Assessment of the Hydrophysical Properties of Soils with Varying Calcareous Contents as Affected by Vermicompost Application and Their Impact on the Growth and Yield of Faba Bean (*Vicia faba* L.) under Northern Iraq Condition

Maram Khairallah Ahmed[1*] Wael F. A. Alshamary[2]
[1]College of Agriculture, University of Kirkuk, Iraq
[2]Department of Soil and Water Resources, College of Agriculture, University of Kirkuk, Iraq
[*]Corresponding author: aksm24022@uokirkuk.edu.iq
Email address of coauthors: waelfahmi@uokirkuk.edu.iq

Abstract
Two experiments were conducted during the autumn growing season of 2025 at the College of Agriculture, University of Kirkuk, to evaluate the hydrophysical properties of soils with different calcareous contents amended with vermicompost and to investigate their effects on the growth and yield of faba bean (*Vicia faba* L.) under northern Iraq conditions. The study included two factors: soil calcareous content at four levels (1%, 15%, 26%, and 40%), while the second factor was vermicompost application at three levels (0%, 0.4%, and 0.8% of soil weight). Both experiments were arranged in a split-plot design within a randomized complete block design (RCBD) with three replications. Data were statistically analyzed using SAS software, and treatment means were compared using Duncan's Multiple Range Test (DMRT) at the 0.05 probability level. The results showed that the treatment C1V2 significantly enhanced soil hydrophysical properties, recording the highest values of sorptivity, diffusivity, and hydraulic conductivity, whereas C4V0 recorded the lowest values. The improvement in soil hydrophysical properties was positively reflected in plant growth parameters and yield components. The treatment C1V2 produced the highest values of plant height, leaf area, green pod yield, and number of branches. Conversely, the lowest values were recorded under C4V0. This study provides new insights into improving the hydrophsical properites of calcareous soils using vermicompost. The findings support the use of vermicompost to improve soil quality and faba bean productivity.

Keywords: Calcareous soils, Vermicompost, Sorptivity, Green pod yield, *Vicia faba* L.

Introduction

Calcareous soils are among the most widespread soils in arid and semi-arid regions. They are characterized by a high content of calcium carbonate, which significantly affects their physical and chemical properties and reduces the availability of essential nutrients required for plant growth, particularly phosphorus and micronutrients such as iron and zinc. These soils are also characterized by a high pH value, which negatively impacts crop growth and productivity unless appropriate management practices are adopted to improve their fertility and enhance their agricultural utilization [3]. Calcareous soils are extensively distributed throughout Iraq due to the abundance of calcium carbonate in the parent material and the limited leaching processes. Reports by the Food and Agriculture Organization (FAO) indicate that their calcium carbonate content generally ranges from 15% to 35%, and may exceed these values in certain locations [30]. Such conditions are often associated with low organic matter content and deterioration of soil hydraulic

ISSN 2072-3857

properties and fertility characteristic. Vermicompost is considered one of the most effective organic soil amendments. It is produced through the biological decomposition of organic wastes by earthworms, resulting in a stable material rich in nutrients that enhances soil fertility and biological activity [9]. Vermicompost is distinguished by its high porosity and water-holding capacity, as well as its ability to improve soil aeration and drainage, thereby enhancing the physical and hydraulic properties the of soil and positively influencing plant productivity [19]. Such knowledge supports the efficient and sustainable management of water resources and soil conservation practices [31]. Faba bean (Vicia faba L.) is one of the most important winter legume crops of considerable economic and nutritional value due to the high protein content of its seeds [14]. Moreover, it contributes to improving soil fertility through its ability to biologically fix atmospheric nitrogen [12]. Although numerous studies have investigated the role of vermicompost in soil improvement, research evaluating its effectiveness in calcareous soils with varying calcium carbonate contents, particularly regarding soil hydraulic properties and their interaction with crop growth, remains limited and requires further investigation. This study is scientifically and practically significant because it provides valuable information for improving the management of calcareous soils and enhancing faba bean productivity under different calcareous conditions. Therefore, the present study aims to evaluate the effects of varying calcium carbonate contents and different vermicompost application levels on selected hydraulic properties of calcareous soils and to determine how these improvements are reflected in the growth parameters and yield of faba bean (*Vicia faba* L.)

Material and Methods

Study Site and Soil Sampling

Two experiments were conducted during the autumn season of 2025 at the College of Agriculture, University of Kirkuk, to evaluate the hydraulic properties of calcareous soils with varying calcium carbonate contents amended with vermicompost, as well as their effects on the growth and yield of faba bean (*Vicia faba* L.) under the environmental conditions of northern Iraq.

Soil samples were collected from the surface layer (0-0.30 m) after removing the surface crust. Sampling sites were selected based on differences in their calcareous content to represent varying levels of calcareous soils within the study area. The collected soil samples were divided into two portions:

First portion: The soil was air-dried, ground, and passed through a 2-mm sieve, then stored in plastic containers for the laboratory determination of selected physical and chemical properties.

Second portion: The soil was maintained as close as possible to its natural condition. It was gently crushed and passed through a 4-mm sieve to remove impurities and coarse fragments before being used in the experiment. Table (1) presents some of the physical and chemical properties of the

soils collected from the study sites prior to the experiment.

Table 1. Selected physical and chemical properties of the soils from the study sites before the experiment.

Property		Unit	Penjwen Soil	Rania Soil	Al-Zab Soil	Daqoq Soil
Sand			259.6	359	486	487.6
Silt		g kg^{-1}	300	160	160	200
Clay			440.4	481	354	312.4
Texture			Clay	Clay	Sandy Clay	Sandy clay loam
Bulk density		Mg m^{-3}	1.53	1.59	1.64	1.72
Particle density			2.18	2.05	1.93	2.07
Porosity		%	0.42	0.40	0.38	0.35
Mean Weight diameter (MWD)		mm	0.27	0.53	0.70	0.16
Ec		ds m^{-1}	0.40	0.35	0.49	3.70
pH			6.9	7.7	7.8	7.9
Organic matter		g kg^{-1}	10.52	13.75	19.05	6.39
$CaCO_3$			10	150	260	400
Cation and Anion	Ca^{2+}	Mmol L^{-1}	2.4	3.2	3.2	25.2
	Mg_2^{+}		3.6	4.2	8.4	35.2
	Na^{+}		0.46	0.38	0.79	5.23
	K^{+}		0.05	0.07	0.29	0.27
	Cl^{-}		0.9	0.7	0.7	4.9
	CO_3^{2-}		Nill	Nill	Nill	Nill
	HCO_3^{-}		0.08	0.13	0.16	0.11
	SO_4^{2-}		1.34	1.97	2.14	22.16

Treatments and Experimental Design

The experiment included the study of the following factors:

1. Soil Calcium Carbonate Content (C)

This factor consisted of four levels:

1. C1: 1% calcium carbonate content.
2. C2: 15% calcium carbonate content.
3. C3: 26% calcium carbonate content.
4. C4: 40% calcium carbonate content.

2. Vermicompost Application Levels (V)

Vermicompost was thoroughly mixed with the soil at a depth of 0.20 m. This factor included the following levels:

ISSN 2072-3857

1. VO: No vermicompost application (control treatment).
2. V1: Addition of vermicompost at 0.4% of the soil weight.
3. V2: Addition of vermicompost at 0.8% of the soil weight.

The experiment was conducted with three replications using a Randomized Complete Block Design (RCBD) arranged in a Split-Plot Design. Calcium carbonate levels were assigned to the main plots, while vermicompost levels were allocated to the subplots. Consequently, the study comprised a total of 12 treatment combinations.

Properties of Vermicompost

Chemical analyses were performed on the vermicompost used in the experiment to determine its characteristics. The results of these analyses are presented in Table (2).

Table 2. Selected chemical properties of the vermicompost used in the study.

Property		Unit	vermicompost
$Ec_{(1:2.5)}$		ds m^{-1}	7.7
$pH_{(1:2.5)}$			7.8
Organic matter		%	6.08
Organic carbon			3.53
Available nutrients	Phosphorus (P)	Mg kg^{-1}	384.73
	Potassium (k)		4866
Cation and Anion	Ca^{2+}	Mmol L^{-1}	15.2
	Mg_2^{+}		14.2
	Na^{+}		7.32
	K^{+}		5.49
	Cl^{-}		68.8
	CO_3^{2-}		Nill
	HCO_3^{-}		0.33
	SO_4^{2-}		18.38

Incubation Experiment

The incubation experiment was conducted in the wooden shade house of the College of Agriculture, University of Kirkuk, to investigate the effects of different calcium carbonate contents and vermicompost application levels on the hydraulic properties of soil. Plastic pots were filled with 10.5 kg of soil previously sieved through a 4-mm mesh and thoroughly mixed with vermicompost according to the designated treatment levels. The soils were incubated in the pots for two months at field capacity.

Plant Growth Experiment

The same treatments and experimental design described previously were adopted. Pots were sown on 16 October 2025 using seeds of the faba bean cultivar RAMA F1. Seeds were planted at a depth of 5cm, with five seeds per pot. After emergence, seedlings were thinned to three plants per pot. Standard crop management practices

ISSN 2072-3857

were applied throughout the growing season, including manual weed control and fertilization with compound fertilizer, urea, triple superphosphate, and humic acid according to the recommended guidelines[2]. Irrigation was scheduled whenever 50% of the available water had been depleted, as determined using a Moisture Sensor v1.2.

Measured Parameters

1. Hydraulic Properties of the Study Soils

Soil sorptivity was determined from the relationship between cumulative infiltration and the square root of time according to the equation proposed by [25].

$$S = \frac{I}{\sqrt{t}} \quad \text{(1)}\ldots\ldots\ldots\ldots$$

Where:

S = sorptivity (cm min $^{-1/2}$),

I = cumulative water infiltration depth(cm)

T $^{1/2}$ = square root of time (min$^{-1/2}$).

Soil permeability was calculated based on the advance distance of the wetting front with time under horizontal water flow through soil columns, according to the method proposed by [18], using the following equation:

$\lambda = X\, t^{-1/2}$ ... ...(2)

Where:

λ = soil water permeability (cm min $^{1/2}$)

X = distance of wetting front advance (cm)

t$^{1/2}$ = square root of time (min$^{1/2}$).

Soil water diffusivity was estimated using unsaturated hydraulic conductivity data and the slope of the soil water retention curve, following the equation proposed by [23], as presented below:

$$D(\theta) = \frac{K(\theta)}{C(\theta)} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

2. Plant Growth Parameters and Yield

At the time of full flowering, plant height was measured by taking an average of three plants selected from each experimental unit. The number of branches per plant was also recorded at the time of full flowering. Mean values of the selected plants within each experimental unit were calculated. unit was recorded. Leaf area was estimated using a flatbed scanner and Image software according to the method described by [28]. a plant population density of 80,000 plants ha^{-1}, using the following equation:

Green pod yield (Mg ha^{-1}) = Average

yield per treatment × Plant population density ..... (4)

Results and Discussion

1. **Effect of Calcareous Content and Vermicompost on Soil Hydraulic Properties**

Sorptivity (cm min $^{-1/2}$)

Sorptivity is defined as the capillary absorption of water by the soil and hence describes the very initial process of movement of water into the soil under dry conditions. It is mainly governed by the size and distribution of fine pores and

ISSN 2072-3857

organic matter that enhances the capacity of the soil to absorb and hold water.

Figures (1 and 2) show the relationship between the square root of time ($t^{1/2}$) against cumulative infiltration depth (I) for different calcium carbonate contents in the soil at various levels of vermicompost application. The points on the graph are the measured values, while the straight lines are the best fit lines obtained by linear regression for each treatment. There was a good, positive linear relationship between

cumulative infiltration depth (I) and the square root of time ($t^{1/2}$) across all treatments, consistent with the findings of [25]. Furthermore, R^2 values were very high for all treatments, ranging from 0.92 to 0.985, showing a very good fit of the linear model. The slope of the regression line between cumulative infiltration depth (I) and $t^{1/2}$ is the soil sorptivity. There were noticeable differences in the slopes among treatments, which indicate the differences in sorptivity values resulting from the differences in soil calcareous content and vermicompost application rates.

Sorptivity values were always higher in soils with low calcium carbonate content compared to soils with high calcareous content.

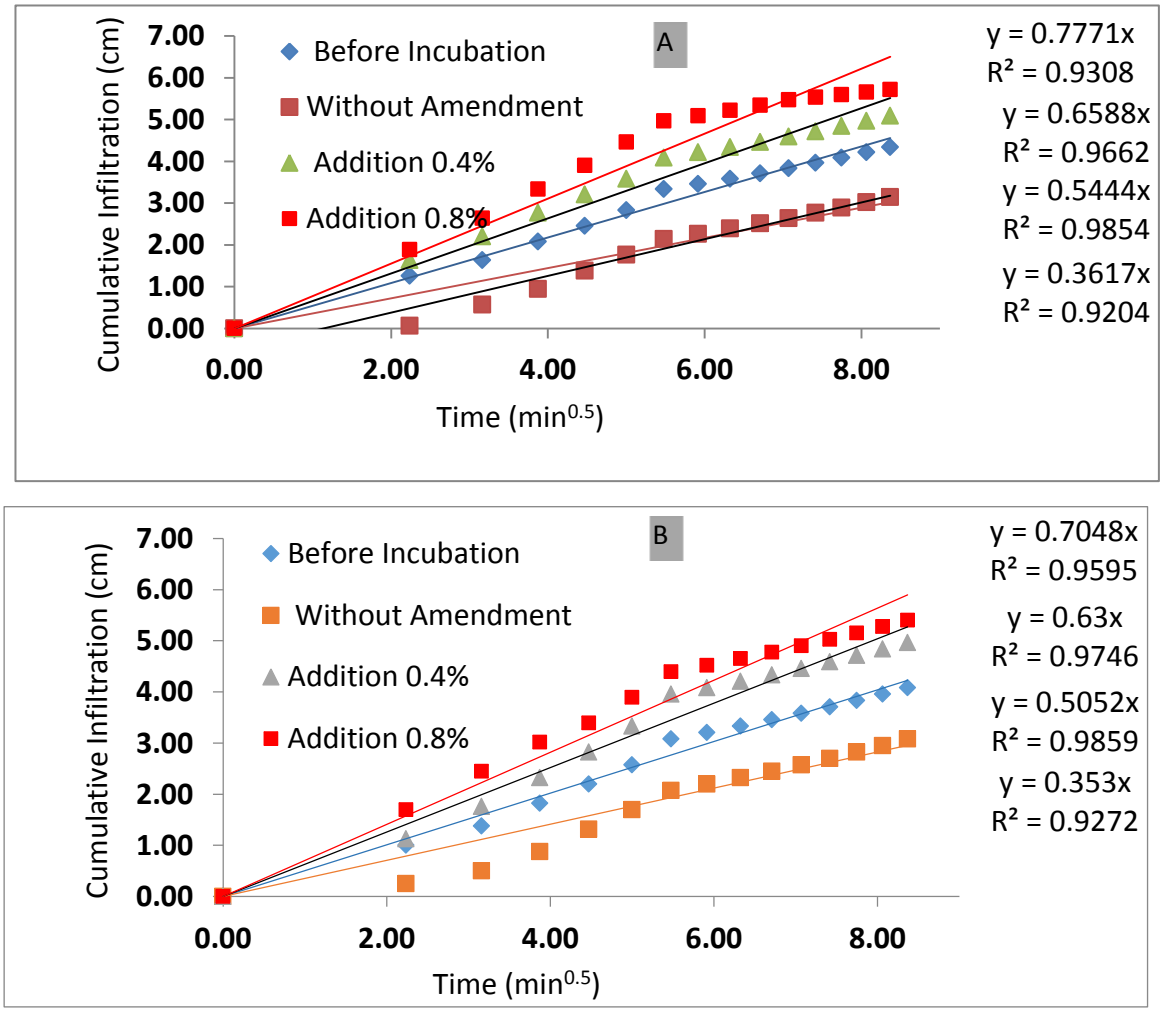


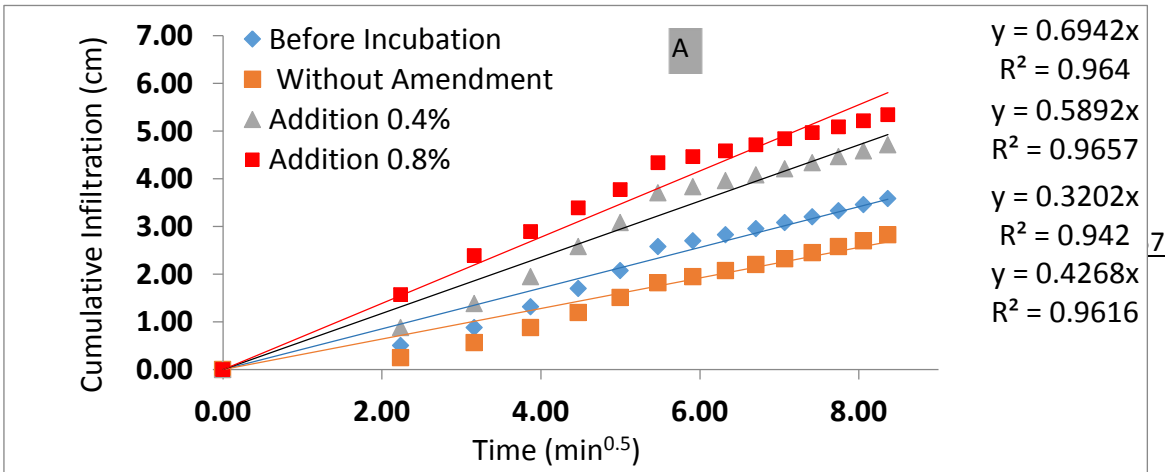
Figure 1. Effect of calcareous soil content and vermicompost application on soil sorptivity (cm $min^{-1/2}$) in (A) Penjwen soil and (B) Rania soil.

ISSN 2072-3857

This may be attributed to the increased calcium carbonate concentration, which alters the soil pore-size distribution by increasing the proportion of larger pores. In addition, calcium carbonate promotes the precipitation of cementing materials between soil particles, reducing pore continuity and consequently decreasing the rate of water entry into the soil. The addition of vermicompost markedly increased sorptivity compared with the control treatment, and this improvement became more pronounced with increasing application rate. The highest sorptivity values were recorded at the highest vermicompost application level (0.8%), regardless of soil calcium carbonate content. This improvement can be attributed to the role of vermicompost in enhancing soil structure and aggregate stability, thereby increasing total porosity and improving pore-size distribution, particularly the continuity of pores which conduct water, and in the end, the capacity of the soil to absorb water. Figures (1A and 1B) and (2A and 2B) also clearly show differences in sorptivity among the studied soils. Sorptivity decreased progressively with increasing content of calcium carbonate, as soils with lower calcareous content consistently had higher values than those with higher calcareous content. These results show that soil calcium carbonate content has a very significant effect on this hydraulic property.

An increase in calcium carbonate content would disrupt the soil pore system by decreasing the continuity of effective pores and increasing the process of cementation, which would increase hydraulic resistance and decrease the capacity of the soil to absorb water.

On the other hand, soils with low calcium carbonate content have a more stable network of pores connected well which facilitates the movement of water and gives higher values of sorptivity. A slight deviation from linearity was observed at the later stage of measurement. This can be attributed to the decreasing matric potential with time of infiltration due to the increase in soil water content and the subsequent reduction in capillary forces and the greater effect of gravitational forces, thus retarding the rate of water absorption.



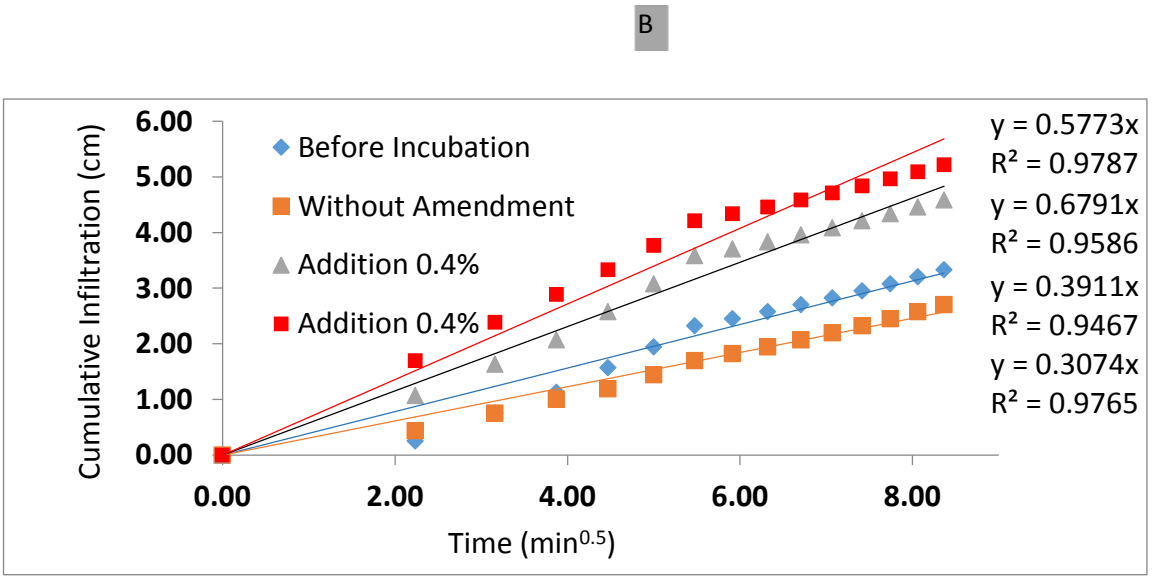


Figure 2. Effect of soil calcareous content and vermicompost application on sorptivity values (cm min$^{-1/2}$): (A) Zab soil and (B) Daquq soil.

In general, the results showed that there were interactive effects between soil calcium carbonate content and vermicompost application on soil sorptivity. Sorptivity was decreased by calcium carbonate but increased by vermicompost, and the magnitude of this increase depended on the characteristics of the soil and the rate of application.

Table (3) presents the effects of soil calcium carbonate content and vermicompost application on sorptivity.

It showed significant effects of calcium carbonate content, vermicompost application levels, and their interaction on soil sorptivity.

The results showed that there was a significant effect of soil calcium carbonate content. The soil containing 1% calcium carbonate recorded the highest sorptivity value (0.59 cm min $^{-1/2}$), whereas increasing the calcium carbonate content to 40% reduced sorptivity to 0.52 cm min $^{-1/2}$. This decrease can be attributed to the increase in soil bulk density and the cementing effect of calcium carbonate, which reduced effective porosity and the continuity of capillary pores responsible for water movement. Consequently, water entry into the soil was restricted, resulting in lower sorptivity values. These findings agree with Lal and [20] and with [11], who reported that calcium carbonate precipitation reduces pore continuity and

ISSN 2072-3857

adversely affects soil hydraulic properties, particularly sorptivity.

Table (3). Effect of soil calcium carbonate content and vermicompost application on sorptivity (cm min $^{-1/2}$).

Calcareous Content	Vermicompost 0%	0.4%	0.8%	Mean (C)
1%	0.36 i	0.65 e	0.77 a	0.59 a
15%	0.35 j	0.63 f	0.70 b	0.56 b
26%	0.32 k	0.58 g	0.69 c	0.53 c
40%	0.30 l	0.57 h	0.67 d	0.52 d
Mean (V)	0.33 c	0.61 b	0.71 a	0.554

The results further showed a significant effect of vermicompost application rate on soil sorptivity. Vermicompost application significantly increased sorptivity as compared to the control treatment. The highest sorptivity value of 0.71 cm min$^{-1/2}$ was recorded at the highest application rate of 0.8% while that of the control treatment was the lowest at 0.33 cm min$^{-1/2}$. This improvement can be attributed to the beneficial effects of vermicompost on soil structure and aggregate stability which increase total porosity, particularly the proportion of macropores responsible for water transmission. Organic matter also enhances soil wettability by reducing the contact angle between water and soil particles thus ease water entry and promote its movement through the soil profile. These results are in harmony with those found by [15], [25], and [21]. The results in Table (3) also showed a significant interaction effect on sorptivity between soil calcium carbonate content and vermicompost application. The maximum sorptivity value of 0.77 cm min$^{-1/2}$ was obtained in the soil containing 1% calcium carbonate amended with 0.8% vermicompost and the minimum value of 0.30 cm min$^{-1/2}$ was recorded in the soil containing 40% calcium carbonate without any vermicompost application. The interaction suggests that vermicompost was more effective in improving sorptivity at lower calcium carbonate levels. However, increasing calcium carbonate content reduced this effect due to its cementing action, which restricted pore continuity.

Penetrability (cm min$^{-1/2}$)

Figures (3 and 4) illustrate the relationship between the wetting front advance distance (L, cm) and the square root of time ($t^{1/2}$, min),

where the slope of the linear regression line represents the soil penetrability coefficient (1), measured using horizontal soil columns over a total infiltration period of 240 min. The measurements were conducted on soils with different calcium carbonate contents under various vermicompost application rates. All treatments exhibited a direct and positive linear relationship between L and $t^{1/2}$, with correlation coefficients varying from 0.991 to 0.999, which is an excellent linear fit. As observed in the photographs, the front of wetting moved progressively as time increased for all the treatments. Penetrability values varied depending on

ISSN 2072-3857

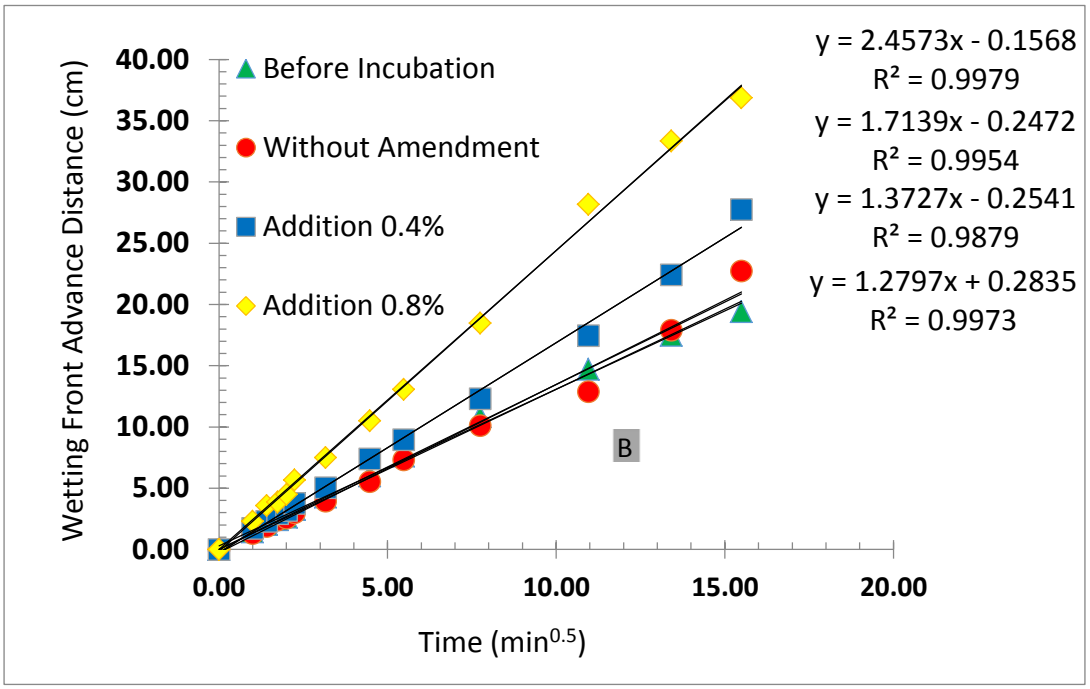
the rate of vermicompost application; they increased steadily with each addition of vermicompost, while the lowest values were recorded in the control treatment prior to incubation. Variations in penetrability were also noted among the soils under study, with penetrability decreasing as the content of soil calcium carbonate increased and this trend lasted throughout the whole period of measurement. In Table (4), the interactions of soil calcium carbonate content and vermicompost application on penetrability are presented.

The results indicated significant effects of calcium carbonate content, rate of vermicompost application, and their interaction on penetrability. They also showed that increasing calcium carbonate content significantly reduced penetrability.

The soil containing 1% calcium carbonate recorded the highest penetrability value (1.84 cm $min^{-1/2}$), whereas the soil containing 40% calcium carbonate recorded the lowest value (1.32 cm $min^{-1/2}$). This decrease can be attributed to the adverse effect of calcium carbonate on water movement by capillarity, as it reduced the effectiveness and continuity of fine pores and blocked some direct flow paths, causing the wetting front to move more slowly through the soil. Furthermore, increasing calcium carbonate content may increase the contact angle and reduce soil wettability, thereby slowing water entry during the initial stages of infiltration. These findings are consistent with those reported by [24] and [32]. The results also demonstrated a significant effect of vermicompost application on soil penetrability,

A

ISSN 2072-3857



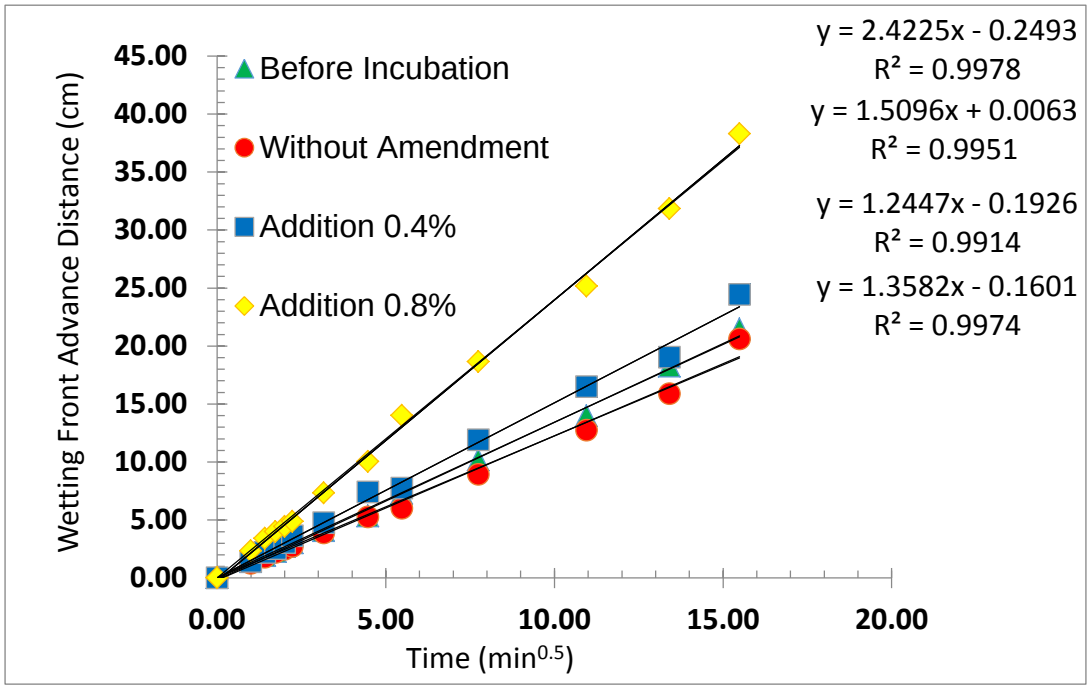
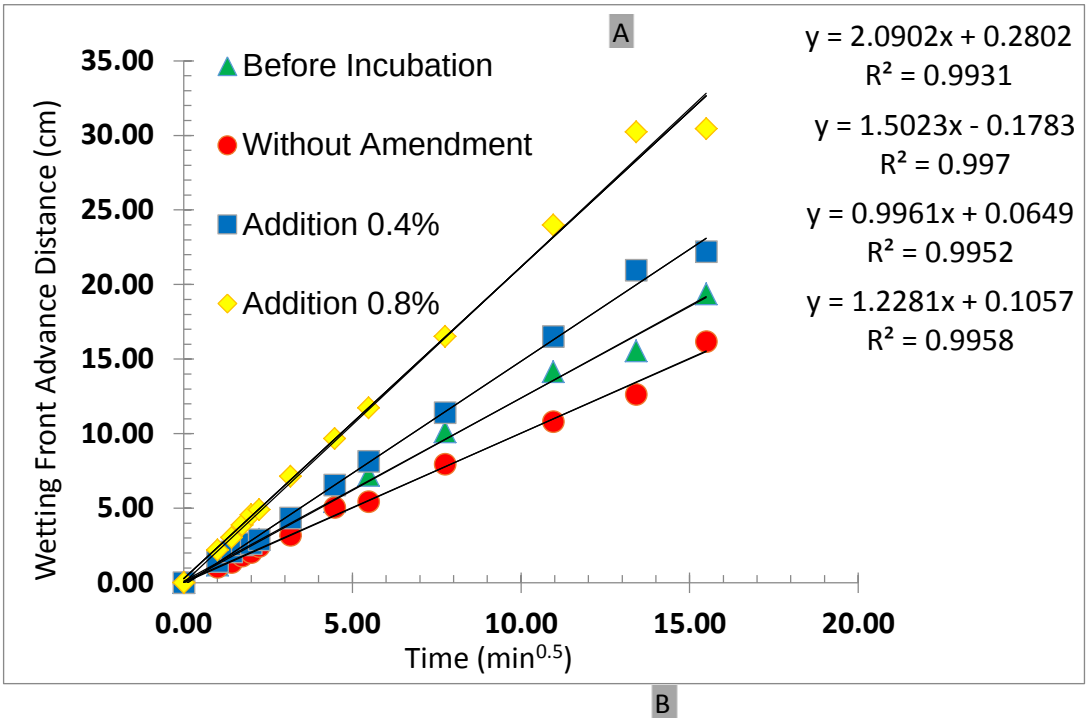


Figure 3. Relationship between wetting front advance distance and the square root of time in (A) Penjwen soil and (B) Rania soil.

ISSN 2072-3857



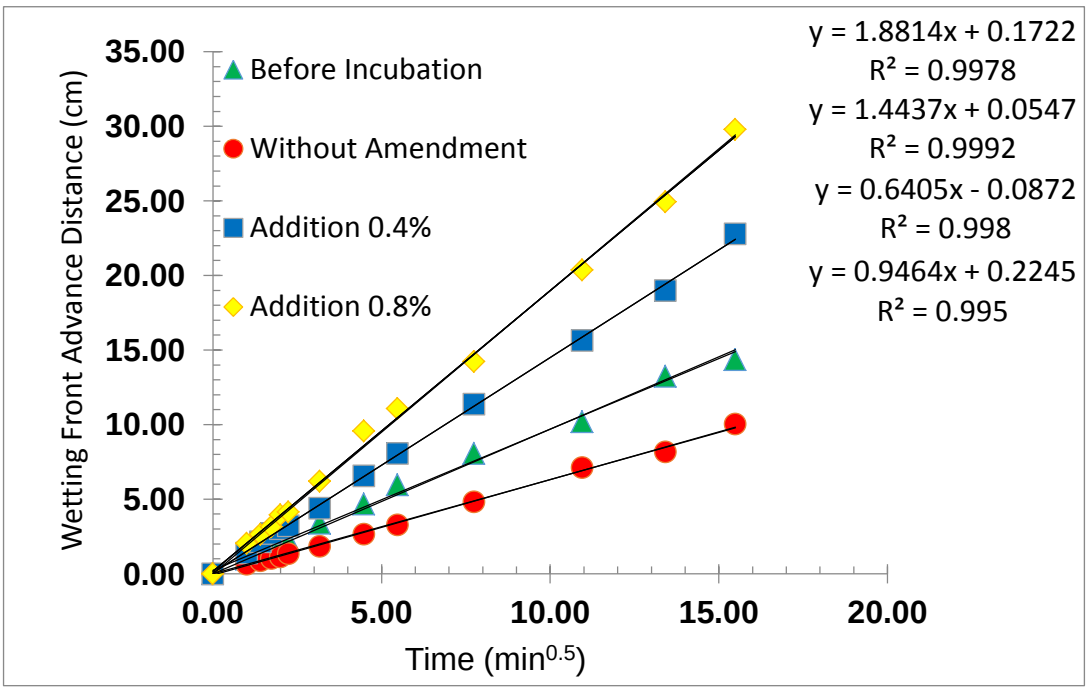


Figure 4. Relationship between wetting front advance distance and the square root of time in (A) Zab soil and (B) Daquq soil.

ISSN 2072-3857

with vermicompost greatly increasing the penetrability values as opposed to the control. The control treatment had the lowest penetrability value at 1.06 cm $min^{-1/2}$, while the highest value was obtained at the highest rate of vermicompost application, 0.8%. The increase in penetrability after the application of vermicompost can be ascribed to its effect on optimizing pore-size distribution, which allows easy entry of water and enhances water movement through the soil matrix, as also reported by [17]. Organic and humic compounds from vermicompost enhance the interaction between water and the soil surface, thus increasing the rate of water uptake during the initial stages of wetting. This improvement is reflected in the higher penetrability values obtained. The simultaneous decrease in the contact angle further substantiates this evidence of improved soil wettability. Table (4) shows the interaction effect between soil calcium carbonate content and vermicompost application rate on penetrability. Results indicated a significant interaction between the two factors. The highest value of penetrability (2.45 cm $min^{-1/2}$) was recorded in the soil with 1% calcium carbonate amended with 0.8% vermicompost and the lowest value (0.64 cm $min^{-1/2}$) in the soil with 40% calcium carbonate without vermicompost application.

This interaction indicates that the response of penetrability to vermicompost decreased as soil calcium carbonate content increased.

Table (4). Effect of soil calcium carbonate content and vermicompost application on penetrability (cm $min^{-1/2}$).

Calcareous Content	Vermicompost 0%	0.4%	0.8%	Mean (C)
1%	1.37 i	1.71 e	2.45 a	1.84 a
15%	1.24 j	1.50 f	2.42 b	1.72 b
26%	0.99 k	1.50 g	2.09 c	1.52 c
40%	0.64 l	1.44 h	1.88 d	1.32 d
Mean (V)	1.06 c	1.54 b	2.21 a	1.605

Water Diffusivity (cm^2 h^{-1})

Figure (5) shows the relationship between volumetric water content (Θ) and water diffusivity, D(Θ), for soils of different calcium carbonate contents under three vermicompost application rates (0, 0.4, and 0.8%). Generally, water diffusivity increased with the increase in volumetric water content in all soils and vermicompost treatments as the soil moisture approached saturation. The diffusivity curves showed a clear upward trend within the range of moisture studied. This is due to the fact that there is an increase in the water-conducting domain and a decrease in flow-path tortuosity as the soil water content increases towards saturation [15].

ISSN 2072-3857

Table (5) shows the effects of soil calcium carbonate content and vermicompost application on water diffusivity. Results revealed significant effects of calcium carbonate content, vermicompost application rate, and their interaction on water diffusivity. Results also showed that water diffusivity significantly decreased with increasing calcium carbonate content. The highest water diffusivity value (2.66 cm^2 $h^{-1/2}$) was recorded in the soil containing 1% calcium carbonate, whereas the lowest value (0.74 cm^2 $h^{-1/2}$) was recorded in the soil containing 40% calcium carbonate. This decrease can be attributed to the accumulation of calcium carbonate within the fine pores and between soil particles, which reduced effective porosity and the continuity of water-conducting pathways, thereby decreasing the efficiency of the pore network for water transmission. Consequently, water diffusivity decreased with increasing calcium carbonate content. These findings agree with [15] and [8].

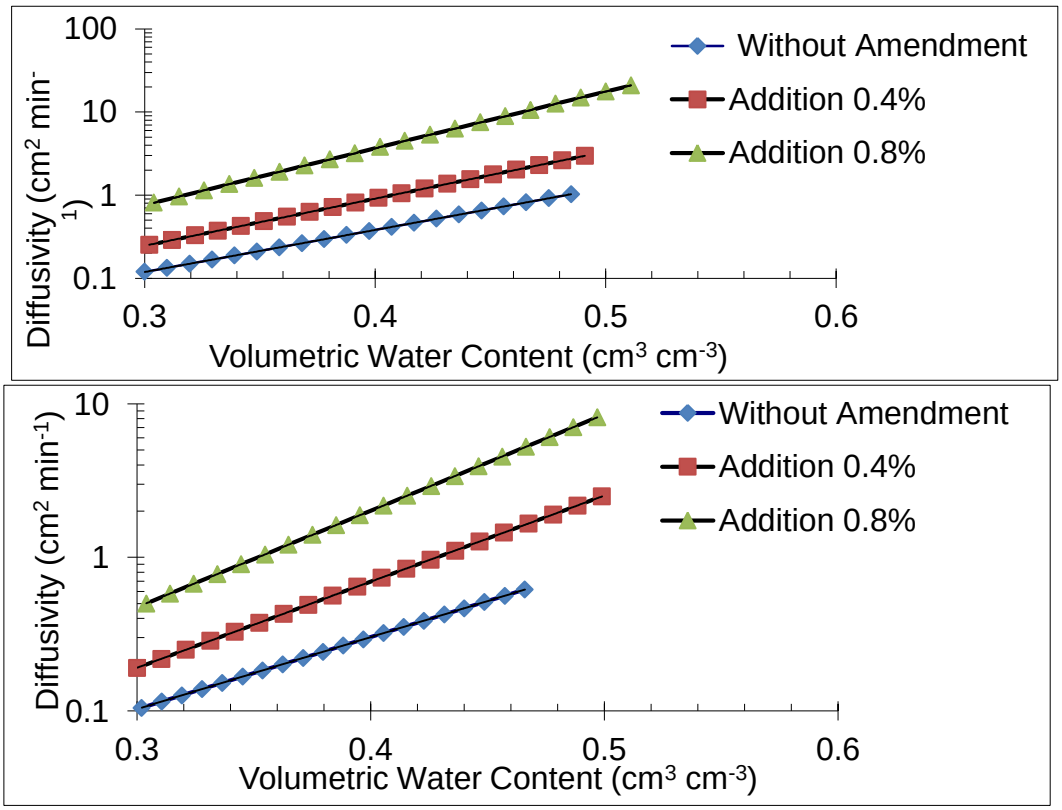
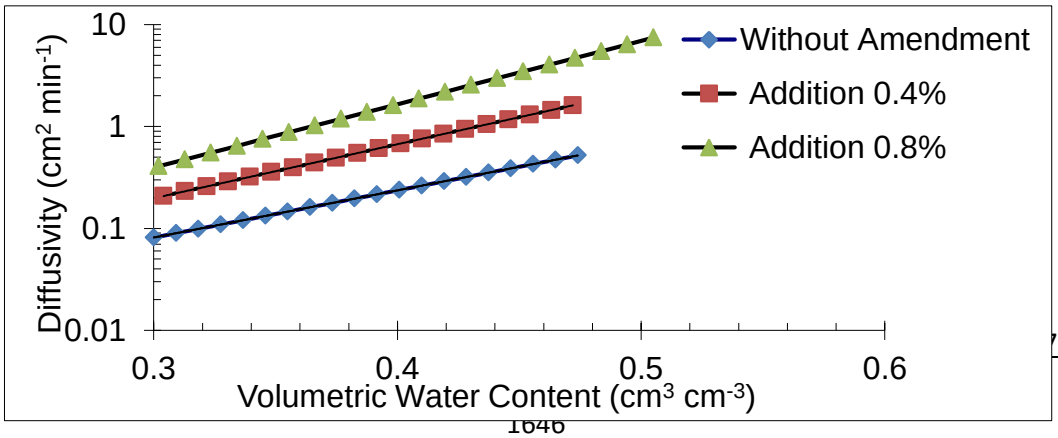


Figure 5. Relationship between volumetric water content and water diffusivity values in A) Penjwen soil and (B) Rania soil.



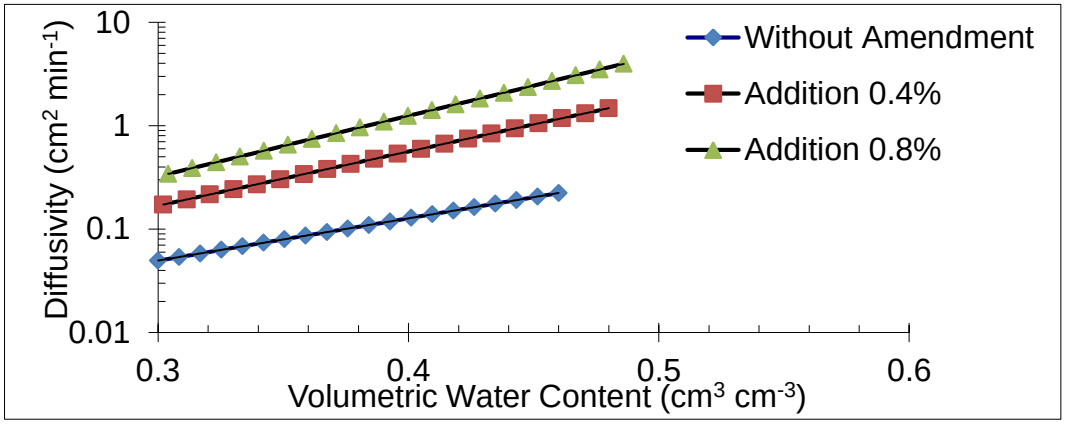


Figure 6. Relationship between volumetric water content and water diffusivity values in (A) Zab soil and (B) Daquq soil

Table (5). Effect of soil calcium carbonate content and vermicompost application on water diffusivity (cm^2 h^{-1}).

Calcareous Content	Vermicompost 0%	0.4%	0.8%	Mean (C)
1%	0.42 i	1.13 e	6.44 a	2.66 a
15%	0.29 j	0.92 f	2.83 b	1.34 b
26%	0.23 k	0.69 g	2.49 c	1.13 c
40%	0.11 l	0.61 h	1.51 d	0.74 d
Mean (V)	0.26 c	0.83 b	3.31 a	1.472

Table (5) also demonstrates the effect of vermicompost application on soil water diffusivity. The results showed that water diffusivity increased significantly with increasing vermicompost application rate. The highest value (3.31 cm^2 h^{-1}) was obtained at the 0.8% application rate, whereas the control treatment (without vermicompost) recorded the lowest value (0.26 cm^2 h^{-1}). This improvement can be attributed to the positive influence of vermicompost on soil hydraulic properties through its effects on both hydraulic conductivity and the soil water retention characteristics, resulting in improved pore-size distribution and greater continuity of water-conducting pathways. Consequently, water movement within the soil became more efficient, leading to higher water diffusivity values[15] [9] [29]. Table (5)

further shows a significant interaction between soil calcium carbonate content and vermicompost application rate. The highest water diffusivity value (6.44 cm^2 h^{-1}) was recorded in the soil containing 1% calcium carbonate amended with 0.8% vermicompost, whereas the lowest value (0.11 cm^2 h^{-1}) was observed in the soil containing 40% calcium carbonate without vermicompost application. This interaction indicates that vermicompost was more effective in improving water diffusivity at lower calcium carbonate levels, whereas its effect decreased as calcium carbonate content increased.

2.Effect of Soil Calcium Carbonate Content and Vermicompost on the Growth and Yield of Faba Bean

Plant Height (cm plant^{-1})

Table (6) presents the effects of soil calcium carbonate content and vermicompost application rates on plant height. The results revealed significant effects of calcium carbonate content, vermicompost application rate, and their interaction on plant height.

The height of the plant reduced significantly with the increase in soil calcium carbonate. The one with 1% calcium carbonate in the soil made it possible for the plants to become the tallest with an average height of 58.09 cm; the height then declined to 37.30 cm with that containing 40% calcium carbonate. This reduction in height can be attributed to reduced availability of essential nutrients, especially phosphorus and micronutrients, due to fixation by calcium carbonate. Such nutrient immobilization adversely affects chlorophyll synthesis, photosynthetic efficiency, and cellular division and elongation, ultimately reducing vegetative growth. The findings agree with those of [4,5]. The higher content of calcium carbonate can also probably restrict the growth and distribution of roots by causing increased cementation of soil particles and reducing effective porosity of soil; this will limit water and nutrient uptake, however,

Table (6). Effect of soil calcium carbonate content and vermicompost application on plant height (cm plant^{-1}).

Calcareous Content	Vermicompost 0%	0.4%	0.8%	Mean (C)
1%	45.40 i	58.87 e	70.00 a	58.09 a
15%	41.30 j	55.53 f	67.40 b	54.74 b
26%	38.10 k	51.50 g	64.10 c	51.23 c
40%	33.40 l	48.20 h	60.30 d	47.30 d
Mean (V)	39.55 c	53.52 b	65.45 a	52.841

The results also showed a significant increase in plant height with increasing vermicompost application rate. The highest plant height (65.45 cm) was recorded at the 0.8% application rate, whereas the control treatment produced the lowest value (39.55 cm). This improvement can be attributed to the ability of vermicompost to enhance soil physical properties by increasing porosity, improving soil structure, and reducing bulk

density. These changes improve soil aeration and water movement, thereby promoting root development and enhancing the uptake of water and nutrients. In addition, vermicompost increases nutrient availability because of its high organic matter content and essential nutrients while stimulating soil microbial activity, resulting in improved vegetative growth and greater plant height. These findings are in agreement with those reported by [27]. Table (6) further illustrates the interaction effect between soil calcium carbonate content and vermicompost application rate on plant height. The highest plant height (70.00 cm) was recorded in the soil containing 1% calcium carbonate amended with 0.8% vermicompost, whereas the lowest value (33.40 cm) was observed in the soil containing 40% calcium carbonate without vermicompost application. This interaction indicates that vermicompost reduced the adverse effects of calcium carbonate on plant growth, resulting in greater plant height, particularly in soils with lower calcium carbonate content.

Number of Branches

Table (7) presents the effects of soil calcium carbonate content and vermicompost application rates on the number of branches. The analysis revealed significant effects of calcium carbonate content, vermicompost application rate, and their interaction on this trait.

The results indicated a significant reduction in the number of branches with increasing soil calcium carbonate content. The soil containing 1% calcium carbonate produced the highest number of branches (3.76 branches plant^{-1}), whereas the number decreased to 2.20 branches plant in the soil containing 40% calcium carbonate.

Table (7). Effect of soil calcium carbonate content and vermicompost application on the number of branches.

Calcareous Content	Vermicompost 0%	0.4%	0.8%	Mean (C)
1%	1.80 i	3.00 e	6.50 a	3.76 a
15%	1.40 j	2.70 f	5.30 b	3.13 b
26%	1.20 k	2.40 g	4.20 c	2.60 c
40%	1.00 l	2.00 h	3.60 d	2.20 d
Mean (V)	1.35 c	2.52 b	4.90 a	2.925

The reduction in the number of branches with increasing calcium carbonate content can be attributed to the fact that elevated calcium carbonate not only affects the physical properties of the soil but also impairs plant physiological functions. Higher calcium carbonate levels reduce the availability of essential nutrients, particularly phosphorus and micronutrients such as iron and zinc, which are directly involved in the development and activity of lateral buds. Furthermore, calcareous soils restrict root system development because of increased soil cementation and

reduced effective porosity, thereby limiting water and nutrient uptake and ultimately reducing branch formation. These findings are consistent with those reported by [1]. The results also showed a significant increase in the number of branches with increasing vermicompost application rate. The highest number of branches (4.90 branches plant^{-1}) was recorded at the 0.8% application rate, whereas the control treatment produced the lowest value (1.35 branches plant^{-1}). This response may - attributed to the fact that vermicompost serves not only as a source of nutrients but is also rich in humic substances and naturally occurring plant growth regulators, such as cytokinins and auxins, which stimulate lateral bud development and reduce apical dominance, thereby promoting branch formation. These findings are consistent with those reported by [3] [27]. In addition, vermicompost improves soil physical properties by increasing porosity and enhancing soil aeration, thereby promoting root growth and improving the efficiency of water and nutrient uptake. Table (7) further demonstrates the interaction effect between soil calcium carbonate content and vermicompost application on the number of branches. The highest value (6.50 branches plant $^{-1}$) was obtained in the soil containing 1% calcium carbonate amended with 0.8% vermicompost, whereas the lowest value (1.00 branch plant $^{-1}$) was recorded in the soil containing 40% calcium carbonate without vermicompost application. This interaction indicates that vermicompost partially alleviated the adverse effects of calcium carbonate on branch formation, particularly in soils with lower calcium carbonate content.

Leaf Area (cm^2 plant $^{-1}$)

Table (8) presents the effects of soil calcium carbonate content and vermicompost application on leaf area. The results revealed significant effects of calcium carbonate content, vermicompost application rate, and their interaction on leaf area.

Leaf area decreased significantly with increasing soil calcium carbonate content. The soil containing 1% calcium carbonate produced the largest leaf area (4266.00 cm^2 plant $^{-1}$), whereas the soil containing 40% calcium carbonate recorded the smallest leaf area (3732.96 cm^2 plant^{-1}). This reduction may be attributed to the decreased availability of essential nutrients caused by the higher calcium carbonate content, in addition to increased soil particle cementation and reduced root efficiency in absorbing water and nutrients. These factors negatively affect leaf growth and expansion, resulting in a smaller leaf area.

Table (8). Effect of soil calcium carbonate content and vermicompost application on leaf area (cm^2 plant $^{-1}$).

Calcareous Content	Vermicompost 0%	0.4%	0.8%	Mean (C)
1%	3421.30 i	4250.50 e	5126.20 a	4266.00 a
15%	3216.20 j	4007.30 f	5015.40 b	4079.63 b
26%	3115.10 k	3815.60 g	4873.20 c	3934.63 c

ISSN 2072-3857

40%	3012.30 l	3610.20 h	4576.40 d	3732.96 d
Mean (V)	3191.22	3920.90	4897.80 a	4003.30

The results also showed a significant effect of vermicompost application on leaf area. The highest leaf area (4897.80 cm^2 $plant^{-1}$) was recorded at the 0.8% application rate, whereas the control treatment exhibited the lowest value (3191.22 cm^2 $plant^{-1}$). This improvement can be attributed to the ability of vermicompost to supply readily available nutrients, particularly nitrogen and magnesium, which are essential for chlorophyll synthesis and enhanced photosynthetic efficiency. In addition, vermicompost contains compounds with growth regulator-like activity that stimulate cell division and elongation, thereby promoting leaf expansion and increasing total leaf area. These findings are in agreement with those reported by [3] [27]. The interaction between soil calcium carbonate content and vermicompost application also had a significant effect on leaf area. The highest leaf area (5126.20 cm^2 $plant^{-1}$) was recorded in the soil containing 1% calcium carbonate amended with 0.8% vermicompost, whereas the lowest value (3012.30 cm^2 $plant^{-1}$) was observed in the soil containing 40% calcium carbonate without vermicompost application. This interaction indicates that the positive effect of vermicompost on leaf area was greater in soils with lower calcium carbonate content, while higher calcium carbonate levels limited this response.

Green Pod Yield (Mg ha^{-1})

Table (9) demonstrates the impact of calcium carbonate content in the soil, vermicompost application rates, and their interaction on the yield of green pods.

The results of the experiment showed the significant effects of all the factors on green pod yield. The green pod yield reduced progressively with the increase in calcium carbonate content in the soil. The maximum yield (26.96 Mg ha^{-1}) was obtained in the soil having 1% calcium carbonate, while it reduced to 17.76 Mg ha^{-1} in the soil with 40% calcium carbonate. This decline shows that high levels of calcium carbonate were a major constraint to the growth of the plants and the development of pods by direct influence on the condition of the roots. Increased levels of calcium carbonate raise soil alkalinity and reduce the availability of essential nutrients, including phosphorus, iron, zinc, and manganese. These nutrients are important for chlorophyll biosynthesis, activation of enzymes, flowering and pod formation; hence, their limitation affects both plant growth and yield. This result is in agreement with those of [22] and [5] Moreover, the buildup of calcium carbonate enhances the cementation of soil particles and partial hardening of the soil matrix, which limits root elongation and hence reduces the efficiency of water and nutrient uptake.

ISSN 2072-3857

Table (9). Effect of soil calcium carbonate content and vermicompost application on green pod yield (Mg ha^{-1}).

Calcareous Content	Vermicompost 0%	0.4%	0.8%	Mean (C)
1%	16.42 i	24.41 e	40.07 a	26.96 a
15%	13.87 j	21.94 f	34.02 b	23.27 b
26%	11.38 k	19.62 g	29.17 c	20.05 c
40%	8.84 l	17.87 h	26.57 d	17.76 d
Mean (V)	12.62 c	20.96 b	32.45 a	22.015

The results also indicated a significant increase in green pod yield as the application rate of vermicompost increased. The highest yield (32.45 Mg ha^{-1}) was recorded at the 0.8% application rate, and the lowest yield was in the control treatment (12.62 Mg ha^{-1}). This can be attributed to the direct effect of vermicompost in making the soil more fertile and increasing nutrient availability besides enhancing soil structure, porosity, and retention of soil moisture. These properties allow for better rooting of plants and uptake of nutrients which result in better vegetative growth with increased photosynthetic activity and increased translocation of assimilates to flowers and developing pods. Similar results were obtained by [6] who reported increased faba bean yield and improved plant growth due to vermicompost application under calcareous soil condition. Table (9) also indicates a significant interaction between soil calcium carbonate content and vermicompost application on green pod yield. The highest green pod yield (40.07 Mg ha^{-1}) was obtained from the soil with 1% calcium carbonate amended with 0.8% vermicompost. The lowest yield (8.84 Mg ha^{-1}) was recorded from the soil with 40% calcium carbonate and no vermicompost application. This interaction indicates that vermicompost was more effective in increasing green pod yield at lower calcium carbonate levels because of improved soil water and nutrient availability.

Conclusion

The calcareous content had a negative effect on the hydraulic properties of the studied soils, as the values of sorptivity, hydraulic conductivity, and diffusivity decreased with increasing calcium carbonate content. The application of vermicompost improved the hydraulic properties of the studied soils, as the values of sorptivity, hydraulic conductivity, and diffusivity increased at the 0.8% application rate compared with the control

ISSN 2072-3857

treatment. Vegetative growth parameters and yield of faba bean (*Vicia faba* L.) increased with increasing vermicompost application rate. The 0.4% and 0.8% application rates significantly improved plant height, number of branches, leaf area, and green pod yield compared with the control treatments. Among the tested treatments, C1V2 was the most effective, achieving the greatest improvement in soil hydraulic properties, vegetative growth, and green pod yield of faba bean. This study provides new insights into the use of vermicompost for improving the hydrophysical properties of calcareous soils with different calcium carbonate contents.

Acknowledgment:

Institutional Support: This research was made possible by the robust support of the College of Agriculture, University of Kirkuk, Iraq. Funding & Collaboration: Gratitude is extended to the Department of Soil and Water Resources for granting access to critical laboratory infrastructure and peer guidance.

References

[1] **Afifi, M.I., El-Akshar, Y.S., Zaen, Y.I.M. and Abd Elrahman, R.A.M. (2017)** Response of faba bean plants to organic amendments on calcareous soil. Egyptian Journal of Microbiology, 47, pp. 128–140.

[2] **Ali, N. S., Rahi, H. S., & Shaker, A. W. A. (2014).** Soil Fertility. Mosul, Iraq: Ibn Al-Atheer House for Printing and Publishing, University of Mosul.

[3] **Al-Khazraji, H.A.K., Alabojaml, N.H.N., Ghailan, S.A., Abdulla, A.A. and Awda, S.H. (2026)** Effect of concentration and application method of compost tea (buffalo manure extract) on green broad bean yield and growth (Vicia faba L.). Journal of Medicinal Plants and By-products, 15(2), pp. 182–187.

[4] **Baccari, B. and Krouma, A. (2023)** Rhizosphere acidification determines phosphorus availability in calcareous soil and influences faba bean (Vicia faba L.) tolerance to P deficiency. Sustainability, 15(7), 6203.

[5] **Barznyi, L.Gh., Fattah, O.A., Mohammed, D.J., Mohammed, H.J. and Mahmood, A.M.R. (2025)** Influence of mycorrhizal inoculation and different phosphorus levels on broad bean (Vicia faba L.) growth, nutrient uptake and yield. Kirkuk University Journal for Agricultural Sciences, 16(1), pp. 147–154.

[6] Bezabeh, M.W., Haile, M., Sogn, T.A. and Eich-Greatorex, S. (2021) Yield, nutrient uptake and economic return of faba bean (Vicia faba L.) in calcareous soil as affected by compost types. Journal of Agriculture and Food Research, 6, 100237.

[7] **Bolan, N., Srivastava, P., Rao, C.S., Satyanarayana, P.V., Anderson, G.C., Bolan, S., Nortjé, G.P., Kronenberg, R., Bardhan, S., Abbott, L.K., Zhao, H., Mehra, P., Satyanarayana, S.V., Khan, N., Wang, H., Rinklebe, J., Siddique, K.H.M. and Kirkham, M.B. (2023).** Distribution, characteristics and management of calcareous soils.

Advances in Agronomy, 182, pp. 81–130.

[8] **Brady, N.C. and Weil, R.R. (2017)** The Nature and Properties of Soils. 15th edn. Harlow, England: Pearson Education Limited.

[9] **Castellini, M., Bondi, C., Giglio, L., Iovino, M. et al. (2024)** Impact of vermicompost addition on water availability of differently textured soils. Heliyon, 10(15), e35699.

[10] **Chatterjee, N., Nandi, R., Das, K. and Bandyopadhyay, S. (2022)** Vermicompost: A sustainable organic amendment for improving soil fertility, soil health and crop productivity. In: Recent Advances in Soil Fertility Management and Crop Production. Singapore: Springer, pp. 171–194.

[11] **Chen, R., Li, G., Mi, Z. and Wei, K. (2024)** Experimental and simulation study of calcium carbonate non-uniform distribution characteristics of bio-cemented sand. Case Studies in Construction Materials.

[12] Etemadi, F., Hashemi, M., Barker, A.V., Zandvakili, O.R. and Liu, X. (2019) Agronomy, nutritional value and medicinal application of faba bean (Vicia faba L.). Horticultural Plant Journal, 5(4), pp. 170–182**.**

[13] Eurasian Journal of Sustainable Agriculture., 5(2):304-309.

[14] **Gutiérrez, N., Avila, C.M., Moreno, M.T. and Torres, A.M. (2008)** Development of SCAR markers linked to zt-2, one of the genes controlling absence of tannins in faba bean (Vicia faba L.). Australian Journal of Agricultural Research, 59(1), pp. 62–68.

[15] **Hillel, D. (1980)** Fundamentals of Soil Physics. New York: Academic Press.

[16] **Hillel, D. (1998)** Environmental Soil Physics. San Diego, CA: Academic Press.

[17] Ibrahim, M.M., Mahmoud, E.K. and Ibrahim, D.A. (2015) Effects of vermicompost and water treatment residuals on soil physical properties and wheat yield. International Agrophysics, 29, pp. 157–164.

[18] **Jackson, R.D. (1963)** Porosity and soil-water diffusivity relations. Soil Science Society of America Proceedings, 27, pp. 123–126.

[19] **Janan, M., Islam, M.S., Rahman, M.M. and Hossain, M.A. (2023)** Vermicompost improves soil physical, chemical and biological properties and enhances crop productivity: A review. Journal of Agriculture and Food Research, 14, 100845.

[20] Lal, R. and Shukla, M.K. (2004) Principles of Soil Physics. New York: Marcel Dekker.

[21] **Letey, J. (2001)** Relationship between soil physical properties and crop production. Advances in Agronomy, 84, pp. 277–294.

ISSN 2072-3857

[22] **Mona, A.M., Sabah, M.A. and Rehab, A.M. (2011)** Influence of Potassium Sulfate on Faba Bean Yield and Quality. Australian Journal of Basic and Applied Sciences, 5(3), pp. 87–95.

[23] **Mualem, Y. (1976)** A new model for predicting the hydraulic conductivity of unsaturated porous media. Water Resources Research, 12(3), pp. 513–522.

[24] **Noiriel, C., Steefel, C.I., Yang, L. and Bernard, D. (2016)** Effects of pore-scale precipitation on permeability and flow. Advances in Water Resources, 95, pp. 125–137.

[25] **Philip, J.R. (1957)** The theory of infiltration. II. The profile at infinity. Soil Science, 83, pp. 435–448.

[26] program for estimating leave area of several vegetable crops. American

[27] **Saadea, S., Abbas, F., Al-Shbatt, H. and Al-Seed, D. (2023)** Effect of vermicompost and mineral fertilizers on growth and productivity of faba bean (Vicia faba L.) under Homs-Syria conditions. Al-Mukhtar Journal of Sciences, 38(2).

[28] Sadik, K. S: al-Taweel; N.S. Dhyeab and Kalaf M. Z. 2011. new computer

[29] **Safadoust, A., Ahmadi, A., Ghorbani, M. and Karimi, H. (2025)** Restoring soil functionality in drylands: Soil texture-specific impacts of vermicompost as an organic waste-based amendment. Journal of Arid Environments, 231, 105446.

[30] **Salhab, T. G. (2024).** Chemical properties of soils in Al-Karma District, Al-Anbar Governorate, Iraq, and their impact on land productivity. Awraq Thaqafiya Journal, 29, 317-336.

[31] **Seki, K. (2023)** SWRC Fit and UnsatFit for parameter determination of unsaturated soil properties. Journal of Toyo University Natural Science, 67, pp. 1–18.

[32] **Weinhardt, F., Deng, J., Hommel, J., Vahid Dastjerdi, S., Gerlach, R., Steeb, H. and Class, H. (2022)** Spatiotemporal distribution of precipitates and mineral phase transition during biomineralization affect porosity–permeability relationships. Transport in Porous Media, 143(2), pp. 527–549.

ISSN 2072-3857