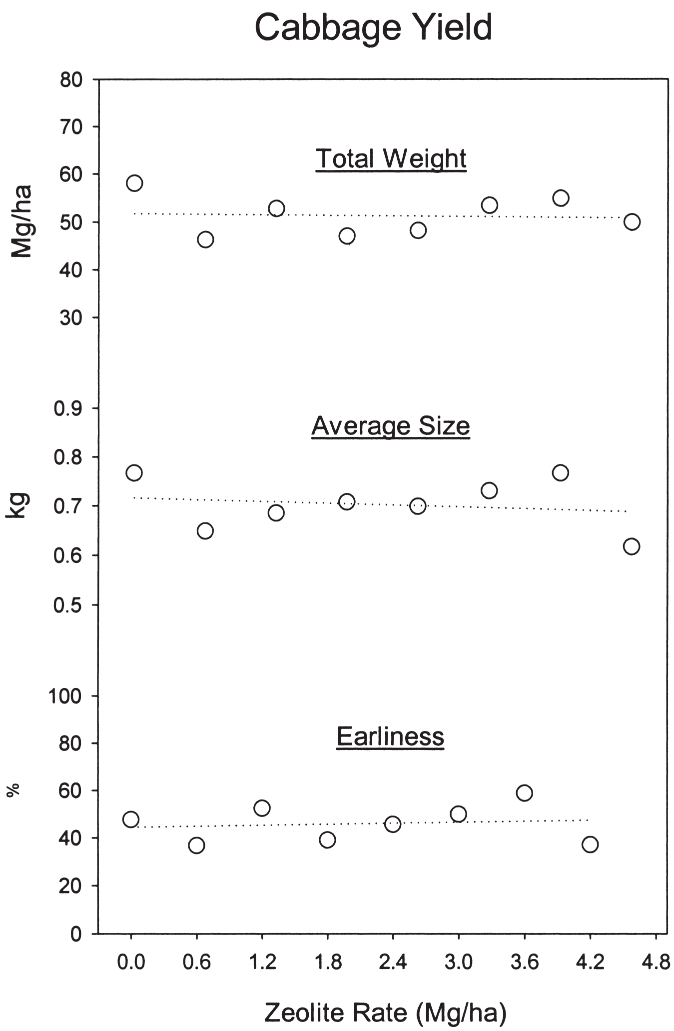

Fig. 2. Cabbage yield, size and earliness as affected by zeolite application rate. No statistically significant responses to zeolite application were found.

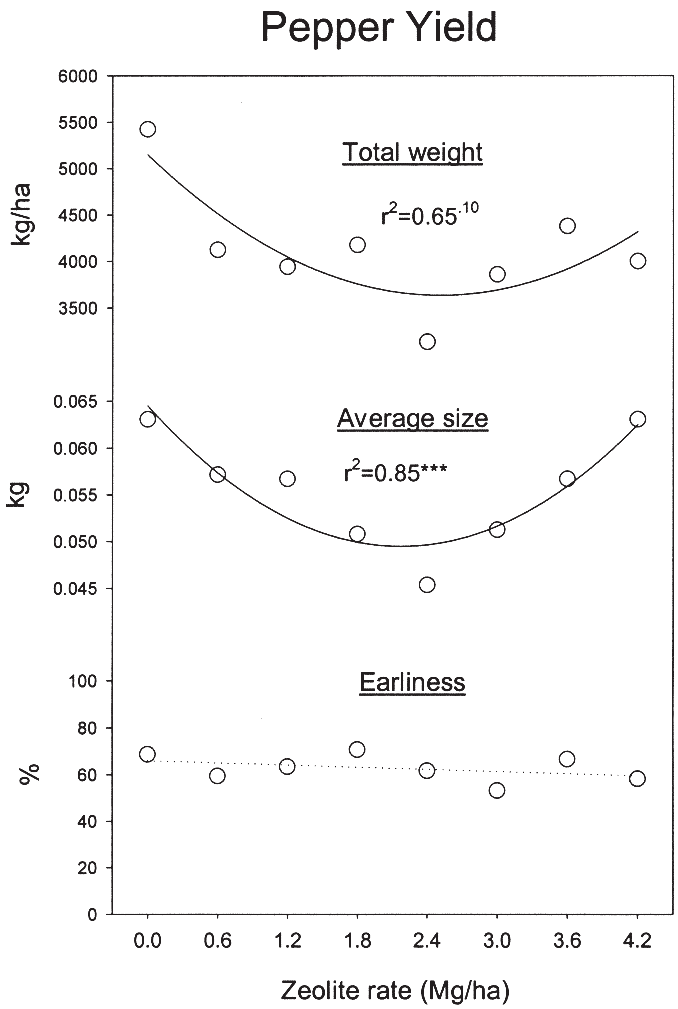

Fig. 3. Pepper yield, size and earliness as affected by zeolite application rate. Total weight and average size showed statistically significant quadratic responses to increasing zeolite application, but no significant response was observed on earliness.

harvests. The results suggests that zeolite may initially immobilize NH_4^+-N in the soil when it is applied, reducing N availability to the crop and resulting in the negative effects on growth.

The conclusion to be drawn from this study is that perhaps beneficial effects of zeolite soil amendment could be expected only on poorer soils such as those low in cation exchange capacity or high in sand where the need for improvement in nutrient retention and moisture holding capacity are greater. The better the edaphic conditions, the less likely a positive response to zeolite application is to occur.

LITERATURE CITED

Ferguson, G.A., I.L. Pepper and W.R. Kneebone. 1986. Growth of creeping bentgrass on a new medium for turfgrass growth: clinoptilolite zeolite-amended sand. Agron. J. 78:1095-1098.

Ferguson, G.A. and I.L. Pepper. 1987. Ammonium retention in sand amended with clinoptilolite. Soil Sci. Soc. Am. J. 51:231-234.

MacKown, C.T. and T.C. Tucker. 1985. Ammonium nitrogen movement in a course- textured soil amended with zeolite. Soil Sci. Soc. Am. J.49:235-238.

Ming, D.W. and J.B. Dixon. 1986. Clinoptilolite in South Texas soils. Soil Sci. Soc. Am. J. 50:1618-1622.

Pierla, H.J., D.G. Westfall and K.A. Barbarick. 1984. Use of clinoptilolite in combination with nitrogen fertilization to increase plant growth. *In* W.G. Pond and F.A. Mumpton (ed.) Zeo-agriculture: Uses of natural zeolites in agriculture and aquaculture. Westview Press, Boulder, CO.

Wallace, A. 1998. Some living plants and some additional products useful as soil conditioners and in various technologies. V. Zeolites and related substances. p. 477-479. *In* A. Wallace and R.E. Terry (ed.) Handbook of Soil Conditioners. Marcel Dekker, Inc. New York.

Zelazny, L.W. and F.G. Calhoun. 1977. Palygorskite (attapulgite), sepiolite, talc, pyrophyllite, and zeolites. p. 435-470. *In* J.B. Dixon and S.B. Weed (ed.) Minerals in Soil Environments. SSSA, Madison, WI.