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Effect Of Adding Different Quantity And Sizes Of Volcanic Ash On Improving Some Hydro-Physical Properties Of Vertisol In Houran Plain (Syria)

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Abstract: The research aims to improve some of the physical and hydro-physical properties of some Vertisols in the southern region (part of the eastern Houran Plateau) in Sweda Governorate at the south of Syria. Using different quantities of volcanic ash, soil samples were collected from the Al-Thahallah village from a depth of (0-30) cm, The experiment was designed according to the complete random design with one factor that represents the ash quantity (1.25, 2.5, 5) %, with three replicates for each treatment in addition to the control treatment a0. The experiment was carried out within the plastic pots during agricultural season 2018/2019, in which the wheat of the Sham variety 3 were cultivated as a cover plant. The results showed that the addition of volcanic ash at the quantity of 5% led to a significant increase in the infiltration rate by (328.60) %,%, where the filtration rate increased from 0.42 cm/hr -1 to 1.80 cm.h-1, as well as for each of the air porosity by (89) % and the volume of infiltrate water by (40) %, compared with the control. The above-mentioned addition also resulted in a decrease in both dry bulk density, total soil porosity and volumetric swelling coefficient by (18.60, 5.80, 314) % Respectively, compared to the control. The addition also contributed to the reduce in the weighted moisture content when saturation and the field capacity, at the level of significance of 5%. The research recommends adding volcanic ash to the soil at a quantity of 5%, and adding enhancements with volcanic ash at various levels such as organic waste.

Keywords: Vertisols; Volcanic Ash; Field Capacity; Air Porosity; Volumetric Swelling

1. Introduction

Vertisols are widespread in all continents [13] (p. 16) with large areas found in Australia, India, Chad, Cuba, Ghana, Taiwan and western America (Ahmad and [2] (p. 16). At the level of the Arab world, this rank covers more than 50 million hectares, which constitutes approximately 15% of the lands allocated to rain-fed agriculture, and is mainly concentrated in Sudan, Morocco, Algeria, Tunisia, and Somalia. In Syria, it covers an area of approximately 2 million hectares [26] (p. 17). It spreads in a limited way as it predominates in some areas located in the northeast of the country near the Turkish-Iraqi borders, as well as in some northwest areas, where the annual precipitation rate exceeds 500 mm, and there are accompaniments to many areas deployed on the northern borders, in the central region, Hauran plain and some Topographic land in Jabal Al Arab (Alawi, 1984). These soils are characterized by a high percentage of smectite clay that is swellable and susceptible to

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cracking, and these soils are almost saturated with water during the winter season, and become very dry during the summer season. Although it is one of the most fertile types of soil when irrigated, some of its physical properties such as: high clay content, swelling and shrinkage, deep cracks, and compaction are undesirable, especially for agricultural and other engineering uses [33] (p. 17). The texture clearly affects the rate of water infiltration in the soil. The finer the soil texture, and the greater its content of smectite mineral, the higher the swelling of the soil and the lower the infiltration rate in the soil. Soil infiltration rate depends on the continuity of pores, their size and distribution. Soil physical properties, including bulk density, porosity, and hydraulic conductivity, greatly influence the infiltration rate of the soil. The higher the bulk density of the soil, the lower the porosity and infiltration rate [29] (p. 17). Reducing water infiltration down the soil sector in Vertisols leads to soil erosion [22] (p. 16). The phenomenon of swelling and shrinkage in these soils causes many agricultural problems such as cutting the roots of plants, and these soils are subject to water erosion, especially when there is high rainfall and no vegetation cover and if the soil slope is about 3% or more [27] (p. 17) Vertisols are characterized by a wide range of bulk density, as [14] (p. 16) indicated that they are characterized by high density, noting that the bulk density changes according to humidity. The physical properties of soil for suitable for cultivation are: aeration, good drainage, adequate water holding capacity, high water conductivity and low bulk density [16] (p. 17). Farmers are trying to overcome soil shrinkage in nurseries and greenhouses by adding soil conditioners with an inert chemical composition that does not change. Nursery growers in the northwestern United States of America in the Pacific region use pumice stone (volcanic ash) as a primary inorganic component in mixtures It is a porous material that occurs naturally in volcanic areas and is easy to obtain because its locations are distributed all over the world [31] (p. 17).

Volcanic ash is considered one of the improvers that can be used to improve the properties of clay soils. It is chemically inert and consists of SiO2 (50%) that does not react with water and therefore does not lose weight and does not release harmful organic or inorganic substances [9] (p. 16). Volcanic ash is usually added at levels ranging from (10-20) % by volume to nursery mixtures because it increases soil aeration and drainage. [23] (p. 16) Showed in a study that the addition of volcanic ash to the Vertisols led to an improvement in the soil porosity and the continuity of the pores, which leads to a decrease in the ability of the soil to retain water, which reduced the values of both field capacity and wilting point and contributed to reducing the soil swelling. [34] (p. 17) showed that the use of basaltic volcanic ash as a cover on the soil surface contributes to increasing the rate of infiltration and reducing the surface runoff and thus reducing the rate of soil erosion.

[10] (p. 16) showed that the addition of volcanic ash (pumice), zeolite and diatomite (SiO2 nH2O) contribute to an increase in both soil total porosity and permeability. [12] (p. 16), [36] (p. 17) and [23] (p. 16)) showed that the addition of fly ash to soil improves soil texture, aeration, reduces soil swelling, soil bulk density at field capacity, and reduces surface crust formation, runoff and degradation the soil. [19] (p. 16) showed when he studied some soils in the Hauran plain and Jabal Al-Arab region that the studied soils are characterized by the predominance of smectite mineral, followed by kaolinite, with a small presence of mica. In addition to good organic matter content, homogeneity of soil section, relatively

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heavy texture, and high cation exchange capacity, in the microscopic study, it was found that the surface horizon of the soil is loose and highly porous, while the subsurface horizons are compact. [28] (p. 16) showed that the soil in the village of Al Tha'ala (the study area) is located above the pyroxene olefin basement basaltic rocks. As for the clay minerals, smectite was observed, followed by kaolinite and then illite. He also showed that the type of smectite mineral is mostly nontronite, indicating that the swellable clay mineral in Vertisols could be one of the smectite group minerals and this is consistent with [35] (p. 17). The justifications of Research lie in: 1-Poor physical properties of Vertisols in the Hauran plain, especially the permeability and porosity due to the poor texture and the high level of swellable clay when humidified, which causes cracking when dry, thus damaging the roots. 2- These soils are subject to erosion after being saturated with water if they are found in sloping terrain, especially when there is no vegetation cover. 3-Volcanic ash is widely available in the regions of southern Syria, such as Shahba, Tel Shehan, Tel Dakoura, the site of the castle and the site of Qararah, as well as some areas of northern Syria [6] (p. 16) and the ease of obtaining and transporting it to benefit from it.
The research objectives to 1- Study of some water-physical properties of Vertisols in the southern region (Houran plain). 2-Improving some of the water-physical properties of these soils.

2. Materials and Methods

2.1. Research Materials

The study area included the eastern part of the Hauran Plain on the south of Syria, where Vertisols samples were collected from the village of Al Thaala in Al Suwayda Governorate, from a depth of (0-30) cm. Volcanic ash samples were collected from Al Shahba region, where they were crushed and sieved on sieves with diameters of 2-4 mm and less than 2 mm to obtain two sizes of ash, the first less than 2 mm and the second 2-4 mm, then ash samples were added to the soil and mix it homogeneously. The experiment was designed within pots with a capacity of 4 kg of soil, and the experiment was designed according to a complete random design with one factor with two levels, where the first level was (a) volume of ash, and the number of its treatments was(a=2), which are (2-4) mm and less than 2 mm,

The second level b is the level of ash, and the number of its treatments is b=3, which is (1.25, 2.5, 5%) by volume of the soil, which is equivalent to 37.5, 75 and 150 m3.ha-1 of ash. The analysis of variance test ANOVA-F-test- was used to find out if there are significant difference between the studied treatments, and then the treatments were arranged according to the least significant difference LSD test, as well as the CV (%) coefficient was calculated to indicate.

the extent of the dispersion of the data, at a level of significance 5% ($p \leq 0.05$), the statistical analysis program Genstat 12th edition was used [30] (p. 16). The treatments were as follows:

Treatment of ash volume less than 2 mm: denoted by a1 with volcanic ash levels, the treatments were as follows:

Treatment 1: Add 1.25% of volcanic ash by three replicates (three pots) and its symbol is a1b1, and this is equivalent to (37.5 m3.ha-1).

Treatment 2: Add 2.5% of volcanic ash by three replicates (three pots) and its symbol is a1b2, and this is equivalent to (75 m3.ha-1).

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Treatment 3: Add 5% of volcanic ash by three replicates (three pots) and its symbol is a1b3, and this is equivalent to (150 m3.ha-1).

Ash volume treatment from (2-4) mm: symbolized by a2 with volcanic ash levels, the treatments were as follows:

Treatment 4: Add 1.25% of volcanic ash by three replicates (three pots) and its symbol is a2b1, and this is equivalent to (37.5 m3.ha-1).

Treatment 5: Add 2.5% of volcanic ash by three replicates (three pots) and its symbol is a2b2, and this is equivalent to (75 m3.ha-1).

Treatment 6: Add 5% of volcanic ash by three replicates (three pots) and its symbol is a2b3, and this is equivalent to (150 m3.ha-1).

Treatment 7: The control was soil without adding volcanic ash with three replicates (three pots) and its symbol is a0.

There were 21 pots. The experiment was carried out during one agricultural season 2018/2019 at the Faculty of Agriculture - Damascus University, wheat (class Sham 3) was planted as a cover plant on 12/15/2018 and harvested on 25/6/2019.

The fertilization process was carried out according to the fertilizer recommendation of the Ministry of Agriculture for high yielding rainfed wheat in the second settlement area where nitrogen fertilizer was added in the form of urea (46%), equivalent to 163 kg.ha-1, and triple superphosphate fertilizer (46%) including equivalent to 167 kg.ha-1, and potassium sulfate equivalent 60 kg.ha-1. The irrigation process was carried out depending on the field capacity, so that the watering takes place when the humidity drops to 80% of the field capacity, taking into account the rotation and change of the places of the pots every period to ensure uniformity of exposure to the sun.

1- Mechanical composition: Using the hydrometer method with the addition of sodium hexametaphosphate solution as a separator [17] (p. 16).

2- Bulk density (g.cm-3): By the field cylinder method [8] (p. 16)**, in the field and in** the laboratory for saturation, field capacity and complete air dryness.

3-The true density: the true density (**g.cm-3**): By the pycnometer method [9] (p. 16)

4-The Coefficient of linear extensibility (COLEL) (%): It was calculated mathematically after measuring the height of the soil within the metal cylinder when it was saturated and completely air dried by letting the soil sample air dry under the laboratory atmosphere for three months as follows [25] (p. 16):

$$COLEL = \frac{(LM - LD)}{LD} \times 100$$

Where:

COLEL: Longitudinal bulge coefficient (%).

LM: Height of the soil within the cylinder at saturation (cm).

LD: Height of the soil within the drum when air dried (cm).

5-The total volumetric swelling coefficient (COLEV) (%): It was calculated mathematically after measuring the volume of the soil inside the cylinder when saturated and completely dry as follows [25] (p. 16):

$$\boldsymbol{OLEV = \frac{(VM - VD)}{VD} \times 100}$$

where:

COLEV: Total volumetric swelling coefficient (%).

VM: Volume of soil within the cylinder at saturation (cm).

VD: The volume of soil within the cylinder when completely dried out aerobically (cm).

6-Constant Infiltration Rate IR (cm.h-1): The double cylinder method was used, where a cylinder with a diameter of (10 cm) was placed in the middle of the pot so that it represented the inner cylinder and the pot wall represented the outer cylinder [25] (p. 16):

7-Weight moisture content at saturated (%) $\boldsymbol{\theta_{gS}}$: The pots were irrigated by adding different volumes of water at different intervals until the water began to seep from the bottom of the pot and a watery layer was formed on the surface of the soil. After a period

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of two hours, samples were taken using metal cylinders of known size and placed in the oven until completely dry, then the weight and bulk density when saturated was calculated [11] (p. 16):

8-**Weight moisture content at field capacity (%):** θ_{gFC} The previous pots were covered after saturation (as mentioned above) with plastic strips tightly to prevent evaporation for 72 hours, then samples were taken using cylinders of known size and placed in the oven until complete dryness and then the content was calculated

Weight moisture and bulk density at field capacity [11] (p. 16).

9- **The volume of infiltrated water VIW (m3.h-1):** It was calculated after calculating the water content at saturation and the field capacity (%) assuming the absence of evaporation as follows:

$$VIW=(\theta_{gs} - \theta_{gFC})\times\rho_{bfc} \times h$$

where:

VIW: Volume of infiltrated water in **m3.h-1.**

θ_{gs}= The content of weight welt at (%).

ρ_{bfc}= Bulk density at field capacity.

θ_{gFC} = The content of weight welt at saturate (%).

h = Depth (cm) it is the depth of the collected samples.

[22] (p. 16).

10- **The weighted moisture content at the wilting point (%) $\boldsymbol{\theta_{gpf}}$**: The weighted moisture content at the wilting point was calculated by estimating the maximum hygroscopicity of the soil by placing it in a humidifier containing a saturated solution of potassium sulfate and multiplying it by 1.3 where the permanent wilting coefficient (WP) is equal to 1-3 times the maximum hygroscopicity For most soils, on average, the permanent wilting coefficient was considered to be equal to the hygroscopic maximum multiplied by 1.3 [3] (p. 16).:

11-**Available water volume AW (m3.h-1)**: It was calculated after calculating the field capacity and the wilting point.

As follows - [11] (p. 16):

$$AW =(\theta_{gfc} - \theta_{gpf}) \times\rho_{bfc} \times h$$

Aw: Volume of Available Water **m3.h-1.**

θ_{gFC} = The content of weight welt at saturate (%).

θ_{gpf}= The content of weight welt at WP.

ρ_{bfc}= Bulk density at field capacity.

h= Depth (cm) it is the depth of the collected samples.

[22] (p. 16).

12-**Hygroscopic**: By drying in the oven at a temperature of 105° C for 24 hours until the weight is stable [22] (p. 16).

3. Results

The results of the water-physical analyzes of the soil before adding volcanic ash to it showed that it is characterized by a high clay content (25-59%) and it has a very fine texture, according to the American Triangle of Strength [32] (p. 17) (Soil Survey Division Staff, 1993), as shown in Table (1).

The bulk density of the volcanic ash used in this research was 0.89 g.cm^{-3}, and the particle density was 2.20 g.cm^{-3}.

Table (1). Results of some physical analyzes of the soil sample before adding volcanic ash to it.

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Mechanical composition (%)			Soil texture	Bulk density	Particle density	Total porosity
sand	silt	clay		g.cm^{-3}		(%)
26.30	14.45	59.25	clay	1.17	2.73	57.14

3-1-Effect of adding different levels and volumes of volcanic ash on the mechanical composition of soil (%):

- **Average sand content of soil**:(%)

The results of the statistical analysis of the percentage values of sand when comparing the volumes of volcanic ash added and the control within the b_1 level showed that the size a_2 was superior to the size a_1 and the treatment of the control a_0 with significant differences, while there were no significant differences between the size a_1 and the treatment of the control a_0, as well as at the level of b_2 The size a_2 outperformed, followed by the size a_1, then the control treatment, while within the b_3 level, the two treatments a_1 and a_2 outperformed the control treatment with significant differences without significant differences between the two mentioned sizes, as shown in table (2).

Table (2). Effect of adding different volumes of volcanic ash on the soil content of sand (%).

Ash volume (Mm)	Ash level (%)		
	b_1 = 1.25	**b_2 = 2.50**	**b_3 = 5.00**
a_0 = control	26.30$_b$	26.30$_b$	26.30$_b$
a_1 = 2 >	27.50$_b$	30.00$_b$	30.17$_a$
a_2 = 2-4	30.03$_a$	32.47$_a$	32.50$_a$
LSD$_{(0.05)}$	0.1776	0.2401	2.528

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

- **Average soil silt content (%):**

The results of the statistical analysis of the values of the percentage of silt when comparing the volumes of volcanic ash added and the control treatment showed that the size a_1 exceeded all the studied treatments with significant differences without significant differences between the control treatment a_0 and size a_2 for all levels of studied addition, as shown in table (3).

Table (3). Effect of adding different volumes of volcanic ash on soil content of silt (%).

Ash volume (Mm)	Ash level (%)		
	b_1 = 1.25	**b_2 = 2.50**	**b_3 = 5.00**
a_0 = control	14.45$_b$	14.45$_b$	14.45$_b$
a_1 = 2 >	18.76$_a$	18.85$_a$	19.73$_a$
a_2 = 2-4	14.97$_b$	15.00$_b$	15.00$_b$

$LSD_{(0.05)}$	0.2528	0.1917	2.529

The different letters within the same column indicate the presence of significant differences ($P \leq 0.05$).

- **Average soil clay content (%):**

The results of the statistical analysis showed when comparing the volumes of volcanic ash added and the control treatment. The control treatment a_0 outperformed all the studied treatments with significant differences, followed by the size a_2 and then the size a_1 at the level for all levels of the studied addition, as shown in table (4).

Table (4). The effect of adding different volumes of volcanic ash on the soil content of clay (%).

Ash volume (Mm)	Ash level (%)		
	$b_1 = 1.25$	$b_2 = 2.50$	$b_3 = 5.00$
a_0 = control	59.25_a	59.25_a	59.25_a
a_1 = 2 >	53.65_c	51.24_c	50.10_c
a_2 = 2-4	55.00_b	52.53_b	52.50_b
$LSD_{(0.05)}$	0.1762	0.103	0.1332

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

The increase in the soil content of sand and more of silt and the decrease of clay directly with the levels of addition can be explained when adding a_1 volcanic ash to the grinding and sieving process, which led to a decrease in the size of the ash particles to the size of the silt particles more than to sand, which in turn will contribute to the improvement The texture of the studied clay soils is consistent with [18] (p. 16).and [21] (p. 16) While in size a_2, the soil was not ground and sifted during mechanical analysis on a_2 mm diameter sieve to maintain its mechanical structure, so the ash grains (2-4) mm entered the range of sand and silt grains.

3-2-Average bulk density ρ_b *at field capacity (g.cm-3)*:

The results of the statistical analysis of bulk density values when comparing the two added volumes of volcanic ash showed that size a_1 and size a_2 outperformed the control within level b_2, while there were no significant differences between the two volumes and the control a_0 within level b_1, while within level b_3 the size a_1 followed by size outperformed. a_2 and then witness a_0, as shown in table (5).

Table (5). The effect of adding different volumes of volcanic ash on the bulk density at field capacity (g.cm-3).

Ash volume (Mm)	Ash level (%)		
	$b_1 = 1.25$	$b_2 = 2.50$	$b_3 = 5.00$
a_0 = control	1.06_a	1.06_b	1.06_c
a_1 = 2 >	1.07_a	1.08_a	1.12_a

a_2 = 2-4	1.07_a	1.08_a	1.11_b
LSD(0.05)	0.0182	0.0275	0.0232

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

3-3-Average Bulk Density ρ_b (g.cm-3) of Air Dry Soil:

The results of the statistical analysis of air-dry bulk density values showed when comparing the two added volumes of volcanic ash. The control treatment a_0 outperformed a_1 and a_2 for all added volcanic ash levels, while there were no significant differences between the volume treatments a_1 and a_2 table (6) illustrates this.

Table (6). Effect of adding different volumes of volcanic ash on the air-dry bulk density (g.cm-3).

Ash volume (Mm)	Ash level (%)		
	b_1 = 1.25	**b_2 = 2.50**	**b_3 = 5.00**
a_0 = control	1.53_a	1.53_a	1.53_a
a_1 = 2 >	1.39_b	1.32_b	1.29_b
a_2 = 2-4	1.41_b	1.33_b	1.31_b
LSD(0.05)	0.0791	0.0972	0.0886

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

The bulk density of swellable soils (Vertisols) is closely related to the total porosity of the soil, the diameter of the pores, the moisture content of the soil and thus the extent of swelling, shrinkage and compaction of the soil, and everything that affects the porosity and moisture content affects the bulk density. It is noted through the results obtained that the addition of volcanic ash contributed to reducing the moisture content of the soil, whether at full saturation or at field capacity as a result of an increase in the leaching rate and a decrease in the soil's ability to retain water. Which slightly contributed to a decrease in soil swelling and a decrease in its volume, and consequently an increase in the bulk density of the soil for all the studied treatments, especially the treatment (a_1b_3) compared to the control, where the moisture content of the control was greater and thus greater swelling compared to the rest of the treatments and this is consistent with (Adriano and Weber, 2001). It is concluded that the swelling of Vertisols is directly proportional to their moisture content and inversely with the levels and volume of volcanic ash added and bulk density, which is consistent with what reported in Fredlund and Rahardjo.(1993), As for the increase in the values of the bulk density of the control (1.5) $g.cm^{-3}$ compared to the soil treatments to which volcanic ash was added (1.3) $g.cm^{-3}$, it is due to the greater shrinkage of the control samples and their lower volume as a result of their high moisture content and the role of volcanic ash in reducing the moisture content and consequently soil shrinkage. [14] (p. 16).

3-4-The average of true density ρ_s (g/cm3):

The results of the statistical analysis of the true density values when comparing the volumes within the same level showed that there were no significant differences between all the treatments table (7) illustrates this.

Table (7). The effect of adding different volumes of volcanic ash on the true density (g.cm3).

Ash volume (Mm)	Ash level (%)		
	$b_1 = 1.25$	$b_2 = 2.50$	$b_3 = 5.00$
a_0 = control	2.730_a	2.720_a	2.725_a
$a_1 = 2 >$	2.730_a	2.717_a	2.722_a
$a_2 = 2\text{-}4$	2.730_a	2.710_a	2.717_a
$LSD_{(0.05)}$	2.730_a	2.720_a	2.725_a

The different letters within the same column indicate the presence of significant differences ($p \le 0.05$).

The inverse relationship between the volume of volcanic ash added and the true density of the soil is due to the decrease in the true density of volcanic ash compared to the true density of the soil, and no significant differences appeared under the conditions of this experiment due to the low levels of added ash, where significant differences require adding ash at a level exceeding 10%.

3-5-Effect of adding different levels and volumes of volcanic ash on infiltration rate(IR) (cm.h-1):

Fig. (1, 2) show the effect of adding different levels and volumes of volcanic ash on constant Infiltration Rate of the soil. Usually, the Infiltration Rate is rapid in the beginning and then begins to decrease with the passage of time until it becomes almost constant, and this is due to several factors, as the soil is dry at first and then becomes more and more wet, The large pores are filled first, then the smaller and smaller pores are filled with water in addition to the possibility of demolition to build up and blockage of small pores with fine soil particles under the influence of the intensity of rainfall or irrigation, which leads to a decrease in the leaching rate. Pores, which in turn affects the filtration rate and causes it to decrease [29] (p. 17).

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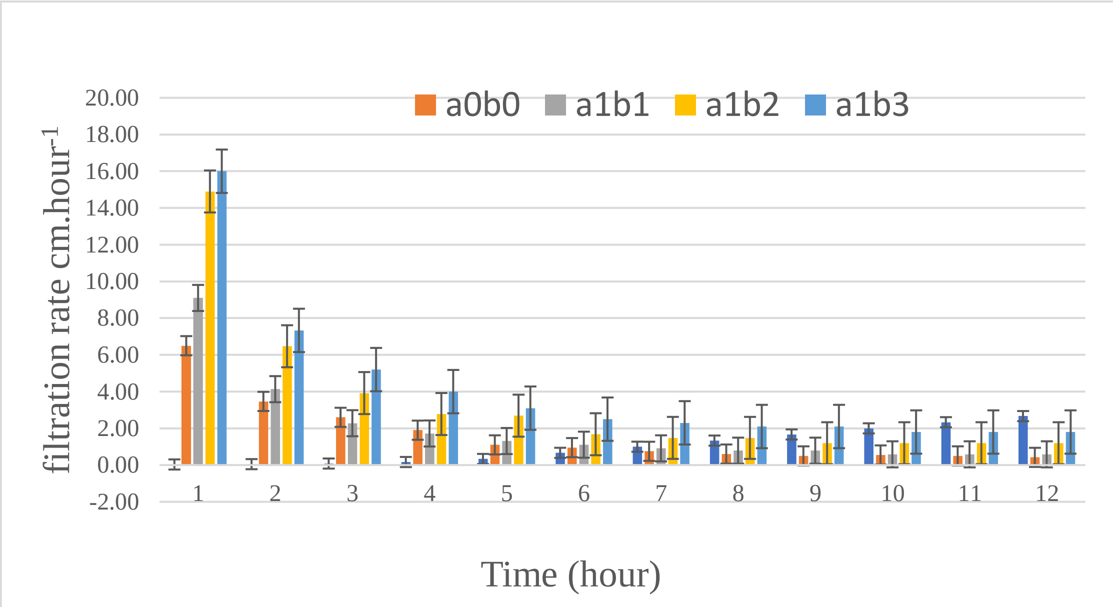

Fig. (1). Effect of adding different levels of volcanic ash a1 size (<2mm) on the constant Infiltration rate.

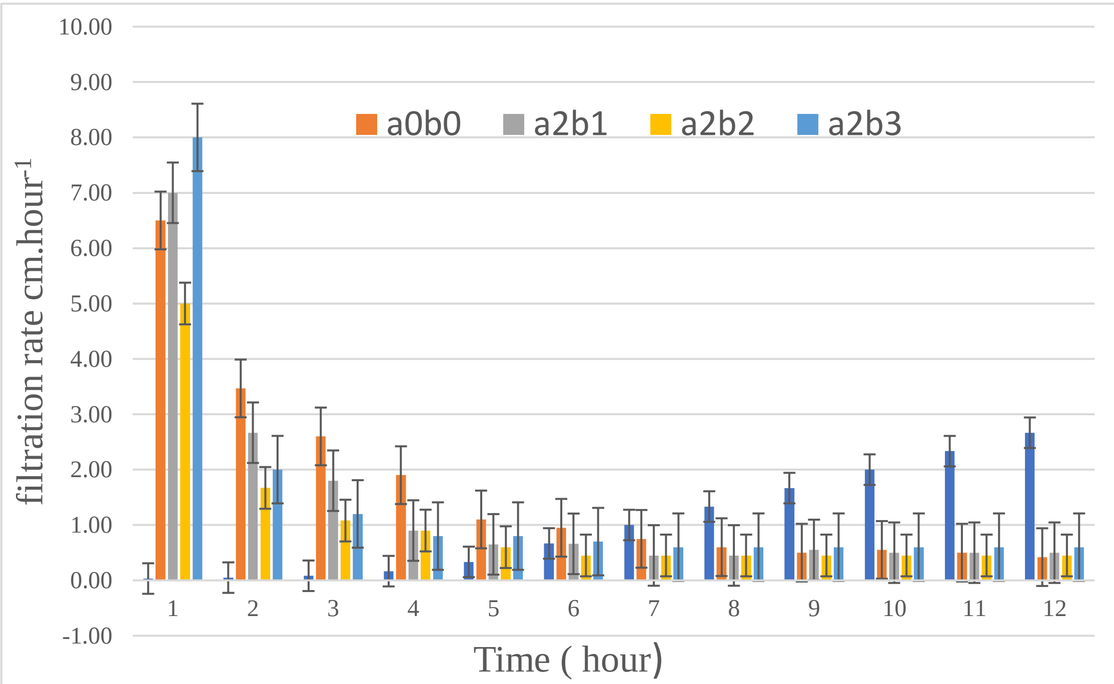

Fig. (2). Effect of adding different levels of volcanic ash with a size of a2 (2-4) mm on constant Infiltration rate.

The results of the statistical analysis of the values of the fixed Infiltration rate showed that the addition of volcanic ash contributed significantly to the increase of the fixed Irrigation rate. When comparing the two added volumes of volcanic ash, the volume a_1 significantly outperformed the volume a_2 and the control for the levels of addition b_1 and b_2 and the percentage increase was (38.1, 183.3) (%) respectively compared to the control and (34.9, 164.4)% respectively compared to treatment a_2, while there were no significant differences between the treatments of size a_2 and the control, while at level b_3, the size a_1

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outperformed, followed by the size a_2 while the control a_0 occupied the rank The latter, as shown in table (8).

Table (8). Effect of adding different volumes of volcanic ash on constant Infiltration rate (cm.hr-1).

Ash volume (Mm)	Ash level (%)		
	b_1 = 1.25	**b_2 = 2.50**	**b_3 = 5.00**
a_0 = control	0.42_b	0.42_b	0.42_c
a_1 = 2 >	0.58_a	1.19_a	1.80_a
a_2 = 2-4	0.43_b	0.45_b	0.60_b
$LSD_{(0.05)}$	0.0834	0.509	0.1668

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

Soil infiltration is an important factor in water management in an area because it affects the amount of water that can percolate into the soil. Reduced infiltration can lead to increased surface run-off, soil erosion, and reduced water drainage, which may cause flooding and waterlogging in agricultural areas. On the other hand, a decrease in the rate of infiltration leads to a decrease in the rates of water that recharges the aquifer. There are many factors that affect infiltration rate such as rainfall rate, soil texture, type of clay minerals, surface crust and land use, and consequently the addition of volcanic ash led to a transition in infiltration velocity from the clay soil class to the loam class, [22] (p. 16). Within the conditions of this experiment and based on the results obtained, an increase in the constant infiltration rate, especially within treatment a_1b_3, can be attributed to the following:

1-The soil texture improved as a result of increasing the proportion of sand and silt at the expense of decreasing the proportion of clay, and the higher the proportion of sand and silt, the faster the infiltration.
2-An increase in the percentage of air porosity responsible for the transfer and leaching of water at the expense of decreasing the water porosity and also the increase in the diameters of the pores as a result of the formation of large-sized dirt aggregates (building units) that form large pores between them that improve soil aeration and its ability to filter water.
3-The increase in the infiltration rate is not only due to the improvement in the mechanical composition of the soil only, but also to the earthen aggregates that ensure the continuity and continuity of the pores and the homogeneity of their distribution, which ensures the continuity of the water movement downward, and this was not achieved well when adding volcanic ash of volume (2 -4) mm because large volcanic ash particles are more likely to be filled with small clay particles that clog the large pores of volcanic ash with the passage of time and thus hinder the leaching process. This is consistent with [21] (p. 16); [10] (p. 16)

4-The decrease in the infiltration rate in the control treatment compared to the rest of the treatments is attributed to the decrease in the air porosity and the occurrence of a greater swelling of the soil and to the decrease in the pore diameters and directly with the increase in the proportion of clay and moisture content [20] (p. 16).

5-Increasing the water infiltration rate as a result of adding volcanic ash contributes to the rapid disposal of free water to the bottom of the soil sector, reducing surface run-off and soil susceptibility to water erosion [34] (p. 17). waterlogging and suffocation of plant roots, especially when there is an impermeable layer that is impermeable to water.

3-6-Effect of adding different levels and volumes of volcanic ash on the moisture content when saturated (%):

The results of the statistical analysis showed that when comparing the added volumes of volcanic ash a_1 and a_2 and the control treatment a_0 within the level of b_1, b_2 and b_3, it was noted that the control treatment a_0 was superior to the studied treatments, while there were no significant differences between the treatments except for the treatment a_1b_3 where the value of the moisture content at saturation was the lowest and reached (55.55) % as shown in table (9).

Table (9). Effect of adding different volumes of volcanic ash on the moisture content at saturation (%).

Ash volume (Mm)	**Ash level (%)**		
	b_1 = 1.25	**b_2 = 2.50**	**b_3 = 5.00**
a_0 = control	61.44_a	61.44_a	61.44_a
a_1 = 2 >	60.10_b	58.72_b	55.55_c
a_2 = 2-4	60.08_b	58.54_b	57.38_b
$LSD_{(0.05)}$	0.694	0.3392	0.3512

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

This can be explained by the role of the added volcanic ash in reducing the clay content and improving the soil texture and structure, which helped to increase the infiltration rate and reduce the soil's ability to retain moisture, thus reducing the moisture content retained in the soil, [20] (p. 16); [34] (p. 17).

3-7-Effect of adding different levels and volumes of volcanic ash on the field capacity (%):

The results of the statistical analysis of field capacity values showed that when comparing the volumes of volcanic ash added and the control within the b_1 level, there were no significant differences between the studied treatments. There were significant differences within the b_3 level, where the treatment a_0 outperformed the two treatments a_2b_2 and a_1b_3 with significant differences, where the highest value of the treatment a_0 reached (54.38%), followed by treatment a_2b_3 (49.15) %, and in the last place came the treatment a_1b_3 by (46.18%) As shown in table (10).

Table (10). Effect of adding different volumes of volcanic ash on field capacity (%).

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Ash volume (Mm)	Ash level (%)		
	$b_1 = 1.25$	$b_2 = 2.50$	$b_3 = 5.00$
a_0 = control	54.38$_a$	54.38$_a$	54.38$_a$
$a_1 = 2 >$	53.47$_a$	51.33$_b$	46.18$_c$
a_2 = 2-4	53.60$_a$	52.34$_b$	49.15$_b$
LSD$_{(0.05)}$	2.334	1.666	1.192

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

The decrease in soil moisture content at field capacity with an increase in the added ash levels may be attributed to the fact that the addition of volcanic ash reduced the proportion of clay and increased the proportion of sand and silt, which in turn led to an increase in the size of air pores, an increase in the volume of leached water, and a decrease in the moisture tensile strength, thus reducing the capacity of Soils to retain water [20] (p. 16), [24] (p. 16). 3-8- Effect of adding different levels and volumes of volcanic ash on the volume of percolating water (m3.ha-1):

The addition of volcanic ash contributed to an increase in the volume of leaching water within the soil sector, as the results of the statistical analysis showed when comparing the comparison between the volumes of volcanic ash added and the control within the b_1 level and the b_2 level, there were no significant differences between the studied treatments, while there were significant differences within at the b_3 level, treatment a_1b_3 (314.6) $m^3.h^{-1}$ outperformed treatments a_2b_2 and a_0 with significant differences, followed by treatment a_2b_3 (275) $m^3.h^{-1}$, and then treatment a_0 (224.8) $m^3.h^{-1}$, as shown in table (11).

Table (11). Effect of adding different volumes of volcanic ash on the volume of percolating water (m3.h-1).

Ash volume (Mm)	Ash level (%)		
	$b_1 = 1.25$	$b_2 = 2.50$	$b_3 = 5.00$
a_0 = control	224.8$_a$	224.8$_a$	224.8$_c$
$a_1 = 2 >$	213.4 $_a$	259.5$_a$	314.6$_a$
a_2 = 2-4	207.8$_a$	200.5$_a$	275.0$_b$
LSD$_{(0.05)}$	87.9	61	23.96

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

Increasing the rate of infiltration water to the bottom of the soil sector may contribute to increasing the storage of sub-surface water in the soil and the possibility of using it later during drought periods, and also contribute to reducing surface run-off and the vulnerability of the soil to water erosion [34] (p. 17).

3-9-Effect of adding different levels and volumes of volcanic ash on WP (%):

The addition of volcanic ash led to a decrease in the moisture content at the withering point, as the results of the statistical analysis showed that when comparing the volumes of volcanic ash added and the control within the b_1 level, there were no significant differences between the studied treatments, while there were significant differences within the b_2 and b_3 levels, where The control outperformed both sizes a_1 and a_2 with significant differences without any differences between the two mentioned sizes, as shown in table (12).

Table (12). Effect of adding different volumes of volcanic ash on wilting point WP(%) .

Ash volume (Mm)	Ash level (%)		
	$b_1 = 1.25$	$b_2 = 2.50$	$b_3 = 5.00$
a_0 = control	31.82_a	31.82_a	31.82_a
a_1 = 2 >	31.36_a	30.47_b	28.10_b
a_2 = 2-4	31.31_a	30.50_b	28.41_b
$LSD_{(0.05)}$	0.5273	0.476	0.662

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

3-10-Effect of adding different levels and volumes of volcanic ash on the volume of soft water Available water (m3.ha-1):

The addition of volcanic ash contributed to a decrease in the volume of soft water within the soil sector, as the results of the statistical analysis showed that when comparing the volumes of volcanic ash added and the control within the b_1 level, there were no significant differences between the studied treatments, while there were significant differences within the b_2 level and the level b_1. b_3, where the control and size a_2 outperformed the size a_1 with significant differences, as shown in table (13).

Table (13). Effect of adding different volumes of volcanic ash to soft Available water (m3.ha-1).

Ash volume (Mm)	Ash level (%)		
	$b_1 = 1.25$	$b_2 = 2.50$	$b_3 = 5.00$
a_0 = control	717.29_a	717.29_a	717.29_a
a_1 = 2 >	709.89_a	673.85_b	607.75_b
a_2 = 2-4	715.56_a	707.82_a	690.69_a
$LSD_{(0.05)}$	30.14	27.39	31.18

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

It is noted from the previous tables that the addition of volcanic ash contributed to a decrease in the moisture content at the point of wilting, as well as in the volume of soft water for the plant. It must be pointed out that the water facilitated in the control treatment is not completely available to the plant due to the high binding strength on the surfaces of the fine soil particles and this may cause water stress for the cultivated plants

3-11-Effect of adding different levels and volumes of volcanic ash on the hygroscopicity (%):

The results of the statistical analysis of hygroscopic values showed when comparing the volumes of volcanic ash added and the control within the levels b_1, b_2, and b_3. It was noted that the control treatment a_0 was superior to all treatments with significant differences, where the treatment a_0 came in the first place, followed by the size a_2, and then the size a_1 which came in the last rank, as shown in table (14).

Table (14). Effect of adding different volumes of volcanic ash on hygroscopicity (%).

Ash volume (Mm)	Ash level (%)		
	b_1 = 1.25	b_2 = 2.50	b_3 = 5.00
a_0 = control	7.93_a	7.93_a	7.93_a
a_1 = 2 >	7.81_c	7.7_c	7.62_c
a_2 = 2-4	7.89_b	7.93_b	7.65_b
$LSD_{(0.05)}$	0.01153	0.01332	0.01332

The different letters within the same column indicate the presence of significant differences ($p \leq 0.05$).

The inverse relationship between the added ash levels and the hygroscopic percentage can be explained by the decrease in the total specific surface area due to the decrease in the soil content of clay versus the increase in the soil content of sand and silt

4. suggestions

Adding volcanic ash to the soil at a level of 5% and with a particle size of less than s mm.
Application of laboratory results in the field or in field conditions.
Add other enhancers with volcanic ash and at different levels such as organic waste.

Data Availability Statement: In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Please refer to suggested Data Availability Statements in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics. If the study did not report any data, you might add "Not applicable" here.

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