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The application effects of natural zeolite on soil runoff, soil drainage and some chemical soil properties in arid land area

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ABSTRACT: In many arid and semi-arid regions of the world, water deficiency is becoming a major limitation for sustainable regional development. Applying zeolite to the soil can improve its ability to hold nutrients and water. The main aim of this study was to investigate the humidity and ions uptake by natural zeolite when used as an ingredient during the irrigation with rainfall. A rainfall simulator was used to evaluate the impact of natural zeolite on soil properties and soil infiltration rate. The studied parameters were three level of zeolite application (0%, 10% and 20% of zeolite) and two level of rainfall intensity (10 and 15 mm/h). Runoff and soil sample were analyzed for total EC (Electrical conductivity), soil water content, and ions concentration in two soil columns one treated with zeolite, other one untreated soil columns. The results show that infiltration rate and soil water content significantly increased in soil treated with zeolite, compared with the untreated soil. A significant decrease in runoff volume, drained water volume and sediment amount was observed after application of zeolite ($P<0.01$). The amounts of Ca, Na, and K were increased significantly in the soil treated with zeolite compared to no treated soil ($P<0.01$). No significant differences were observed between treated and control soils for pH ($P<0.05$).

KEYWORDS: Natural zeolite, Infiltration rate, Soil Properties, Runoff, Erosion control.

1 INTRODUCTION

The water consumption in the arid and semi-arid areas of the world has increased, due to increasing per capita water use, population growth, and irrigation. In these areas, the most part of water resources, originated from rainfall, are consumed by agriculture [1] [2]. Low quantity and the uneven distribution of rainfall in such area lead to unstable production of agriculture because of lack of water supply. The low soil water infiltration and the high intensity of rainstorm usually produce large amount of surface runoff, leading to severe soil erosion and nutrient loss, and consequently, leading to land degradation [3] [4]. High potential evapotranspiration from surface and sub- surface soil in arid and semiarid regions is also a principal mechanism for water loss.

Increase infiltration component, rise the ability of the soil to store water for plant use, and decrease soil evaporation could reduce the need for supplemental watering, decrease runoff and growth the sustainability of the plants [5] [6].

In the recent years, an increasing interest for using of natural aluminosilicates such as zeolite in the agricultural activity has been observed [7]. Applying zeolite to the soil could increase infiltration rate and improve its ability to hold nutrients and water [6].

Zeolite is a naturally volcanogenic sedimentary mineral composed primarily of aluminosilicates. The mineral has a three-dimensional crystal lattice, with loosely bound cations, capable of hydrating and dehydrating without altering the crystal structure [8].This provides a natural material with the ability to exchange ions, absorb gases and vapors, act as molecular-scale sieves [6] [9] and catalyze reactions owing to fixed pore sizes and active sites in the crystal lattice [10].

Made of a special crystalline structure that is porous but remains rigid in the presence of water, zeolites can be adapted for a variety of uses. Zeolites have increasingly been used in many industrial, agricultural and environmental applications.

About 40 natural zeolites and 100 synthetic zeolites exist [11]. Zeolites have a very open framework with a network of pores giving it a large surface area for trapping and exchanging valuable nutrients [12] [11].

Zeolite assists water infiltration and retention in the soil due to its very porous properties and the capillary suction it exerts. Acting as a natural wetting agent, it is an excellent amendment for non-wetting sands and to assist water distribution through soils [11] [13]. Zeolite can hold nutrients in the root zone for plants to use when required. This leads to more efficient use of N and K fertilizers - either less fertilizer for the same yield or the same amount of fertilizer lasting longer and producing higher yields [14] [15].

In the arid and semi-arid regions of the world, water resources are limited, and under severe and increasing pressure due to population growth, increasing per capita water use and irrigation [16]. Consequently, the management of water resources has become an increasing pressing issue in this area. Increase infiltration component of rainfall and water storage capacity does not only lessen the pressure of water shortage, but also decrease runoff and flood damages. The present study aims to investigate the impact of natural zeolite application in rainfall infiltration into the soil, runoff, and soil water storage capacity.

2 MATERIALS AND METHODS

The zeolite mineral sample is taken from natural zeolite mine in Iran. Table 1 summarizes the chemical composition of the natural zeolite sample used in the experiments. Soil samples were taken from the Agricultural research farm of Shiraz University located in Fars Province, south Iran. Table 2 indicates some physico-chemical soil properties of soil samples.

Table. 1 The Chemical composition and some related properties of zeolite powder used in the experiment

related properties	SiO2	Al2O3	Fe2O3	TiO2	CaO	MgO	Na2O	K2O	LOIa	ρ(gr.cm-3)	CEC (meg/l00gr)
%	67.24	11.7	0.58	0.42	3.04	1.16	1.19	1.48	13.47	1	175

Table. 2 Some physico-chemical characteristics of soils samples used in the experiment

Soil texture	Particle size fraction (%)			pH	EC ds/m	CEC (Meg/100gr)
	Sand	Silt	Clay			
Sandy-silt	60	29	11	7.6	0.69	24.78

The studied parameters were three levels of zeolite application (0%, 10% and 20% of zeolite) and two levels of rainfall intensity (10 and 15 mm/h).Treatments and control soils were applied to field plots (Figure 1).

Experiment was conducted in plots in the laboratory with artificial rainfall. Plots fill with untreated (control) and the zeolite-treated soil. In each experiment, constant rainfall intensity was created via artificial rainfall simulator with two replications. The runoff and seepage amounts were measured in the outlets of the plots at 15 minute interval (Figure 1). Measurements were continued until soil profile becomes saturated and the outlet runoff and infiltrated water reaches a constant value.

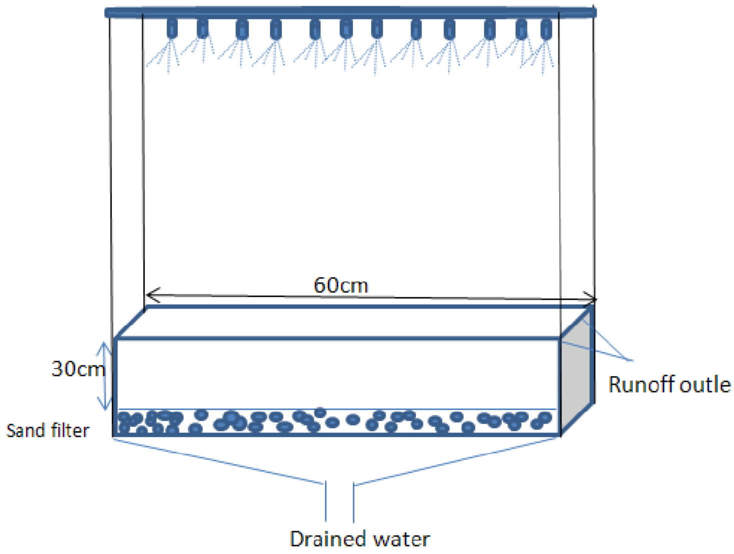

Fig.1 Schematic of the study field plot

After each rainfall, soil sampling was conducted within the study plots. The soil sample weighed in one day interval until soil weight becomes constant. Each day, the weight of water determined as the before and after readings. Finally, the samples were analyzed for selection of Sodium, Calcium, Potassium, Electrical conductivity (EC), pH, and Cation Exchange Capacity (CEC). Selecting of these elements was done based on the assumption that changing of them will be effective soil infiltration rate, soil water holding capacity and some physico-chemical soil properties. Sodium and potassium values were determined using Flam photometry method. Calcium was determined using titration method.

For statistical analysis of the data, the MINITAB statistical package (Minitab 14 Statistical Software) and Excel (Microsoft Office Excel 2007) were used.

3 RESULTS AND DISCUSSION

3.1 EFFECTS ON RAINFALL INFILTRATION AND SURFACE RUNOFF

According to results, runoff and drained water were significantly different in the soil treated with zeolite compared to untreated soil (Table 3). For 10 mm of rainfall intensity, time of runoff beginning was 15 min in no treated soil and raised to 30 min in treated soil with 20% of zeolite. When rainfall intensity was increased to 15 mm per hours, time of rainfall beginning decreased to 10, 23 and 27 min for 0, 10 and 20 % of zeolite application respectively.

The starting time for drainage was also increased with increasing amount of zeolite. The starting time for drainage for 10 mm of rainfall intensity was 56, 76 and 100 min for 0, 10 and 20 % of zeolite respectively. This time decreased to 40, 45 and 90 min when rainfall intensity increased to 15 mm per hour.

Results indicate a significant decrease in runoff volume, drained water volume and sediment amount after application of zeolite ($P<0.01$).The volume of surface runoff of the zeolite-treated soil was greatly decreased by 70.23–83.72% for 10 mm per hours of rainfall intensity and more than 50% for 15 mm per hours of rainfall intensity (table 3), with all significantly different from the no treated soil ($P<0.01$).

Table. 3 Impact of zeolite application on runoff and infiltrated water

Rainfall intensity (mm.hr-1)	Zeolite %	Time of runoff beginning(min)	Runoff			Infiltrated water			Average of Sediment (gr.lit-1)
			Time that outlet runoff reaches a constant value(min)	Runoff amount in the first 15 min	Average of Sediment (gr.lit-1)	Time of drained water beginning (min)	Time that outlet drained water reaches a constant value (min)	Infiltration amount in the first 15 min	
10	0	15	75	2.15	0.66	56	175	2.96	3.38
	10	20	60	0.64**	0.44**	76	225	1.2**	1.51**
	20	30	45	0.35**	0.37**	100	300	1.79**	1.64**
15	0	10	60	3.42	0.89	40	120	3.8	4.12
	10	23	45	1.71**	0.67**	45	165	3.1**	2.08**
	20	27	45	1.12**	0.4**	90	240	3**	2.21**

In the treated soil, sediment was reduced in both runoff and infiltrated water (Table 3). For soil treated with 10 and 20 percent of zeolite, decreasing of sediment amount in outlet runoff was 23.7% and 37.2% respectively for 10 mm per hours of rainfall intensity and 50% and 67.25% for 15 mm per hours of rainfall intensity. For soil treated with 10 and 20 percent of zeolite, the average of sediment in outlet drained water was 44.7% and 48.25% of sediment in no treated soil for 10 mm per hours of rainfall intensity and increased to 50.48% and 53.64 % when rainfall intensity increased to15 mm per hours. All results significantly different from the untreated soil ($P<0.001$).

3.2 Effects on soil properties

3.2.1 Soil moisture

In both treated and control soil sample, soil moisture decrease with time, but soil water content in the treated soil was higher than untreated soil during the whole period(Figure 2). Soil water content measured in one day interval were significantly different in the soil samples treated with zeolite compared to untreated soil. High water holding capacity, and high adsorption capacity of natural zeolite was reported in many researches [17] [16].

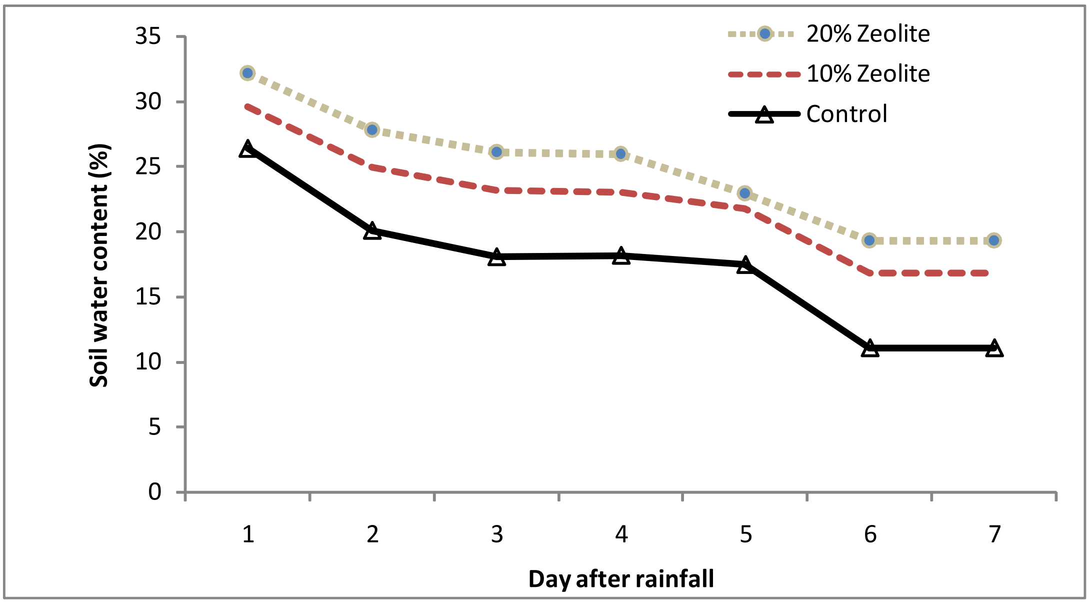

Fig. 2 Soil water content change of the normal soil and zeolite-treated soil

3.2.2 Chemical soil properties

Soil sample were removed from each plot irrigated with 10 and 15 mm of rainfall intensity and combined to produce a sample for each level of zeolite application .The soil samples were analyzed for selection of sodium, calcium, potassium, EC, and pH (Table 4). According to results, no significant differences were observed between electrical conductivity in the soils treated with 10% of the natural zeolite and control, but Ec increased significantly in the soil treated with 20% of the natural zeolite(P<0.01).

Table. 4 Average amount of chemical soil properties (and their standard division below them) in control and treated soils

Soil properties	Control	10% Zeolite	20% Zeolite
EC	0.69^{a} 0.01	0.88^{a} 0.01	0.92^{b} 0.01
Ca	0.68^{a} 0.1	0.73^{b} 0.14	1.9^{c} 0.20
K	0.46^{a} 0.04	0.54^{b} 0.06	0.83^{c} 0.12
Na	0.34^{a} 0.02	2.23^{b} 0.05	2.5^{b} 0.09
pH	7.91^{a} 0.1	7.89^{a} 0.1	7.90^{a} 0.05

Mean value with the same letter ***in each rows*** *within the treated soils do not differ significantly*

A significant differences were observed in the amount of K, Ca, and Na between control, soil treated with 10% of zeolite and soil treated with 20% of zeolite (P<0.01). The amounts of Ca, Na, and K were increased significantly in the soil treated with zeolite compared to no treated soil. No significant differences were observed between treated and control soils for pH. Increasing of K and Ca via zeolites application should improves the soil aggregation, while increasing of Na and EC should destroyed soil structure. In order to get a good results, an optimum amount of zeolite should be added to the soil due to soil and water properties .Impact of zeolite on physical soil improvement via increasing of the availability of Ca and K and reduced losses by leaching of exchangeable captions, especially K were reported by several researchers [18] [19] [20] [7] [21]. The effects of natural zeolite on poultry litter compost was indicated that the salinity level of the compost was decreased with increasing the amount of natural zeolite [14].

4 Conclusion

To determine the effectiveness of natural zeolite in reducing runoff, sediment, drained water, and some of the soil properties, the sample collected from treated and control soil were analyzed. According to results, a significant decrease was observed in runoff volume, drained water volume and sediment amount after application of zeolite.

Also zeolites improves the efficiency of water and nutrient use of plants and decrease runoff and sediments amount by increasing the soil water holding capacity, but it also could increase other ions such as sodium and some toxic minerals. So, some technical aspects such as application rates, soil and water quality need investigated significantly and experiment before its application to the field.

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