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Modification of Jordanian Zeolite as Slow-release Fertilizers and Soil Conditioner

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Authors' contributions

This work was carried out in collaboration between both authors. Author ZAA wrote the original draft. Author ZAA and IIA edited and improved the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Zeolites are alumina- silicate minerals that can lose, absorb water and various ions and gases. Grinned zeolites rock is treated with selected natural material and used as environmentally friendly slow release fertilizer and found to improvement physical and chemical properties of soil. This natural mixture product can release slowly important salts of phosphate ($PO_4{}^{2-}$) and sulphate (SO^{4-}) of the elements: potassium (K^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), iron (Fe^{3+}), Zinc (Zn^{2+}), Manganese (Mn^{2+}), Copper (Cu^{2+}) in the zeolites porous structure which is expected to release nutrients and even micronutrients leaching throughout crop growth and improve soil fertility and water use efficiency.

To the grinded zeolite rocks having sizes from 0 - 4.0 mm four selected materials were added to produce an efficient slow release fertilizer named modified Zeolite, which is evaluated as fertilizer and soil conditioner for selected plants in this study, and there use found to reduce both the amount of chemical fertilizer, and irrigation water consumption, increase in plant growth in terms of quality and quantity was reported, another aspect is a decrease in the soil pH and electron conductivity upon using the prepared modified Zeolite.

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1. INTRODUCTION

Zeolites are a group of naturally framework aluminosilicates with high cation exchange capacities, high adsorption, and hydration - dehydration properties. They are formed when volcanic ash was deposited in ancient alkaline lakes, Natural zeolites include minerals that are capable of ion exchange. The global zeolites market is expected to grow due to increase in construction and building material requirements as they are the biggest users of natural zeolites, China is the most abundant source of natural zeolites, followed by South Korea and Slovakia [1].

Zeolite-fertilizers are suitable for growing agricultural crops, vegetables - sowing and planting of seedlings and potatoes, planting and fertilization of fruit seedlings and trees. slow release of nutrients guarantees a sufficient supply of nutrients for plants throughout the entire vegetation period with a reduced necessity to use additional fertilizers [2,3].

Zeolite's ability to retain moisture is important aspect of using Zeolite as a soil amendment. The porous structure of natural zeolite helps to keep the soil well aerated, unlike other soil amendments such as lime and clay. Zeolite's porous structure will not clog soil pores over time like clay will [4-7].

Using slow-release fertilizers (SRFs) can reduce the concentration of of potassium, nitrogen, and phosphorus in surface water bodies (eutrophication) or of groundwater nitrates [8,9].

Thus zeolites have several positive effects on soil properties, such as increasing soil moisture, promoting hydraulic conductivity, and increasing yields in acidified soils; they are widely used as soil conditioners to improve soil physio-chemical properties [10,11]. The production of Zeolitic tuff in Jordan started in 1998, which was consumed by Jordan Cement industries. With the large size of the agricultural sector in Jordan, it is estimated that regular supply of nutrients facilitates a consistent growth of vegetation, its healthy condition and increased resistance to fungal diseases, which is an excellent precondition to boost agricultural production at high quality levels. Additionally, zeolitic tuff could be used successfully in removing Cu^{+2}, Cr^{+3}, Ni^{+2}, Pb^{+2} and Zn^{+2} from industrial wastewater. Thus contributes to environmental protection, reduce soil degradation, environmental pollution, and improve soil efficiency [12-16].

2. MATERIALS AND METHODS

This study was carried out at the laboratory of Jordan Valley Authority, farm Dair-Ulla dim and area 22, farm unit 91which is located at Ulla, Al-Balqa. The climate of the Jordan valley region is very dry, semi-cool, winter extremes, rain in winter precipitation exceeding 30%, in summer the temperature range from 38 t0 39 ºC [17-18].

2.1 Preparation of Treated Zeolite

To 50.0 kg of Ground zeolite samples provided by Imtedad International Engineering for Mining, at Jordan. Selcted size range 0 - 4.0 mm and dried at 40° C were used. One gram of each sample was weighed out carefully and treated with 0.01% powder sulfur and 0.05% crystals of soluble organic carboxylic acids.

Table 1. shows the amount of added modified zeolite and chemical fertilizers to the soil. The modified zeolite used

plant	Modified Zeolite g/m2	Chemical Fertilizer g/m^2
Cucumber1	0.00	140.0
Cucumber2	500	50.0
Cucumbe3	1000	25.0
Egg plant 1	0.00	120
Egg plant 2	500	50
Egg plant 2	1000	25
Hot pepper 1	0.00	25
Hot pepper 2	500	100
Hot pepper3	1000	0.0

Picture 1. Growth and production

Available:https://www.google.com/maps/dir/32.2261806,35.6086086//@32.2255324,35.6186531,1360m/data=!3m1!1e3!4m2!4m1!3e2?entry=ttu

2.2 Methods and Analysis

Weight out 10.0 g from the blank sample to prepare soil extraction in the ratio (one modified zeolite : five prepared organic acid extract) following the procedure in method of soil analysis, measure the electrical conductivity (EC) by using electron conductivity meter (Jen way type), the pH was also measured using PH-meter (METROHOM) [19].

Digest 25.0 g from the blank sample “modified zeolite” digest completely with solution of equal amount of the three acids ($HF/HCl/HNO_3$), addition MUST be under fume hood at 160 ^{0} for 6 hrs, the keep it to cool down for a period of two days until the soil solution is completely digested for trace elements iron, Zinc , manganese and copper, and the elements phosphorus, potassium , calcium and magnesium.

The calcium carbonate content of soil is determined by treating a 1.0-gram dried soil specimen with hydrochloric acid (HCl) in closed reactor vessel, carbon dioxide gas was evolved during the reaction between the acidic solution mixture and carbonate anion. The diethylenetriaminepentaacetic (DTPA) micronutrient extraction method is a non-equilibrium extraction for estimating the potential soil availability of Zn, Cu, Mn, and Fe). The electrical conductivity (EC) ms/cm was measured using electron conductivity meter (Jen way type), and the pH was measured using Metrohm AG PH- meter, The extracted Cu, Zn, Mn, Fe was measured using the Perkin Elmer 300 Atomic Absorption Spectrometer [20].

3. RESULTS AND DISCUSSION

The modified Zeolite formulation used in this study are agricultural improver and natural slow-release fertilizer, which is composed of powdered volcanic rocks, mixed with selected organic materials and ionic salts. After the treatment of soil with this formulation, a decrease in the electron conductivity of the soil was found with increasing the amount of modified zeolite, as the pH of the soil decreased, plant production, growth increased up to around 35% [18].

The soil electron conductivity increased as in Table 2, it is expected that plant micronutrients elements tend to be less available in relatively alkaline soils that is having high pH, and the microbial population in soil thus increases [18]. Addition of different quantities of fertilizer will improve the quality of soil and minimizing the effect of ions such as sodium, as sodium plays an adverse effect on plants and reduce production, resulting the removing the water content of plant roots, thus weekend the plant and may cause its death, it is expected increasing the sodium contents in the soil will cause closing of the soil pores [21].

Table 2. Chemical analysis of the modified zeolite before adding to the soil

Sample name	Particle size	EC 1:5 ms/cm	PH1:5	SIO2 %	T-Fe ppm	T-Mn ppm	T-Zn ppm	T-k2O %	T-P2O5 %	T-CaO %	T-MgO %
Modified Zeolite	0-4.0 micron	0.5-0.80	5.8-6.7	40-45	200-230	280-330	35-42	1.0-1.40	3.0-3.4	4.0-5.0	2.8-3.5

Table 3. Plant growth after the soil mixed with the modified zeolite and chemical fertilizers

Plant	Adding only modified zeolite g/m2	Plant growth First 2 months	Adding only Chemical fertilizer g/m2	Plant growth First 2 months
Cucumber 1	0.00	Increase 10%	140.0	Increase 40%
Cucumber 2	500	Increase 20%	50.0	Increase 30%
Cucumber 3	1000	Increase 25%	25.0	Increase 30%
Egg plant 1	0.00	Increase 10%	120	Increase 30%
Egg plant 2	500	Increase 25%	50	Increase 25%
Egg plant 2	1000	Increase 25%	25	Increase 25%
Hot pepper 1	0.00	Increase 15%	25	Increase 35%
Hot pepper 2	500	Increase 25%	100	Increase 30%
Hot pepper 3	1000	Increase 25%	0.0	Increase 25%

Table 4. Percentage of plant growth after treatment of the soil with both the modified zeolite and chemical fertilizers

Plant	Adding only modified zeolite g/m2	Plant growth First 2 months	Adding only fertilizer g/m2	Plant growth First 2 months
Cucumber 1	0.00	Increase 10%	140.0	Increase 40%
Cucumber 2	500	Increase 20%	50.0	Increase 30%
Cucumber 3	100	Increase 30%	25.0	Increase 30%
Egg plant 1	0.00	Increase 10%	120	Increase 30%
Egg plant 2	500	Increase 20%	50	Increase 25%
Egg plant 2	1000	Increase 30%	25	Increase 20%
Hot pepper 1	0.00	Increase 10%	100	Increase 30%
Hot pepper 2	500	Increase 20%	50	Increase 25%
Hot pepper 3	1000	Increase 30%	25	Increase 20%

Table 5. Soil test for treated soil with modified zeolite and chemical fertilizer after one year farming

plant	Adding only Treated zeolite g/m2	Ec Ms/cm	pH	Adding only Chemical fertilizer g/m2	Ec Ms/cm	pH
Cucumber 1	0.00	2.6	7.51	140.0	4.8	8.21
Cucumber 2	500	2.81	7.35	50.0	3.65	8.17
Cucumber 3	1000	3.1	7.21	25.0	3.28	8.10
Egg plant 1	0.00	2.85	7.59	120	5.4	8.15
Egg plant 2	500	3.10	7.39	50	4.11	8.12
Egg plant 2	1000	3.20	7.25	25	3.80	8.07
Hot pepper 1	0.00	2.90	7.72	100	5.21	8.23
Hot pepper 2	500	3.30	7.40	50	4.74	8.10
Hot pepper 3	1000	3.50	7.32	25	4.01	8.05

Table 6. Comparison of the amount of product using modified zeolite and chemical fertilizers

plant	Adding only Treated zeolite g/m2	Product Kg / year Of 500m2	Adding only Chemical fertilizer g/m2	Product Kg / year Of 500m2
Cucumber 1	0.00	1500	140.0	2800
Cucumber 2	500	1900	50.0	2000
Cucumber 3	1000	2500	25.0	1700
Egg plant 1	0.00	2500	120	4000
Egg plant 2	500	3000	50	3050
Egg plant 2	1000	3700	25	2500
Hot pepper 1	0.00	2250	100	3400
Hot pepper 2	500	2700	50	2750
Hot pepper 3	1000	3300	25	2250

Table 7. The effects of modified zeolite and the chemical fertilizers on soil properties

Sample	EC ms/cm	pH	available k ppm	available p ppm	available Fe ppm	$CaCO_3$ %
Soil tests before adding modified zeolite	4.0	8.1	310.0	60.0	8.3	31.3
Soil test after 5 months from adding modified zeolite	3.7	7.4	360.9	72.3	11.6	27.6
Soil test before adding chemical fertilizers	4.2	8.0	329.4	55.9	9.1	32.8
Soil tests after 5 months from adding chemical fertilizers	4.9	8.3	380.6	80.4	8.7	33.0

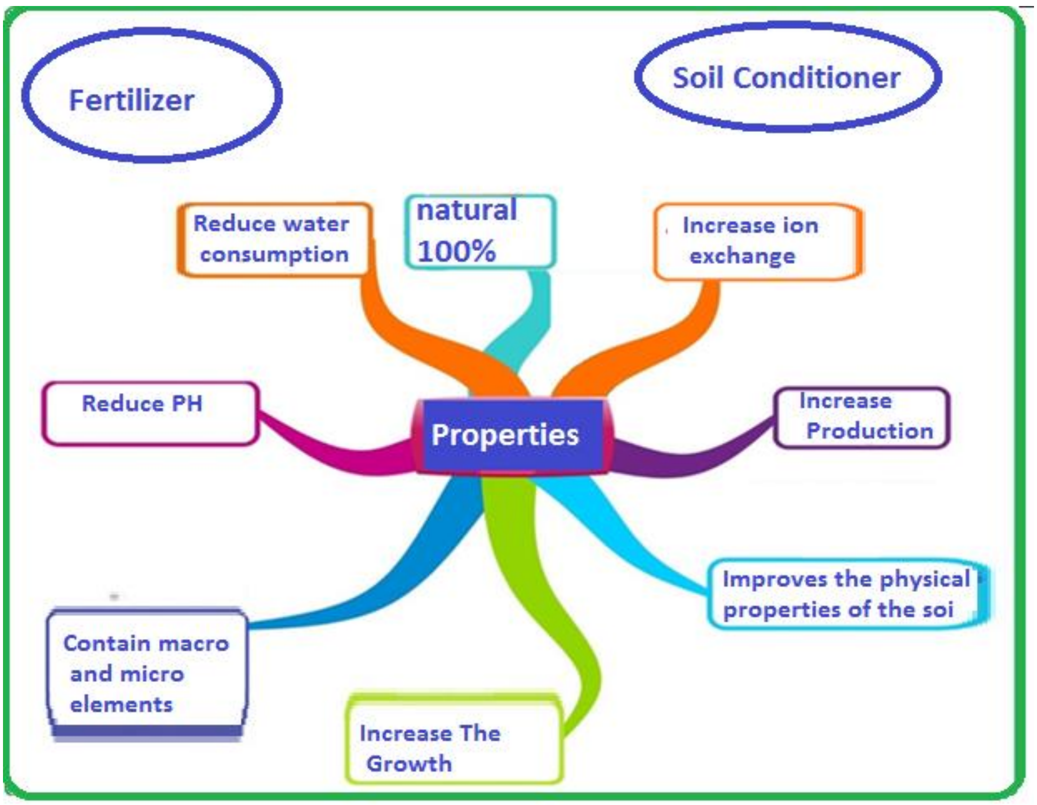

Fig. 1. Effect of adding slow fertilizer (Treated zeolite) to soil

The addition of modified zeolite to calcareous soil will help solving many of plants problems, [15] which are advantages to soil due to the fact that reduction of pH increases the uptake of the trace elements Fe, Cu, Zn, Mn, when they change them from the insoluble metallic form to the ionic soluble form and this is important to plant nutrient availability [16]. It has been reported that increasing cupper ion (Cu^{2+}) concentration in soil can lower the pH and damage the soil pathogens [22].

Fig. 1 shows the comparison of the soil properties using the chemical fertilizer combination and the modified zeolite (soil conditioner). It is clear here many of the soil properties are enhanced with great effects on soil properties and plant products and growth.

4. CONCLUSIONS

Zeolite modification is important process for compatibility of soil and plant growth and production. Macro and micronutrients availability and soil physical and chemical properties can be altered to suit the requirements and overcome many problems such as such as lowering soil pH, which is an advantage to the plants and soil, decrease in the pH increase uptake of trace elements such as Fe, Cu, Zn, Mn which are important to plants growth and production.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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