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Role of Gypsum Stone to improve some physical and Hydrological Properties of heavy soil and yield of Sunflower *Helianthus annuus* L.

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ABSTRACT

A factorial experiment using a randomized complete block design (RCBD) was carried out in one of the fields of the University of Mosul's College of Agriculture and Forestry. Gypsum stone was employed as an amendment in various physical and hydrologic qualities of silty clay soil and its impact on sunflower yield in different sizes and proportions. With three replications, gypsum stone was added in three sizes (<2, 8-10, 20-25 mm), three addition percentages (5, 10, and 15%), and a control sample. The results demonstrated the superiority of adding 15% gypsum stone with size of less than 2 mm in all examined soil characteristics compared to other treatments; the thickness of the soil surface crust and its bulk density by 15% and size of <2 mm was (2.5 mm, 1.43 Mg m^{-3}) as opposed to (6.00 mm and 1.58 Mg m^{-3}) in the control, respectively. The same addition significantly increased the WHC and moisture at the FC, recording (44.20 and 40.53) %, respectively, compared to (41.00 and 37.00) %, respectively, at control level. The lowest hydraulic conductivity was recorded when adding 15% for <2 mm (1.7 cm/h), and the highest hydraulic conductivity (HC) was recorded when adding 15% for 8–10 mm (7.1 cm/h) while it was 2.3 cm/h in the control treatment. The improvement of the physical conditions of the soil and the availability of moisture content at the level of adding 15% to volume <2 mm led to an increase in the height of the sunflower, blossom diameter, and leaf area to increase, giving them (48.66 cm, 4.33 cm, and 8.02 cm^2) as compared to (38.66 cm, 2 cm, and 5.27 cm^2) in the control level.

استخدام حجر الجبس في تحسين بعض الخصائص الفيزيائية والهيدرولوجية للتربة الثقيلة وحاصل زهرة الشمس *Helianthus annuus* L.

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الخلاصة

أجريت تجربة عاملية بتصميم القطاعات العشوائية الكاملة (RCBD) في حقول كلية الزراعة والغابات في جامعة الموصل. تم استخدام أحجام ونسب مختلفة من حجر الجبس كمصلح في بعض الخواص الفيزيائية والمائية لتربة الطينية غرينية وتأثيرها على محصول زهرة الشمس. أضيف حجر الجبس بثلاثة أحجام (<2، 8-10، 20-25) ملم، وثلاث مستويات إضافة (5، 10، 15)٪ لكل حجم بالإضافة الى نموذج تربة بدون اضافة (Control) وبثلاث مكررات. أظهرت النتائج تفوق إضافة حجر الجبس بنسبة 15٪ لحجم <2 ملم في جميع صفات التربة المدروسة مقارنة مع المعاملات الأخرى، حيث قلل من سمك وكثافتها الظاهرية عند استخدام معاملة 15٪ لـ 2 ملم فكانت (2.5 ملم ، 1.43 ميكاغرام م$^{-3}$) مقارنة بـ (6.00 ملم و 1.58 ميكاغرام م$^{-3}$) في معاملة المقارنة، كما ساهمت نفس الإضافة في زيادة السعة التشعبية المائية (WHC) والمحتوى الرطوبي للترب عند السعة الحقلية (FC)، حيث سجلت (44.20 و 40.53)٪ على التوالي، مقارنة بـ (41.00 و 37.00)٪ على التوالي عند معاملة المقارنة، كما اظهرت النتائج انخفاض الايصالية المائية (HC) مع زيادة اضافة مفصولات الجبس الناعمة زيادة الاصالية المائية مع زيادة مفصولات الجبس الخشنة مقارنة مع معاملة المقارنة. أدى تحسن الظروف الفيزيائية للتربة وتيسر المحتوى الرطوبي عند مستوى اضافة 15% للحجم <2 ملم إلى زيادة ارتفاع نبات زهرة عباد الشمس وقطر الزهرة والمساحة الورقية حيث بلغ (48.66 سم، 4.33 سم، 8.02 سم^2) مقارنة بـ (38.66 سم، 2 سم، 5.27 سم^2) على التوالي في معاملة المقارنة

الكلمات المفتاحية: الخصائص الفيزيائية، القشرة، مفصولات حجر الجبس، زهرة الشمس

INTRODUCTION

Crusting can occur on most soils, with the exception of those with high amounts of coarse sand and negligibly small amounts of silt and clay (Bradford and Huang 1992). According to El-Husseiny (2021), crusting or sealing occurs when clay that has been dispersed by raindrop impact on the soil surface washes into soil pores and seals them. Plants in crusty soil could have less access to water because of the restricted infiltration. Furthermore, the limited aeration and hard structure of some crusts beneath them may restrict the emergence of seedlings and the growth of their roots close to the soil surface (Bhardwaj *et al.*, 2009 and Feng *et al.*, 2013 and Lin *et al.*, 2022).

Many amendments have been used in different regions around the world to improve the physical, chemical and fertility properties of soils (Al-Hamdawi and Al-Wally 2020), one of these amendments is gypsum stone (Norton. and Rhoton, 2007 and Darrell, 2008 and Al-Naser 2018), which has wide uses in improving the physical and chemical properties of heavy clay soils (Taha, 2018 and Luiz *et al.*, 2022). Zublena et al, (1995) stated that the addition of gypsum to the soil reduces the negative effect of increasing sodium ions in the soil, increases the cationic exchange capacity and reduces soil erosion. Norton and Rhoton (2007) and Uusitalo *et al.*, (2010) mentioned that gypsum plays an important role in improving the physical properties of soil, reducing crust formation, increasing soil ability to retain water, and seedling emergence. Al-Naser (2018) also found that gypsum rock segments with diameters smaller than 28 mm are more effective in preventing the formation of surface crust than fractions larger than 28mm. Hammadi (2012) mentioned that the sunflower crop is grown in most types of soils and thrives in well-ventilated lands.

The purpose of the study was to determine the impact of utilizing gypsum rocks on clay soils' physical and hydrological characteristics, surface crust development, and sunflower crop production as one of Iraq's main economic crops.

MATERALS AND METHODS

An experiment was conducted using silty clay soil (Vertisols) (0–15 cm) from the Teleskuf area of northern Iraq's Nineveh Governorate. According to the procedures described in Page *et al.,* (1982), the soil was air-dried and sieved with a 2 mm sieve, from which various physical and chemical parameters of the soil were calculated (Table 1).

Table (1) physical and chemical properties of the study soil

Soil separates g kg^{-1}			Texture	BD *Mg* m^{-3}	EC dS m^{-1}	pH	OM	$CaCO_3$
							g kg^{-1}	
Clay	Silt	Sand						
503.2	430.3	66.5	Silty clay	1.32	1.25	7.95	17.6	340.0

The gypsum stones were broken as directed by the Soil Survey Manual (SSS, 2017). After then, it was fractionally divided into three sizes (<2, 8–10, and 20–25 mm) to represent the sizes of stones that don't interfere with field agricultural operations.

The gypsum stones were broken with a hammer, then sifted with sieves of different diameters according to the required work plan to obtain specific sizes as follows: <2 mm, 8-10 and 20-25 mm. these fragments were mixed with the soil in accordance with the experiment's design in a factorial experiment using a randomized complete block design (RCBD) to evaluate the effects of different gypsum stone fragments on the fundamental soil physical and hydrological parameters.

The treatments for the study included; <2 mm at 5% (T1), <2 mm at 10% (T2), <2 mm at 15% (T3), 8-10 mm at 5% (T4), 8-10 mm at 10% (T5), 8-10 mm at 15% (T6), 20-25 mm at 5% (T7), 20-25 at 10% (T8) and 20-25 mm at 15% (T9) in addition to treatment without addition (Control) (T10), with three replicates, Thus, the total number became 30 treatments. In all the soils of the experimental treatments, sunflower seeds (Menkerine (Turkish)) were planted, and they were let to grow in the presence of natural precipitation, using additional irrigation to maintain the humidity at 50% of the soil's available water.

At the conclusion of the experiment, the thickness of the crust and bulk density of the surface soil crust were assessed using the Verneir and a core method, respectively (a special core of 3 mm height and 15 mm diameter).

For all experimental treatments, the soil's water holding capacity (WHC),soil moisture content at the field capacity (FC) and saturated hydraulic conductivity (SHC) were also measured. Daily observations in each treatment were also made when wilting signs appeared, and the germination percentage also was calculated.

In addition, measurements of plant height, flower diameter, and leaf area were made using the Elshahooki and Eldabas (1982) equation, which reads: Leaf area= 0.65 L^2. Critical difference was used in a statistical analysis of the data with a 5% threshold of significance.

RESULTS AND DISCUSSION

It should be noted that the values of the crust's bulk density decreased as the size of the gypsum segments decreased and addition rates increased (Table 2). The application of various gypsum fractions used to have a significant impact on the crust's bulk density. The bulk density values for sizes 8–10 and 20–25 mm were 1.46 and 1.51 Mg m^{-3} at the same amount of addition, respectively. The lowest bulk density of the crust was 1.43 Mg m^{-3} after adding 15% to the <2 mm compared to 1.58 Mg m^{-3} at the control and other treatments. Gypsum's ability to improve soil structure, increase water permeability, and improve aggregate stability may be the cause of this, which in turn reduces crust formation. These findings are in agreement with those reported by Zublena *et al.,* (1995) and Norton and Rhoton (2007) and Opoku-Kwanowaa *et al.,* (2020).

Table (2) effect of gypsum fraction on bulk density and thickness of crust

gypsum fraction		crust bulk density	crust thickness
mm	**%**	***Mg* m^{-3}**	**mm**
< 2	5	1.52 c	5.67 b
	10	1.46 d	4.00 bcd
	15	1.43 e	2.50 d
8-10	5	1.54 b	5.17 b
	10	1.47 d	4.00 bcd
	15	1.46 d	3.17 cd
20-25	5	1.52 c	5.67 b
	10	1.51 c	5.00 b
	15	1.51 c	4.67 bc
Control		**1.58 a**	**6.00 a**

According to the findings in Table (2), the crust's thickness significantly decreased as well as a diameters of the fragments of Gypsum stone fragments and the addition rates. As the lowest thickness of the crust was 2.50 mm when adding 15% of <2 mm, compared with 6.00 mm at the control level, while the thickness of the crust was 3.17 and 4.67 mm at the same levels of the diameters 8-10 and 20-25 mm, respectively.The data also show that the crusts with sizes of 20–25 mm had the thickest crusts at all levels of gypsum addition; these thicknesses were 5.67, 5.00, and 4.67 mm at the levels of (5, 10 and 15)%, respectively. Based on the findings, it can be concluded that adding gypsum to soil enhances soil structure and increases aggregate stability, which reduces crust development. This is consistent with earlier research by Zublena *et al.,* (1995), Yan *et al.,* (2015) and Nias et al (2023), which reported that adding gypsum to soil decreases soil dispersion and surface hindrance.

The infiltration rate and the cumulative infiltration of the study soil were estimated as shown in Figure (1), where it was found that the cumulative infiltration increased with time as the value of R2 = 0.9849, while the value of the infiltration rate decreased with time and stabilized at 50 minutes.

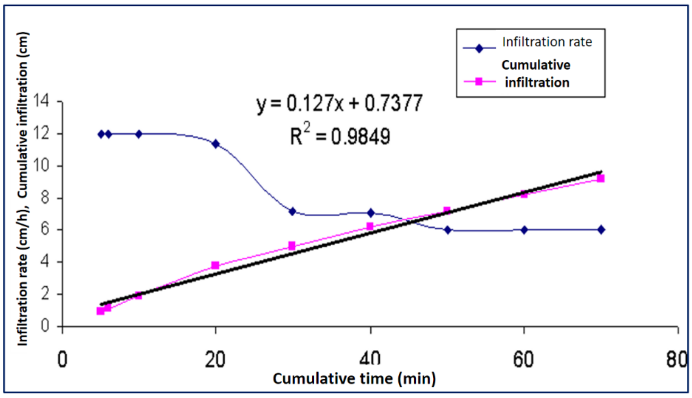

Figure (1) relationship between infiltration rate and cumulative infiltration over time

Table (3) shows that there are noticeable significant differences in the water holding capacity (WHC) and field capacity (FC) with an increase in the addition of much more gypsum fractions; higher water contents were recorded (44.20 and 40.53%) for WHC and FC at additions of 15% for <2 mm, respectively, and the highest values were found to be 43.50 and 41.00%, respectively, at the addition of 15% for 8–10 mm.

It is also noted that the hydraulic conductivity (HC) of the soil decreases as the size of the gypsum fractions decreases and increases as the size of the gypsum fractions increases, and the differences were significant between that, as the lowest hydraulic conductivity was recorded when adding 15% for <2 mm (1.7 cm/h), and the highest hydraulic conductivity was recorded when adding 15% for 8–10 mm (7.1 cm/h) while it was 2.3 cm/h in the control treatment. The reason for this may be due to the increased ability of gypsum fractions to retain water, especially the small fractions with a high specific surface area, and this led to reduced soil dispersion and increased aggregate stability, and these results certainly agree with those of Darrell (2008), Cosh *et al.,* (2008) and Nias *et al.,* (2023).

Table (3) some properties of hydrological soil surface crusts

gypsum fractions		**FC**	**WHC**	**HC**
mm		**%**		**cm /h**
< 2	5	38.50 bc	42.29 b	1.9 e
	10	39.50 bc	42.52 ab	1.8 e
	15	40.53 a	44.20 a	1. e
8-10	5	38.50 b	40.26 c	4.0 c
	10	39.00 b	41.60 c	4.13 c
	15	41.00 a	43.50 ab	4.2 c
20-25	5	38.45 b	42.50 bc	6.6 b
	10	39.00 b	42.80 bc	6.7 b
	15	39.50 ab	43.00 b	7.1 a
Control		**37.00 c**	**41.00 c**	**2.3 d**

According to the findings in table (4), all experimental treatments had germination percentage between 85 and 95%. The average duration that it took for wilting symptoms to appear on plants was 8 to 11 days, and the longest period for the appearance of signs of wilting was 11 days at the level of 15% for < 2 mm. The results also demonstrated that the addition of gypsum had a significant impact on the rate of plant heights (Table 4), as evidenced by the significant differences in plant heights observed between the proportions and sizes of adding gypsum fragments; the longest duration of Welting symptom was 11 days in the 15% for <2 mm treatment compared to 8 day in the control treatment, the highest plant height was noted when adding 15% for <2 mm, it eventually reached 48.66 cm, while the average plant height at the control was 38.66 cm. Gypsum addition has improved the soil's physical and water conditions, which has encouraged an increase in vegetative growth. As a result, the height of sunflower plants has increased with higher levels of addition, which is consistent with findings from Elshahooki and Eldabas (1982) and Heleen *et al.,* (2020).

Table (4) effect of gypsum additions on sunflower properties

gypsum fractions mm	%	Germination %	Welting symptom day	Plant height cm	Leaf Area cm^2	Flower diameter cm
< 2	5	85	9 b	41.50 bc	6.15 a	3.50 ab
	10	85	9 b	44.50 ab	6.78 a	3.83 ab
	15	90	11 a	48.66 a	8.02 a	4.33 a
8-10	5	90	9 b	42.50 bc	5.07 a	3.50 ab
	10	95	10 ab	43.30 bc	6.32 a	3.26 bc
	15	90	10 ab	44.33 ab	7.38 a	3.66 ab
20-25	5	90	8 bc	41.16 bc	5.75 a	2.50 cd
	10	95	8 bc	39.66 c	6.10 a	2.00 d
	15	90	9 b	40.50 bc	5.58 a	2.50 cd
Control		**90**	**8 bc**	**38.66 d**	**5.27 a**	**2.0 cd**

Gypsum addition had a considerable impact on average plant heights, as demonstrated by the significant differences in plant heights observed between treatments (Table 4). The maximum plant height was measured when adding 15% of <2 mm, reaching 48.66 cm. whereas the plant heights at the control level were 38.66 cm. This is because the addition of gypsum improved the physical and water conditions of the soil and thus encouraged the increase in vegetative growth, and the plant heights increased with the increase in the levels of addition, the results are consistent with those found by Elshahooki and Eldabas, (1982).

Also, the results in Table (4) showed that the adding 15% to < 2 mm gave the largest paper space and flower diameter, reaching 8.02 cm^2 and 4.33 cm compared to 5.27 cm^2 and 2.0 cm at the control level, where the paper area and flower diameter increased with the increase in the levels of addition, despite the absence of significant differences between the different treatmnts, which is consistent with findings from Hammadi (2012) and Taha, (2018).

CONCLUSION

The study's findings demonstrated that adding gypsum amendments considerably enhances the soil's physical and hydrological characteristics. 15% for < 2 mm among various treatments considerably decreased soil surface crust formation and crust bulk density, and increased soil moisture retention. So, using gypsum can be an effective strategy for improving soil quality and germination conditions.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

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