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COMPARISON OF ZEOLITE (CLINOPTILOLITE) WITH DIATOMITE AND PUMICE AS SOIL CONDITIONERS IN AGRICULTURAL SOILS

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In this study, natural origin diatomite and pumice were compared with zeolite (clinoptilolite) as soil conditioners in agricultural soils in terms of the effects on various physical properties of soil. It is found in this study that diatomite, pumice and zeolite have same and/or more efficient on different physical properties of soils investigated. The field capacity increased between 5.6% and 21.10% for zeolite, between 2.2% and 16.86% for diatomite and between 2.2% and 30.10% for pumice in all soil types. Among the soil type, the highest increase in field capacity was measured in N7 soil with with a medium-coarse textured. The wilting point was affected by all applications and the highest increase was measured in zeolite applications according to diatomite and pumice applications. The standard variations were not observed for bulk density, particle density, porosity and hydraulic conductivity.N5 soil, the silty clay loam soil class reduces the bulk density more effectively than zeolite and pumice. Diatomite and pumice have the same efficient as zeolite on improving field capacity, wilting point, and bulk density; and reducing porosity and hydraulic conductivity of medium-fine textured soil N3. To reduce the hydraulic conductivity of N7 soil from sandy loam soil, zeolite and pumice were determined to be used as soil conditioners. Therefore, it was determined that diatomite and pumice can be used in organic farming in the same manner as zeolite (clinoptilolite).
Keywords: Clinoptilolite, organic farming, soil structure, soil properties

INTRODUCTION

An increasing world population causes a decrease in agricultural areas. Using more chemicals to achieve more products from declining agricultural areas causes soil pollution and destroys the natural balance. To eliminate these adverse effects, rather than reducing the chemicals used in agriculture, the use of natural resources with the same functions has become widespread in recent years.

The initial objective for organic farming's the addition of organic compounds to protect the viability and efficiency of the soil and to ensure that nature maintains the continuity of vital activities without synthetic additives. For this purpose, to regulate the soil structure, clinoptilolite (zeolite), slag, perlite, and vermiculite can be used (Karacalar, 2008).

Due to the structural characteristics of the soils, some physical and chemical problems may occur. The rates of scarcity and abundance of clay and sand contained in the soil may lead to problems. To resolve the problems due to the physical properties of soils, various soil conditioners are used.

Mumpton (1983) and Gote and Nimaki (1980) observed that the addition of zeolite to soil improves the water regime and prevents plant nutrients from being cleaned. Cangir *et al*. (2003) reported that there is a formation of multi-part fracture in earths as a result of 3% stable manure, 6% sand, 3% histosol, 9% zeolite and 3% zeolite + 3% stable manure treatment on earths having shell formation (silty clay loam, smectitic, superactive, no acidic, thermic, Typic or Lithic Xerorthent) and fracture (clayey, smectitic, superactive, very few calcareous, thermic, Chromic Haploxerert). Noland *et al*. (1992) reported that the most important characteristic of pumice for the improvement of soil is its physicochemical properties. Songi (1999) highlighted the importance of pumice for cultivation, also claiming that provides a suitable environment due to its water retention capacity and porosity in greenhouse experiments. Verdonck (1984) reported that fine-grained pumice cannot be used in agriculture; however, it can be used to increase water retention capacity low water retention materials, such as glass debris. Additionally, it was reported that medium-coarse pumice is optimal for agriculture and also it increase aeration. The results of a pot experiment by Marumoto and Shindo (1993) revealed that 0.1 tha^{-1} diatomite increased the water retention ratio and permeability of soil on rice paddies. Deying *et al*. (1999) reported a 13% water retention ratio for compressed and uncompressed samples of calcitic diatomite earth (CDE) applications. Aksakal *et al*. (2011) applied diatomite earth (DE) to sandy loam soil and revealed an increase in field capacity for 30% diatomite application. According to the results of the studies, diatomite can be used to improve the physical properties of soil. For this reason, this study compares the effect of zeolite (clinoptilolite) used in agricultural soils and pumice and diatomite soil in nature as soil conditioner on various physical properties of soils.

MATERIAL AND METHODS

In a randomized, complete block design pot experiment, zeolite (0, 1.25, 2.5 and 5%), diatomite (0, 0.5, 1 and 2%), and pumice (0, 5, 10 and 20%) were added to 2.1 kg pots, including the control, on the basis of four different dose volumes, and the study was carried out in two replications. Zeolite, with particle sizes smaller than 1 mm, and diatomite, in powder form, were applied. Pumice, with a particle size of 0-4 mm, was applied to pots.

Soil samples were taken from a depth of 0-20 cm and sieved using 4 mm sieve and placed into pots. For analysis, 2 mm sieve was used. Particle size distribution (texture) was determined by the hydrometer method (Bouyoucous, 1951). To label texture classes, a texture triangle was used (Anonymous, 1993). Lime was determined by the volumetric calcimeter method (Saglam, 2008). A pH meter was used to measure pH saturation in mud (Kacar, 1995). Volume weight was estimated using the method of Black (1965). Specific gravity (particle density) was achieved using degraded soil samples with the pycnometer method (Black, 1965). Porosity was found using the method of Cangir (1991). Salt percentage (%) was estimated using the value given by conductometer depending on the electrical conductivity of saturation mud (Kacar, 1995). Hydraulic conductivity was determined using degraded soil samples via the method given by Tuzuner (1990). Organic matter content (%) was determined via Modified Walkley Black Wet Combustion Method (Kacar, 1995). Field capacity and wilting point analysis was performed according to the methods given by Tüzüner, 1990. Analyses of variance was performed according to Düzgüneş (1963) and Yurtsever (1984) at splitted experiment pattern modified as randomized complete blocks for result obtained at the end of the experiment and for significant differences, groups were specified. SPSS 16.0 package program was used variance for analysis of data collected at the experiment.

RESULTS AND DISCUSSION

The physical and chemical properties of the soil used in this study and the plant nutrient contents are given in Table 1. According the chemical properties of the soils examined: N3 and N7 are neutral soils; N1, N2, N4, N5, and N6 are slightly alkaline soils; and N8 soil is a slightly acidic soil. A salinity problem was not observed. N1, N2, N3, N6, N7, and N8 soils were less calcareous; N4 and N5 were included in the medium-lime category. Organic matter content was low, with the exception of N7 (very little). The effects of zeolite, diatomite, and pumice conditioners on various physical properties of soils in 8 different particle size distributions were evaluated according to variance analysis, and the Duncan test and statistical results are given in Table 2.

Soils used in this study were classified as follows: thin (heavy) textured for N1, N2, N4 and N6; medium-thin textured for N3 and N5; and medium coarse (light) textured for N7 and N8 (Cangir, 1991).

The field capacity increased between 5.6% and 21.10% for zeolite, between 2.2% and 16.86% for diatomite and between 2.2% and 30.10% for pumice in all soil types. But, there are no statistical results for the effect of conditioners on the field capacity of all soils, with the exception of N8, as a result of the use of zeolite, diatomite, and pumice (Table 2). The major contributor to the field capacity of soil N8 is pumice and diatomite also was found to increase the field capacity as

Table 1. General physical and chemical properties of the soils.

Properties	N1	N2	N3	N4	N5	N6	N7	N8
SFC	41.01	41.63	23.06	26.73	27.25	33.92	10.56	27.11
WP	22.65	25.70	13.44	14.82	15.43	21.07	5.33	15.21
PD	269.00	263.00	265.00	270.00	268.00	269.00	262.00	258.00
BD	1.37	1.49	1.19	1.38	1.47	1.54	1.50	1.27
P	49.07	43.35	55.09	48.89	45.15	42.75	42.75	50.78
HC	0.41	1.75	18.50	1.23	0.98	0.82	5.31	5.88
Sand (%)	17.93	40.94	67.05	18.55	19.41	8.43	77.50	64.64
Silt (%)	20.21	12.75	8.20	31.85	41.72	40.20	6.10	16.57
Clay (%)	61.86	46.31	24.75	49.60	38.87	51.37	16.40	18.79
Texture Class	Clay	Clay	Sandy clay loam	Clay	Silty clay loam	Silty clay	Sandy loam	Sandy loam
pH*	7.93	7.55	6.53	7.77	7.70	7.53	7.27	6.40
Salt (%)	0.09	0.07	0.04	0.06	0.07	0.07	0.05	0.06
$CaCO_3$ (%)	2.58	0.97	0.04	4.99	4.51	0.81	2.01	0.04
OM (%)	1.45	1.28	1.25	1.20	1.03	1.57	0.97	1.85

*Determined in saturation extract; SFC: Soil Field Capacity; WP: Wilting Point; BD: Bulk Density; PD: Particle Density; P: Porosity; HC: Hydraulic Conductivity; OM: Organic matter

Table 2. Different doses of zeolite, diatomaceous earth and pumice were applied to soil conditioners the results of the Duncan test analysis of some physical soil.

NoS	NoSC	SFC (%)	WP (%)	BD (g cm^{-3})	PD (g cm^{-3})	P (%)	HC (cm h^{-1})
N1	Zeolite	43.31	26.72	1.45b	2.69	46.04b	0.95ab
	DE	41.95	26.35	1.39a	2.73	48.92a	0.44b
	Pumice	42.80	25.79	1.35a	2.63	48.63ab	1.88a
	Sig.	0.272	0.739	0.002	0.118	0.066	0.047
	S. Error	0.584	0.847	0.017	0.032	0.894	0.356
N2	Zeolite	44.31	28.13	1.43	2.64b	46.05	1.60
	DE	43.65	28.16	1.41	2.64b	46.61	1.63
	Pumice	42.55	27.34	1.39	2.61a	46.75	1.66
	Sig.	0.313	0.577	0.753	0.005	0.923	0.953
	S. Error	0.803	0.619	0.035	0.008	1.305	0.146
N3	Zeolite	26.81	16.21	1.31	2.61	49.68	7.58
	DE	26.20	15.58	1.35	2.65	48.76	7.89
	Pumice	26.30	14.95	1.28	2.59	50.66	8.61
	Sig.	0.862	0.280	0.257	0.224	0.627	0.953
	S. Error	0.840	0.539	0.033	0.024	1.374	2.423
N4	Zeolite	30.46	16.77a	1.45	2.62	44.75	1.37
	DE	30.19	16.16ab	1.48	2.61	43.31	1.88
	Pumice	31.24	15.57b	1.41	2.59	45.58	2.21
	Sig.	0.703	0.065	0.183	0.780	0.551	0.134
	S. Error	0.911	0.341	0.025	0.034	1.464	0.282
N5	Zeolite	29.98	16.90a	1.44ab	2.67b	46.26	1.19
	DE	29.88	16.70a	1.47b	2.68b	45.24	1.13
	Pumice	30.51	15.82b	1.40a	2.63a	46.66	1.33
	Sig.	0.784	0.030	0.063	0.003	0.196	0.640
	S. Error	0.676	0.281	0.018	0.010	0.552	0.156
N6	Zeolite	36.34	21.65a	1.47ab	2.57	42.67	0.94b
	DE	36.02	21.28a	1.50b	2.66	43.58	0.47b
	Pumice	37.02	20.59b	1.42a	2.58	44.84	2.90a
	Sig.	0.542	0.000	0.097	0.331	0.498	0.000
	S. Error	0.644	0.141	0.026	0.047	1.283	0.315
N7	Zeolite	12.88	5.95	1.51	2.63b	42.59	4.08a
	DE	12.34	5.73	1.52	2.64b	42.57	5.95b
	Pumice	13.83	6.10	1.47	2.60a	43.48	3.65a
	Sig.	0.375	0.512	0.154	0.015	0.510	0.006
	S. Error	0.745	0.223	0.018	0.010	0.621	0.476
N8	Zeolite	28.70b	18.61	1.29b	2.60	50.31	4.17
	DE	30.01ab	18.08	1.35a	2.59	47.91	4.77
	Pumice	31.46a	18.43	1.30ab	2.61	50.21	3.47
	Sig.	0.061	0.895	0.073	0.897	0.089	0.174
	S. Error	0.769	0.799	0.018	0.031	0.822	0.471

NoS: Name of Soil; NoSC: Name of Soil Conditioner; SFC: Soil Field Capacity; WP: Wilting Point; BD: Bulk Density; PD: Particle Density; P: Porosity; HC: Hydraulic Conductivity; DE: Diatomaceous Earth

compared to zeolite did. (Fig. 1). According to Dundar (2009) and Aksakal *et al*. (2011), pumice and diatomite increased field capacity, respectively.

Zeolite, diatomite, and pumice statistically have the same effect on field capacity, wilting point, bulk density; particle density, porosity and hydraulic conductivity of N3 soil one of the medium thin textured soils, investigated statistically. To increase the field capacity, wilting point and bulk density and to decrease porosity and hydraulic conductivity, zeolite, diatomite and/or pumice can be used.

According to the evaluation of the effects of conditioners on the values of wilting point of soils, effect of conditioners applied on N4, N5, and N6 soils was found to be significantly significant ($p < 0.01$). It was found that zeolite is the most effective to increase the wilting point of N4 soil. Zeolite and diatomite was found to be the most effective at increasing the wilting point of N5 and N6 soils (Fig. 2).

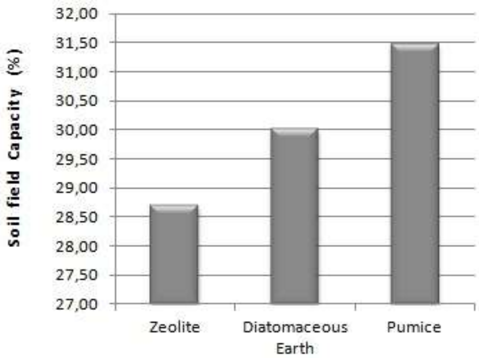

Figure 1. The effect of conditioners on the field capacity of N8 soil.

Although, no change in particle density of soils was expected due to the general characteristics of the soil, it was determined that pumice is the most effective conditioner for decreasing the particle intensities of N2, N5, and N7 soil, according to the statistical analysis ($p < 0.01$) (Fig. 3). This can be explained by the increase in the solid volume portion of the soil pumice applied.

Bulk density is half of the average particle density of soil if half of the total volume consists of pore sand is in between 1.30 - 1.35 g cm^{-3}. This value can increase up to as much as 1.6 g cm^{-3} for sandy soils, whereas aggregated loam and clay soils can reach a value of 1.1 g cm^{-3}. Bulk density can be affected by loose structure and compaction, and swelling and shrinkage can also have an impact, depending on moisture (Aydin and Kilic, 2010).

The effect of conditioners on the bulk densities of N1, N5, N6, and N8 soils was found statistically significant ($p < 0.01$, $p < 0.05$) (Table 2). It was determined that diatomite and pumice were the most effective for decreasing the bulk density of N1 soil. Pumice was found to be the most effective for decreasing the bulk densities of N5 and N6 soils, as well as zeolite. Sahin *et al*. (2001) reported that the application of pumice reduced bulk density. It was also determined that diatomite was the most effective conditioner for increasing the bulk density of N8 soil, with pumice being the second most effective (Fig. 4). Despite of the fact that diatomite has an effect on the bulk density of N8 soil, which a sandy loam soil, Deying *et al*. (1999) reported that the application of calcite diatomite earth (CDE) on sandy loam soil decreased the bulk density.

Porosity or total porosity volume is an important characteristic of soil. Porosity provides information about the total porosity volume per unit volume, whereas it provides no information regarding the distribution of micro and macro pores (Aydin and Kilic, 2010).

The effect of the application of zeolite, diatomite, and pumice on N1 soil was found to be statistically significant ($p < 0.01$). The major contributor to N1 soil porosity was diatomite, followed by pumice (Fig. 5). Gur *et al*. (1997) reported that pumice application increased porosity. The porosity of seven other soils (N2, N3, N4, N5, N6 and N8) was affected by zeolite, diatomite, and pumice in the same amount.

The effect of conditioner applied to N1, N6, and N7 soil son hydraulic conductivity properties of these were found to be statistically significant. It was determined that the medium-slow and medium permeable grade with the addition of pumice, respectively. It was determined that zeolite and pumice were found to decrease the permeability grade of N7

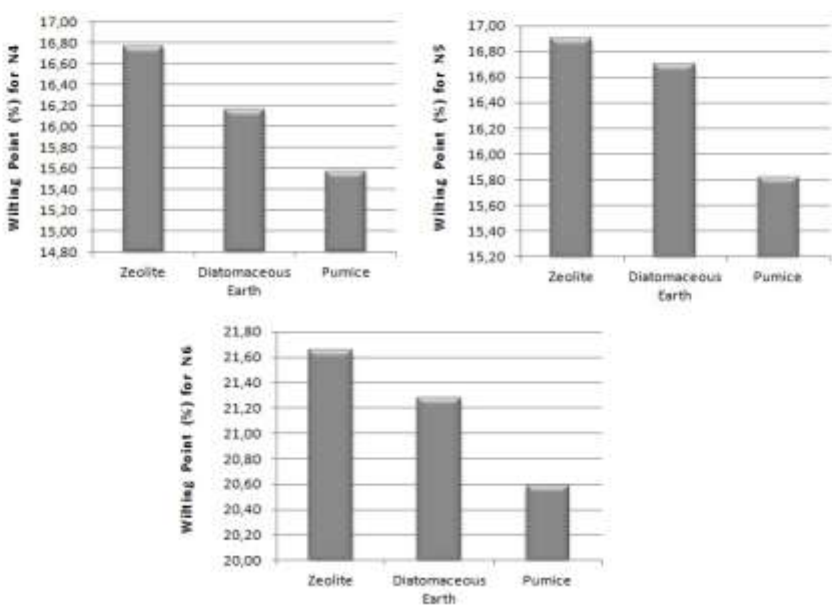

Figure 2. Effect of soil conditioners on the wilting point of N4, N5, and N6 soil.

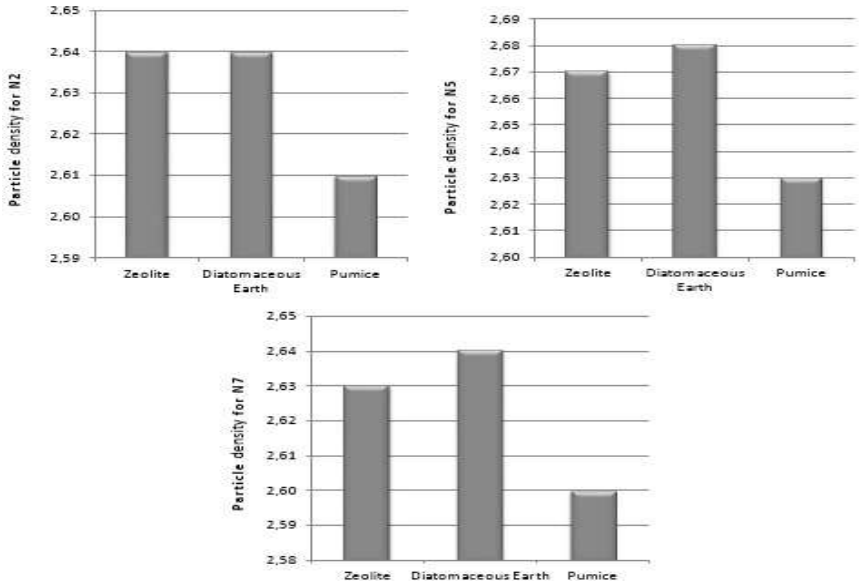

Figure 3. Effect of soil conditioners on the particle density of N2, N5, and N7 soil.

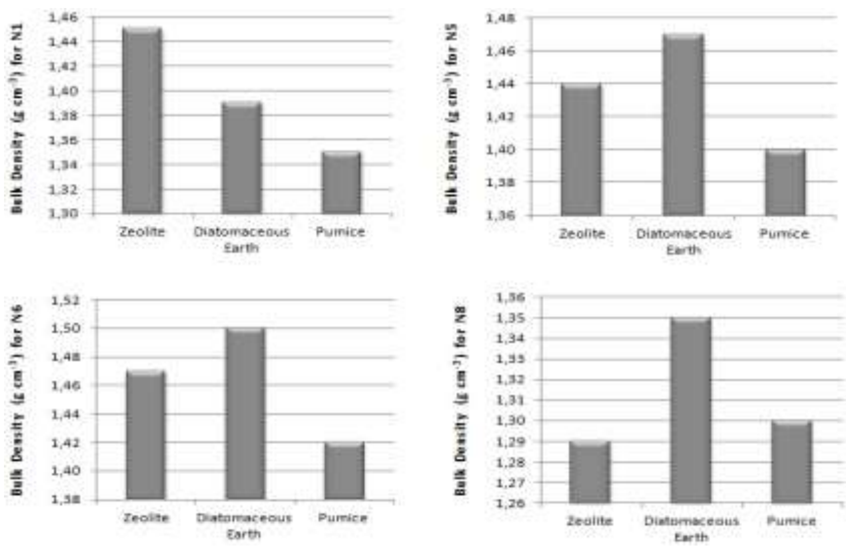

Figure 4. Effect of soil conditioners on the bulk density of N1, N5, N6, and N8 soil.

permeability grade of N1 and N6 from thin soils increased to soil to middle class (Fig. 6). It is understood that the effects of zeolite, pumice, and diatomite had the same effect on the hydraulic conductivity of other soils (N2, N3, N4, N5, and N8).

Soil conditioners diatomite and pumice were compared with zeolite (clinoptilolite) which is used in organic farming and found that diatomite, pumice and zeolite have the same and/or more efficacy on different properties of all soil investigated in this study. Therefore, it was determined that diatomite and pumice can be used in organic farming in the same manner as zeolite (clinoptilolite).

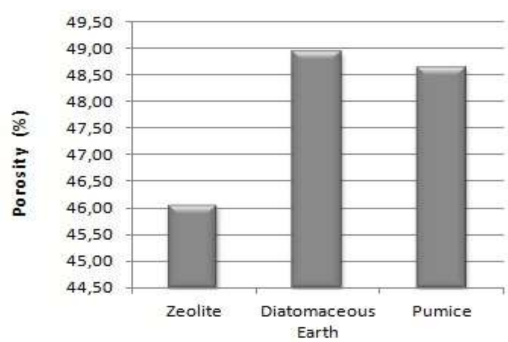

Figure 5. Effect of soil conditioners on the porosity of N1 soil.

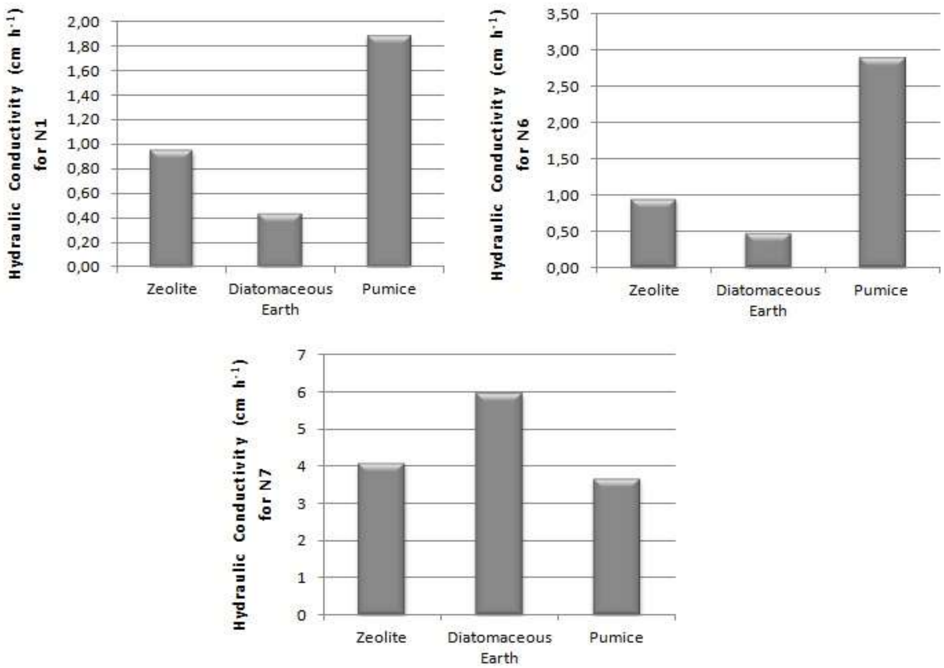

Figure 6. Effect of soil conditioners on the hydraulic conductivity of N1, N6, and N7 soil.

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