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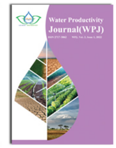

Evaluation of Natural Zeolite Type and Magnetic Water on Raphanus Sativus (Radish) Yield and Yield Components[1]

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Abstract

Introduction: Water productivity is generally defined as crop yield per cubic metre of water consumption, including 'green' water (effective rainfall) for rainfed areas and both 'green' water and 'blue' water (diverted water from water systems) for irrigated areas. Water productivity defined as above varies from region to region and from field to field, depending on many factors, such as crop patterns and climate patterns (if rainfall fits crop growth), irrigation technology and field water management, land and infrastructure, and input, including labor, fertilizer and machinery. There has been a great need to improve agric cultural yield in arid and semi-arid regions in countries like Iran due to climate conditions and poor soils quality. Zeolite, as an abundant mineral in Iran, has been proposed to be used as substitutions for chemical fertilizers to increase the yield and yield components of plants. In addition, magnetic water is one of the important factors to increase crop yield.

The discovery of natural zeolites has opened an important chapter in the mineralogy sector owing to their exciting surface and structural properties that have been exploited in many areas: agriculture, industrial technology, animal husbandry, cosmetics and biotechnology industry. Zeolites have numerous applications i.e. in catalysis, in gas

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adsorption, industrial gas separation, water treatment (wastewater and drinking water), agriculture, and metal immobilization in soils, ion exchange, aquaculture, odour control, and desiccation and as phosphate substitutes in detergents. Zeolites have various applications, based on their cost and ion exchange behavior the main areas where zeolites are widely used are in detergents; in ammonia/ammonium removal from wastewater effluent; in radioactive isotope removal from spent pile effluent and in agriculture. By far the most important of these is in detergents, where zeolites are employed as water softeners, partially replacing tri-polyphosphate builders.

Materials and Methods: For this purpose, a greenhouse study was conducted based on a factorial design by two factors (Zeolite in three types: control, calcic zeolite and potassic zeolite and water in two types: tap and magnetic) and six replications in University of Birjand, Iran. Birjand is capital of South Khorasan province, eastern Iran. The city is known for its saffron. Birjand is a fast-growing city and a major center of commerce in eastern Iran. It had two forts, one on a prominent high ground in the south and the other on low ground in the north of the city. The old town was about three miles in circumference and had a few gardens and green fields known as Keshman in the southern sections. The district is rich in minerals. Copper is known to have been mined in the past and many remnants of old mines are seen in the mountains. It show be noted the effect of magnetic field on water bears a complex and multifactorial character that in the final result affects the structure of water and hydrated ions as well as the physico-chemical properties and behavior of dissolved inorganic salts. When being applied to water, the magnetic field therein changes the rates of chemical reactions due to the occurrence of competing reactions of dissolution and precipitation of the dissolved salts, facilitates the formation and decomposition of colloidal complexes, and improves electro-coagulation followed by sedimentation and crystallization of scaling salts of Ca^{2+}, Mg^{2+}, Fe^{2+} and Fe^{3+}.

Results: The results showed that the type of water had a significant effect on the leaf length, leaf area, root dry weight, and leaf dry weight (P-value<0.05). The type of zeolite had a significant effect on the leaf length (P-value<0.01), leaf area, and total dry weight. The interaction between water and zeolite showed a significant effect on root length and leaf width (P-value<0.05). Since the application of magnetic water with calcic zeolite had a significant effect on increasing leaf length, leaf area index, and total dry weight compared to other treatments, it is recommended to use both factors together.

Conclusions: This zeolite increased the leaf length by 1.24 and 1.17 times compared to ZP zeolite and control, respectively. For the leaf area, these increases were 1.30 and 1.29 times more than ZP and control, respectively. Increases in the total dry weight in ZG zeolite compared to ZP zeolite and control were 1.38 and 1.25 times, respectively. Besides ZG zeolite increases the percentage of emergence, root length, leaf width, total fresh weight, leaf fresh weight, bulb fresh weight, bulb dry weight, root dry weight, and leaf dry weight but these increases were not significant.

Keywords: Natural Zeolite, Greenhouse Cultivation, Magnetic Water, Radish, water productivity.

1. Introduction

Radish (*Raphanus sativus* L.) is an edible root vegetable belonging to the Brassicaceae family. It is rich in ascorbic acid, folic acid, and potassium. An analysis of the food value of this plant has shown it to be high in dissolved fibrous, antioxidant components of glucosinolates and isothiocyanates (Hara & et al., 2009). Radish is a long-day plant and the high-temperature decreases the time of flowering and seed productions. Due to climate conditions in many parts of Iran, such as Khorasan province, greenhouse agriculture was used for the cultivation of vegetables. In addition, lack of water and poor soil are two factors that affected vegetable cultivation in mentioned regions.

It is well known that both soil and water are the most important parameters in an agricultural system to increase yield and yield components. As the soil particles change, the plant reacts towards it and is a good biological indicator of the unfavorable change of soils (Simon & Eberhad, 2000). In agriculture, zeolite, which is one of the most important mineral materials (Mumpton, 1977; Andrews and Kimi, 1996, Malekian & et al., 2011; Ahmadee & et al., 2014), is mainly used to improve soil conditions (Yapparov & et al.,1988; Mumpton 1999) and plays as a fertilizer for the growth of plants (Polat & et al., 2004). Hence, one of the main reasons for selecting zeolites is the least use of chemical fertilizers (Huang & Petrovic, 1995). Zeolite has been used on several crops such as spinach, saffron, bean, potato, and sorghum (Li & et al., 2013; Ahmadee & et al., 2014; Ozbahce & et al., 2014; Ghannad & et al., 2014; Najafinezhad & et al., 2014).

The change in water characteristics by magnification is reported in many experiments (De Souza & et al., 2006; Ghauri & Ansari, 2006; Castro Palacio, 2007; Pang & Deng, 2008) and is recommended to use it in agriculture (Belov & et al., 1998; Carbonell & et al., 2002, Maheshwari & Grewal, 2009). Some studies have been done about the application of magnetic water in agricultural yield and reported a positive effect of it on plants (Line & Yotvat, 1990; Gyulakhmedov & Seiidaliev, 1991; Danilov & et al., 1994; Esitken & Turan, 2004; De Souza & et al., 2006).

The literature review reveals that there are possibly some benefits of using zeolite and magnetic water on the growth of a crop. Furthermore, since there is not much research carried out on the effects of magnetic water and zeolite treatment on plant growth, the novelty of the research is the simultaneous study of the aforementioned factors on radish. In this study, therefore, the effects of magnetically treated potable water and two natural zeolites on radish yield and yield criteria under controlled environmental conditions in a greenhouse were investigated.

2. Material and methods

This research was conducted using a completely randomized factorial design by two factors (zeolite and water type) with six replications in the greenhouse of the University of Birjand, Iran, in 2014. Zeolite factors in three types: calcic zeolite (ZG), potassic zeolite (ZP), and soil without zeolite as control (ZO) were considered (Fig. 1). Natural clinoptilolite zeolite (ZG and ZP) was collected from Semnan province (53^{o} 15' E, 35^{o} 25' N) and analyzed for its chemical composition by X-ray diffraction. The treatments of zeolite were prepared by adding ZG and ZP zeolites to the soil as weight percentage (4%).

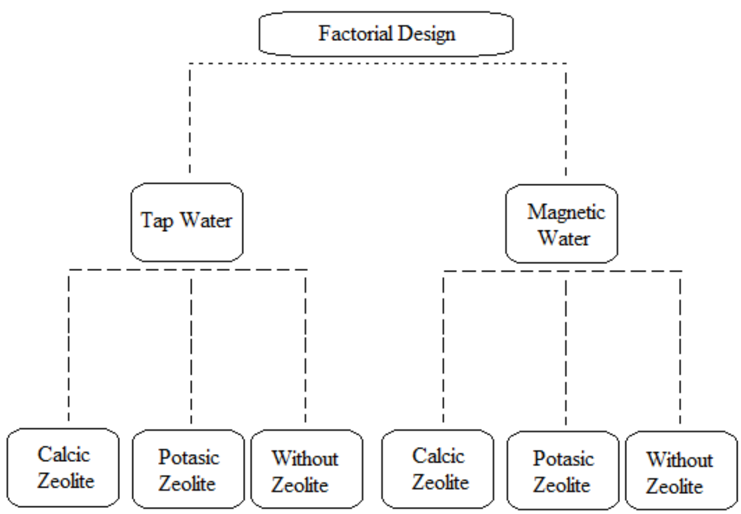

Fig. 1- Schematic of factorial design used in this study

The chemical properties of soil, ZG, and ZP zeolite are given in Table 1-3, respectively. Water treatments consist of tap water in the greenhouse (WO) and magnetic water prepared by a magnetic field of 44mT (WM). The characteristics of tap water are shown in Table 4.

Table 1- Soil properties used in the study

Organic Matter	Organic carbon	Total Ca ($mg.l^{-1}$)	pH	EC (ds/m)	Sand (%)	Silt (%)	Clay (%)	Texture
0.29	0.17	15	7.98	0.46	48	42	10	Loam

Table 2- Components of ZG zeolite

SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	Na_2O (%)	K_2O (%)	MgO (%)	TiO_2 (%)	MnO (%)	P_2O_5 (%)
70.95	7.88	1.31	2.21	3.00	3.67	0.62	0.162	0.022	0.013
Diameter (mm)	**SO_3 (%)**	**Cl (ppm)**	**Ba (ppm)**	**Sr (ppm)**	**Cu (ppm)**	**Zn (ppm)**	**Pb (ppm)**	**Ni (ppm)**	**Cr (ppm)**
0.5-7	1.345	3504	1154	399	54	5	39	12	7

Table 3- Components of ZP zeolite

SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	Na_2O (%)	K_2O (%)	MgO (%)	TiO_2 (%)	MnO (%)	P_2O_5 (%)
70.25	7.68	0.91	1.12	3.10	3.43	0.39	0.153	0.017	0.006
Diameter (mm)	**SO3 (%)**	**Cl (ppm)**	**Ba (ppm)**	**Sr (ppm)**	**Cu (ppm)**	**Zn (ppm)**	**Pb (ppm)**	**Ni (ppm)**	**Cr (ppm)**
0.5-1	0.600	2049	1158	666	56	2	27	5	6

Table 4- Water properties used for irrigation

Type of Water	K ($mg.l^{-1}$)	Na ($mg.l^{-1}$)	Mg ($mg.l^{-1}$)	Ca ($mg.l^{-1}$)	HCO_3 ($mg.l^{-1}$)	CO_3 ($mg.l^{-1}$)	Cl ($mg.l^{-1}$)	pH	EC ($dS.m^{-1}$)
Tap Water	3.3	56.9	0.11	0.45	0.5	0.1	63.9	7	0.087
Magnetic Water	3.1	51.5	0.10	0.44	0.5	0.1	58.1	7	0.079

Ten seeds of radish were cultivated in each pot. After the emergence of seeds in all the pots, the numbers of emergent seeds were counted. Then weeding and the numbers of plants in all the pots equated. This experiment was conducted for 6 weeks. After the end of growth duration, the pots were transferred to the lab for analysis. The dry and fresh weights of plant components were calculated by the use of scale with the accuracy of 0.0001g. Length of plant components was measured with a ruler by the accuracy of 0.01cm and leaf area was measured with a leaf area meter (LI-3100C) by the accuracy of 0.01cm^2. The diameter of the bulb was measured by a caliper with an accuracy of 0.001cm. For measurement of dry weight, the plant components were placed in an Oven by the degree of 70^{o}C for 48 hours. Data related to yield and yield components were analyzed by analysis of variance (ANOVA), using GLM procedure in SAS *9.1.3* software (Anonymous, 2006), and Tukey's test was used for significant differences (P-value<0.05).

3. Results

The results showed that the type of water had a significant effect on the bulb length, leaf area, root dry weight, and leaf dry weight in 5% of probability (Table 5). The type of zeolite showed a significant effect (P-value<0.01) on the leaf length and leaf area and the total dry weight of the plant (P-value<0.05). The interaction effects of zeolite and water on the root length and the leaf width showed a significant effect (P-value<0.05). The use of magnetic water increase the bulb length, leaf area index, root dry weight, and leaf dry weight (Table 6). The rates of increases in the mentioned indices were 1.30, 1.24, 1.21, and 1.22 times, respectively. Magnetic water absorbs some soil minerals and affects the organic structures and as a result, the plants can consume them easily and increase their growth yields (Maheshwari & Grewal, 2009). Although magnetizing the water increased the yield and yield components of radish but did not show a significant effect on them (P-value≥0.05). Similar results were reported by Wiedenfeld (2008) on the sugarcane plant. Results showed that magnetic water reduced root length compare to tap water. It might be due to a reduction in the cell deviation, the size of Mitochondria, and the root growth (Belyavskaya,2004; Turker & et al., 2007).

ZG zeolite caused a significant increase (P-value<0.05) in the leaf length, leaf area index, and total dry weight of radish (Table 7). This zeolite increased the leaf length by 1.24 and 1.17 times compared to ZP zeolite and control, respectively. For the leaf area, these increases were 1.30 and 1.29 times more than ZP and control, respectively. Increases in the total dry weight in ZG zeolite compared to ZP zeolite and control were 1.38 and 1.25 times, respectively. Besides ZG zeolite increases the percentage of emergence, root length, leaf width, total fresh weight, leaf fresh weight, bulb fresh weight, bulb dry weight, root dry weight, and leaf dry weight but these increases were not significant (P-value≥0.05). By focusing on more changes of yield and yield components of radish by the use of ZG zeolite, the possibility by change on the amount of it can reach to increase of these indices to become significant.

The use of zeolite did not show a significant effect on the length and diameter of the bulb (P-value≥0.05). It might be due to the application of soil with low EC according to Table 1 (Noori & et al., 2006).

Table 5- The results of ANOVA (F test) on yield and yield components of radish

S.O.V	Water	Zeolite	Water * Zeolite	Error
Percentage of germination	0.96^{ns}	0.12^{ns}	1.55^{ns}	333.20
Length of bulb	4.36^{*}	0.16^{ns}	0.56^{ns}	0.68
Diameter of bulb	0.67^{ns}	0.90^{ns}	0.63^{ns}	0.25
Length of root	1.83^{ns}	0.52^{ns}	5.27^{*}	3.16
Length of leaf	1.78^{ns}	5.68^{**}	1.52^{ns}	0.41
Width of leaf	1.75^{ns}	1.80^{ns}	3.56^{*}	0.26
Leaf area	6.14^{*}	4.67^{*}	0.90^{ns}	7729.158
Total Fresh weight	0.06^{ns}	1.98^{ns}	0.32^{ns}	5.6527
Fresh weight of root	2.72^{ns}	0.31^{ns}	3.27^{ns}	0.0040
Fresh weight of leaf	0.11^{ns}	2.26^{ns}	0.68^{ns}	0.1261
Fresh weight of bulb	0.2^{ns}	1.55^{ns}	0.26^{ns}	5.5961
Total dry weight	3.22^{ns}	4.10^{*}	0.21^{ns}	0.0200
Dry weight of root	4.60^{*}	0.66^{ns}	2.49^{ns}	0.0001
Dry weight of leaf	4.70^{*}	1.74^{ns}	1.30^{ns}	0.0013
Dry weight of bulb	1.15^{ns}	2.76^{ns}	0.03^{ns}	0.0204

Ns, *, ** and *** are non-significant, significant at 5, 1 and 0.1% probability levels, respectively.

Table 6- The comparison of mean values based on the type of water

Type of water	WO	WM
Percentage of germination	28.66^{a}	34.60^{a}
Length of bulb (cm)	1.89^{b}	2.47^{a}
Diameter of bulb (cm)	1.68^{a}	1.84^{a}
Length of root (cm)	6.41^{a}	5.62^{a}
Length of leaf (cm)	3.62^{a}	3.95^{a}
Width of leaf (cm)	2.50^{a}	2.74^{a}
Leaf area (cm^2)	3163.48^{b}	3928.62^{a}
Total Fresh weight (gr)	4.6508^{a}	4.9315^{a}
Fresh weight of root (gr)	0.0702^{a}	0.1049^{a}
Fresh weight of leaf (gr)	0.9954^{a}	1.0389^{a}
Fresh weight of bulb (gr)	3.5851^{a}	3.7876^{a}
Total dry weight (gr)	0.4425^{a}	0.5351^{a}
Dry weight of root (gr)	0.0331^{b}	0.0401^{a}
Dry weight of leaf (gr)	0.1252^{b}	0.1525^{a}
Dry weight of bulb (gr)	0.2841^{a}	0.3424^{a}

* Means with the same letter(s) in each row have not significantly difference based on Tukey's test (p≤0.05). WO and WM indicant tap and magnetic water, respectively.

Table 7- The comparison of mean values based on type of zeolite

Type of zeolite	ZO	ZG	ZP
Percentage of germination	30.00^{a}	33.33^{a}	31.57^{a}
Length of bulb (cm)	2.18^{a}	2.10^{a}	2.15^{a}
Diameter of bulb (cm)	1.86^{a}	1.83^{a}	1.60^{a}
Length of root (cm)	5.80^{a}	6.40^{a}	5.85^{a}
Length of leaf (cm)	3.65^{ab}	4.27^{a}	3.44^{b}
Width of leaf (cm)	2.50^{a}	2.84^{a}	2.50^{a}
Leaf area (cm^2)	3227.75^{b}	4191.80^{a}	3218.61^{b}
Total Fresh weight (gr)	4.6407^{a}	5.7895^{a}	3.9433^{a}
Fresh weight of root (gr)	0.0802^{a}	0.0883^{a}	0.0941^{a}
Fresh weight of leaf (gr)	0.8917^{a}	1.1858^{a}	0.9740^{a}
Fresh weight of bulb (gr)	3.6686^{a}	4.5154^{a}	2.8751^{a}
Total dry weight (gr)	0.4632^{ab}	0.5829^{a}	0.4203^{b}
Dry weight of root (gr)	0.0350^{a}	0.0393^{a}	0.0356^{a}
Dry weight of leaf (gr)	0.1284^{a}	0.1552^{a}	0.1329^{a}
Dry weight of bulb (gr)	0.2997^{a}	0.3883^{a}	0.2517^{a}

* Means with the same letter(s) in each row have not significantly difference based on Tukey's test ($p \leq 0.05$). ZO indicant control treatment.

Table 8- The comparison of mean values based on the type of water and zeolite

Type of water and zeolite	WOZO	WOZG	WOZP	WMZO	WMZG	WMZP
Percentage of germination	21.67^{a}	28.33^{a}	36.00^{a}	38.33^{a}	38.33^{a}	27.14^{a}
Length of bulb (cm)	2.07^{a}	1.62^{a}	2.00^{a}	2.50^{a}	2.60^{a}	2.31^{a}
Diameter of bulb (cm)	1.67^{a}	1.88^{a}	1.51^{a}	2.05^{a}	1.78^{a}	1.69^{a}
Length of root (cm)	4.83^{a}	7.38^{a}	7.02^{a}	6.77^{a}	5.42^{a}	4.68^{a}
Length of leaf (cm)	3.66^{ab}	3.85^{ab}	3.40^{b}	3.67^{ab}	4.70^{a}	3.48^{b}
Width of leaf (cm)	2.55^{a}	2.40^{a}	2.56^{a}	2.47^{a}	3.28^{a}	2.47^{a}
Leaf area (cm^2)	3108.45^{ab}	3757.73^{ab}	2624.26^{b}	3347.05^{ab}	4625.87^{a}	3812.97^{ab}
Total Fresh weight (gr)	4.2082^{a}	5.4973^{a}	4.2470^{a}	5.0732^{a}	6.0818^{a}	3.639 7^{a}
Fresh weight of root (gr)	0.0783^{a}	0.0941^{a}	0.0382^{a}	0.0821^{a}	0.0825^{a}	0.1501^{a}
Fresh weight of leaf (gr)	0.8490^{a}	1.0915^{a}	1.0458^{a}	0.9345^{a}	1.2801^{a}	0.9022^{a}
Fresh weight of bulb (gr)	3.2808^{a}	4.3117^{a}	3.1630^{a}	4.0565^{a}	4.7191^{a}	2.5872^{a}
Total dry weight (gr)	0.4306^{ab}	0.5442^{ab}	0.3527^{b}	0.4958^{ab}	0.6217^{a}	0.4879^{ab}
Dry weight of root (gr)	0.0290^{a}	0.0409^{a}	0.0293^{a}	0.0409^{a}	0.0377^{a}	0.0418^{a}
Dry weight of leaf (gr)	0.1280^{a}	0.1392^{a}	0.1085^{a}	0.1289^{a}	0.1712^{a}	0.1574^{a}
Dry weight of bulb (gr)	0.2735^{a}	0.3640^{a}	0.2149^{a}	0.3259^{a}	0.4127^{a}	0.2886^{a}

* Means with the same letter(s) in each row have not significantly difference based on Tukey's test ($p \leq 0.05$). ZO indicant control treatment and WO and WM indicant tap and magnetic water, respectively.

ZP zeolite increased 1.06 and 1.17 times the fresh weight of root compare to ZG zeolite and control, respectively, but its effect was not significant (P-value≥0.05). A comparison of types of water and zeolite is shown in Table 8. The application of ZG zeolite with magnetic water (WMZG) had a significant effect on the leaf length, leaf area, and the total dry weight of radish (P-value<0.05). By the use of ZP zeolite, the least length of leaves was observed. The treatment of WMZG increased 1.38 and 1.35 times the leaf length compare to the treatments of WOZP and WMZP, respectively. The least amount of leaf area in WOZP was observed. The WMZG treatment compare to the WOZP treatment, had increased about 1.76 times on the total dry weight of the plant. Magnification of water in ZP zeolite increased leaf area index and total dry weight compared to tap water. The WMZG treatment increased the indices of emergence, bulb length, leaf width, total fresh weight, leaf fresh weight, bulb fresh weight, leaf dry weight, and bulb dry weight but the increases were not significant (P-value≥0.05). However, the use of that zeolite along with tap water increased the root length and root fresh weight. Magnifying water along with the application of ZP zeolite increased the dry weight of the root but it was not significant (P-value≥0.05).

4. Conclusions

The results showed that the application of ZG zeolite and magnetic water increased some of the components of radish but did not show a significant effect on the yield of the bulb especially on the weight of the bulb. With due respect to the increasing effect of zeolite that showed in WM treatment by some indices like bulb length, bulb fresh weight, and total fresh weight, it might be predicted that if different amount of zeolite and stronger magnetic field intensity are used, it will reach significant change in the yield of this crop. Thus, there is a need to conduct more experiments.

5. Acknowledgments

None declared.

6. Conflict of interest

None declared.

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