The Effect of Compaction Levels and Amendments on Chemical Characteristics of Silty Clay Soil

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Abstract

An experiment was conducted in the Soil Physics Laboratories of the Department of Soil Sciences and Water Resources, College of Agriculture, University of Diyala. Silty clay soil was collected from Baladruz District in Diyala Governorate, located between latitudes 300-33° north and longitudes 300-45° east. The experiment was designed according to a completely randomized design (CRD) with three replications and two factors: the first is the compaction treatment at three levels (no compaction, symbolized as C0; compaction with 10 strikes using a 2-kg weight from a height of 50 cm, symbolized as C1; and compaction with 20 strikes using a 2-kg weight from a height of 50 cm, symbolized as C2). The second factor is the addition of amendments, which includes four types of amendments (no amendments added (A0), gum arabic (A1), fertilizer (A1), and sulfuric acid (A2). ECO RWP A2, Bentonite A3), were added based on the dry weight of the soil and treatments were randomly distributed to the experimental units. The results of the statistical analysis showed that the A1 addition treatment recorded the highest average value of soil organic matter (3.463 g kg-1) and the highest average value of available nitrogen (71.16%). While the A2 addition treatment recorded the highest average value of cation exchange capacity in the soil, reaching 28.933 centimoles of charge kg-1. The A3 addition treatment also recorded the highest average value of electrical conductivity in the soil, reaching 3.034 ds m-1. Regarding compaction treatments, the results indicate that the C2 compaction treatment yielded the highest value of available nitrogen in the soil (65.62%) and leached ammonium (5.150 mg L-1) In contrast, the C1 compaction treatment yielded the highest value of leached nitrate in the soil, reaching 6.79 mg L-1.

Keyword/ Compaction, Gum Arabic, ECO.WRP, Bantonite, Silt clay soil.

Introduction

Soils in Iraq suffer from several problems resulting from natural and human-caused causes. These have significantly harmed agricultural activity in general, whether by limiting cultivated areas, reducing productivity per unit area, or increasing production costs. Soil compaction is the process of compacting soil particles (partially saturated with water) and reducing the volume of voids using mechanical methods under a specific water pressure to increase the dry soil density. This process is accomplished by adding water. Compaction, which involves the release of water from soil particles under the influence of constant gravity, should not be confused with air voids. Air voids cannot be completely eliminated by compaction, but they can be minimized through appropriate control [7]. Static compaction is defined as an increase in soil bulk density resulting from a reduction in the interstitial pores available for fluid flow and an increase in the curvature of flow paths due to the increased contact points between particles per unit volume of soil [6]. Soil

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compaction creates unusual conditions that affect the course of chemical reactions in the soil, including the dissolution of nutrients in the soil solution and their movement to the plant. Under such conditions, there is a decrease in the movement and exchange of gases, including oxygen, causing reductive conditions to prevail over oxidative conditions [15]. The concept of soil hardening, which occurs in soil without external influences, differs from the concept of soil compaction, which occurs as a result of external influences. The mechanical force exerted by the soil upon hardening impedes seedling emergence on the one hand and root growth and penetration on the other, thus deteriorating agricultural production in such soils [16]. The micromorphology analyzed is responsible for the noticeable difference between hardened and unhardened soil horizons [12]. Cohesive soils, or soils exhibiting cohesive behavior, are soils with horizons that harden significantly upon drying, forming a structureless mass. Cohesive soils exhibit high mechanical strength when dry and lose much of this strength upon rehydration [13]. Extensive inorganic fertilization in conventional agriculture reduces soil quality. Amendment through balanced fertilization with soil amendments is expected to improve soil quality and increase plant productivity [17]. To improve some soil properties, different types of soil amendments are used. These are technologies used to improve the soils of arid and semi-arid areas that are deteriorated due to problems related to their physical, chemical, fertility and biological properties, which lead to poor plant growth. Amendments are defined as organic or chemical materials of natural or manufactured origin. They are classified from a physical point of view as (water-hating or water-loving materials), which are added to the soil to order to reduce soil losses due to erosion by improving the soil structure and increasing its stability, improving the water and fertility properties of the soil by increasing the capacity to hold water and nutrients and their availability and preserving the soil from loss [8]. A study demonstrated that the use of organic fertilizer and agricultural gypsum improved the concentration of major and minor elements and reduced the exchangeable sodium content, indicating the role of soil conditioners in improving chemical properties under different compaction conditions in silty clay soil [5]. A previous study also showed that the interaction between soil compaction and soil conditioners depends on the nature of the soil, the type of added material, and the intensity of compaction, which necessitates a comprehensive study of these factors to determine the best agricultural recommendations [2]. Therefore, this study was conducted to determine the effect of compaction, soil conditioners, and the interaction between them on some chemical properties in silty clay soil.

Materials and Methods

The experiment was carried out in the Soil Physics Laboratories - Department of Soil Sciences and Water Resources - College of Agriculture - University of Diyala. A silty clay soil was taken from Baladruz District in Diyala Governorate, which is located between latitudes (30-33°) north and longitudes (30-45°) east. The sample was taken from the surface horizon (0-30) cm, air-dried, ground with a wooden hammer, and passed through a sieve with a hole diameter of (2) mm. The experiment was carried out according to the completely random design (CRD) with three replicates. The first factor included the compaction treatment and the second factor was the addition of amendments. The

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treatments were distributed randomly to the experimental units. The treatments included compaction at three levels without compaction (C0), compaction with 10 hits using a weight of 2 kg from a height of 50 cm, and its symbol is C1, compaction with 20 hits using a weight of 2 kg from a height of 50 cm, and its symbol is C2, and adding amendments. It includes (without adding improvers A0, gum arabic A1, ECO RWP fertilizer A2, bentonite A3), at a level of 2%, and is added based on the dry weight of the soil. An iron base was designed to carry the plastic pipes vertically, with three bases, carrying 12 columns. The pipes, which have a diameter of 0.1016 m, were cut to a length of 0.3 m and their concave cover was used, as a central hole was pierced with a 10 mm diameter screw. A layer of gravel with a thickness of 0.02 m and a layer of glass wool were placed at the base of the pipe. The inner surface of the pipes was covered with wax with a layer of paraffin to prevent water from leaking from the sides of the soil. The amendments were mixed with the soil at a concentration of 2% based on the dry soil weight. The treatments were incubated for 14 weeks and continuously moistened to the field capacity of each treatment. The available nitrogen in the soil (mg kg-1) was determined. After completing the washing experiment, soil samples were taken from tubes along the soil column by inserting a 1 cm diameter tube along the soil body. The samples were dried and sieved using a sieve with a 2 mm diameter hole. Organic matter was determined by the wet oxidation method using a 1 N potassium dichromate solution, concentrated sulfuric acid, and phosphoric acid at a concentration of (85)%, followed by back titration with a 0.5 N ammoniacal ferrous sulfate solution, in the presence of diphenylamine indicator, according to the method of Walkerley and Black described in Estefan et al. [11]. Cation exchange capacity (CEC(

was estimated using 1N sodium acetate solution for saturation and washing with 95% ethyl alcohol, and displacement using 1N ammonium acetate solution. The displacement solution was collected and the sodium content was determined using a Jenway flame photometer (model PFP7) according to the method described in Estefan et al. (2013.(

Electrical conductivity (EC(

was determined in a 1:1 soil-water extract using an EC-meter according to the method described by Estefan et al. [11] using an EZODO EC-meter (model CTS-406.(

Available nitrogen in the soil(%)

Available nitrogen was determined using the method of Bremner [10] described in Black [9]. Calcium nitrate fertilizer, $Ca(NO_3)$, was used, and the addition was based on the recommended fertilizer rate of 5 kg per acre. Each tube was dissolved in water within the field capacity to reduce volatility. Soil samples were taken from the tubes along the soil column by inserting a 1 cm diameter tube along the soil body. The samples were dried and sieved through a 2 mm sieve. Available nitrogen was determined using the method of Bremner [10] described in Black [9] using a microkjæl apparatus. 100 ml of 2N potassium chloride was added to 10 g of dry, ground soil, sieved through a 2 mm sieve, in a 250 ml volumetric flask. The contents were shaken for half an hour, then filtered, and the filtrate was stored in a glass bottle. 5 ml of the filtrate was then taken and placed in the heating tube of the micro calculator. 0.2 g of magnesium oxide and 0.2 g of divar were then added. The distilled liquid (liquid ammonia) was then received in a receiving flask containing 5 ml of a mixture of boric acid and the reagents

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Bromo glycerol green and methyl red. 30 ml of liquid ammonia was collected, and the color in the receiving flask changed from purple to bright green. The contents of the receiving flask were then sieved with dilute 0.005 N sulfuric acid until the color changed to light pink. Dissolved nitrate and ammonium were estimated using the method [10], using a micro-Kjeldahl apparatus. 100 ml of filtrate from each tube was collected to estimate soluble nitrate and ammonium. Three washes were performed, one wash per three days, and the filtrate was analyzed immediately. Ammonium was determined using the same steps as for the estimation of ready-mixed nitrogen, except that the divaride alloy was not added. Ammonium and nitrate were determined together using the same steps as for ready-mixed nitrogen, but the filtrate was treated in the evaporation tube with 1 ml of 2% sulfoamic acid for several seconds to break down the nitrite before adding magnesium oxide and divaride. The amount of nitrate was calculated by subtracting the ammonium from the result of the estimation of ammonium and nitrate. Results and Discussion

Organic Matter (g kg-1(

The results of Table (1) show the effect of compaction levels and the type of amendments on the organic matter values in a silty clay soil at 2% addition rates. The gum arabic addition treatment recorded the highest average value of organic matter in the soil, reaching 3.46 g kg-1, compared to the control treatment and the addition of ECO.WRP and bentonite, which reached 2.47, 2.81, and 2.94 g kg-1, respectively, with increase rates of 40.08%, 23.06%, and 39.95%, respectively. As for the compaction treatments, the results indicate that the highest value of organic matter in the soil was in the C1 compaction treatment, reaching 3.10 g kg-1. No significant difference was recorded between the C0 and C2 treatments, in which the organic matter in the soil reached 2.860 and 2.808 g kg-1, respectively. As for the C2 treatment, the results of the two-way interaction showed that treatment C1A1 recorded the highest value of soil organic matter, reaching 3.95, while treatment C2A1 recorded the lowest value of soil organic matter, reaching 2.450 g kg-1, with a decrease rate of 40.81%. The reason behind this is that gum arabic is a complex plant polysaccharide composed of sugars and organic matter rich in organic carbon, which is consistent with Habibi et al. [14]. The highest organic carbon content was obtained (0.31 to 0.36%) in the treatment with the addition of gum arabic, compared to 0.14 to 0.22% without the addition of gum arabic.

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Table 1. Effect of compaction levels and amendment type on Organic Matter (g kg-1(

Compaction levels (C)	**Type of amendments** (A)				**Mean**
	A_0	**A_1**	**A_2**	**A_3**	**(C)**
C_0	2.49 c	3.43 ab	2.92 bc	2.60 bc	2.86 A
C_1	2.48 c	3.95 a	3.02 bc	2.96 bc	3.10 A
C_2	2.45 c	3.01 bc	2.51 bc	3.27 abc	2.81 A
Means (A)	2.47 B	3.46 A	2.81 B	2.94 B	

Means with the same letter for each factor or the interaction between them are not significantly different (P ≤ 0.05) according to Duncan's multiple range.

Cation exchange capacity (cmol kg-1(

The results of Table (2) illustrate the effect of compaction levels and the type of amendments on the values of cation exchange capacity in silty clay soil at 2% addition rates. The ECO.WRP treatment recorded the highest average value of cation exchange capacity in the soil, reaching 28.933 cmol kg-1, compared to the control, gum arabic, and bentonite treatments, which reached 25.02, 24.60, and 25.53 cmol kg-1, respectively. This represents an increase of 15.63%, 17.63%, and 13.32%, respectively. Regarding the compaction treatments, the results indicate that the highest value of cation exchange capacity in the soil was in the C2 compaction treatment, reaching 26.30 cmol kg-1. No significant difference was recorded between the C0 treatment and the C2 treatment. C1, in which the exchange capacity of cations in the soil reached 25.91 and 25.85 centimoles of charge kg-1, respectively. As for the binary interference treatment, the results showed that treatment C2A2 recorded the highest value of the exchange capacity of cations in the soil, as it reached 30.12 centimoles of charge kg-1, while treatments C0A0 and C2A1 recorded the lowest value of the exchange capacity of cations in the soil, as it reached 24.26, with a decrease rate of 19.46%. The reason behind this is the increase in negative charges due to organic acids (humic and fulvic) having carboxylic and hydroxyl functional groups. These groups generate negative charges capable of attracting positive ions and thus increasing the active sites for cation exchange, which leads to an increase in the exchange capacity of cations.

Table 2. Effect of compaction levels and amendment type on Cation exchange capacity (cmol kg-1(

Compaction levels (C)	Type of amendments (A)				Mean (C)
	A_0	A_1	A_2	A_3	
C_0	24.26 d	25.02 d	27.83 bc	26.55 cd	25.91 A
C_1	25.02 d	24.513 d	28.85 ab	25.02 d	25.85 A
C_2	25.79 cd	24.257 d	30.12 a	25.02 d	26.30 A
Means (A)	25.02 B	24.60 B	28.93 A	25.53 B	

Means with the same letter for each factor or the interaction between them are not significantly different ($P \leq 0.05$) according to Duncan's multiple range.

Electrical conductivity (ds m-1.(

The results of Table (3) illustrate the effect of compaction levels and the type of amendments on the electrical conductivity values (ds m-1) in a silty clay soil at 2% addition rates. The bentonite addition treatment recorded the highest average electrical conductivity value in the soil, reaching 3.03 ds m-1, compared to the control, gum arabic, and ECO.WRP treatments, which reached values of 2.90, 3.02, and 2.68 dSm-1, respectively, with increasing rates of 4.51%, 0.56%, and 4.29%, respectively. As for the compaction treatments, the results indicate that the highest value of electrical conductivity in the soil was in the compaction treatment C0, which reached 3.00 ds m-1. No significant difference was recorded between treatments C1 and C2, in which the value of electrical conductivity in the soil reached 2.95and 2.79%, respectively. As for the binary interference treatment, the results showed that treatment C2A1 recorded the highest value of electrical conductivity in the soil, as it reached 3.50 ds m-1, while treatment C2A0 recorded the lowest value of electrical conductivity in the soil, as it reached 2.38 ds m-1, with a decrease of 31%. The reason behind this is that bentonite is mainly composed of montmorillonite, a mineral with a high negative charge on its surface. This charge is balanced by exchangeable cations. When the bentonite is hydrated, these cations are released into the soil solution, which increases the concentration of free ions, and thus the electrical conductivity increases. With what was indicated by Al-Mishyyikh and [4], Jarallah and Abd Alshammari et al. [1] and Al-Amri [3.[

Table 3. Effect of compaction levels and amendment type on electrical conductivity (ds m-1.(

Compaction levels (C)	**Type of amendments** (A) **A_0**	**A_1**	**A_2**	**A_3**	**Mean (C)**
C_0	3.02 a	2.71 a	3.01 a	3.25 a	3.00 A
C_1	3.30 a	2.84 a	2.62 a	3.02 a	2.95 A
C_2	2.38 a	3.50 a	2.42 a	2.83 a	2.79 A
Means (A)	2.90 A	3.02 A	2.68 A	3.04 A	

Means with the same letter for each factor or the interaction between them are not significantly different ($P \leq 0.05$) according to Duncan's multiple range.

Available Nitrogen(%)

The results of Table (4) illustrate the effect of compaction levels and the type of amendments on the available nitrogen values (%) in a silty clay soil at a 2% addition rate. The gum arabic treatment recorded the highest average available nitrogen value, reaching 71.16%, compared to the control treatment and the addition of ECO.WRP and bentonite, which reached values of 57.66%, 56.00%, and 61.05%, respectively, with increases of 23.41%, 27.07%, and 16.56%, respectively. As for the compaction treatments, the results indicate that the highest value of available nitrogen in the soil was in the compaction treatment C2, reaching 65.62%, with a significant difference between the treatment C0 and C1, in which the value of available nitrogen in the soil reached 57.75 and 61.04%, respectively. As for the binary interaction treatment, the results showed that treatment C1A1 recorded the highest value of available nitrogen in the soil, reaching 77.00%, while treatment C0A0 recorded the lowest value of available nitrogen in the soil, reaching 49.00%, with a decrease rate of 36.36%.

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Table 4. Effect of compaction levels and amendment type on available nitrogen(%)

Compaction levels (C)	Type of amendments (A)				Mean
	A_0	**A_1**	**A_2**	**A_3**	**(C)**
C_0	49.00 d	67.66 ab	58.33 bcd	58.33 bcd	57.75 b
C_1	57.50 bcd	77.00 a	52.50 cd	57.16 bcd	61.04 ab
C_2	66.50 abc	68.83 ab	57.16 bcd	70.00 ab	65.62 a
Means (A)	57.66 b	71.16 a	56.00 b	61.05 b	

Means with the same letter for each factor or the interaction between them are not significantly different ($P \leq 0.05$) according to Duncan's multiple range.

Ammonium leached from soil (mg L-1.(

The results of Table (5) illustrate the effect of compaction levels and the type of amendments on the available nitrogen values (%) in a silty clay soil at 2% addition rates after adding calcium nitrate fertilizer. The gum arabic treatment recorded the highest average value of ammonium leached from the soil, reaching 5,00 mg L-1, compared to the control treatment and the addition of ECO.WRP and bentonite, which reached values of 4.86, 4.94, and 4.37 mg L-1, respectively, representing increases of 2.98%, 1.13%, and 14.52%, respectively. As for the compaction treatments, the results indicate that the highest value of available nitrogen in the soil was in the compaction treatment C2, reaching 5.15 mg L-1, with a significant difference between the C0 and C1 treatments, in which the value of available nitrogen in the soil reached 4.825 and 4.40%, respectively .

As for the binary interaction treatment, the results showed that the C2A0 treatment recorded the highest value of ammonium leached from the soil, as it reached 5.566 mg L-1, while the C1A1 and C0C3 treatments recorded the lowest value of ammonium leached from the soil in the soil, as it reached 4.00%, with a decrease rate of 28.13%.

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Table 5. Effect of compaction levels and amendment type on ammonium leached from soil (mg L-1.(

Compaction levels (C)	Type of amendments (A)				Mean (C)
	A_0	A_1	A_2	A_3	
C_0	4.80 abc	5.57 a	4.933 abc	4.00 c	4.83 AB
C_1	4.20 bc	4.00 c	4.933 abc	4.47 abc	4.40 B
C_2	5.57 a	5.43 ab	4.966 abc	4.63 abc	5.15 A
Means (A)	4.86 A	5.00 A	4.944 A	4.37 A	

Means with the same letter for each factor or the interaction between them are not significantly different ($P \leq 0.05$) according to Duncan's multiple range.

Nitrate leached from soil (mg L-1.(

The results of Table (6) illustrate the effect of compaction levels and the type of amendments on the values of nitrate leached from soil (mg L-1) in a silty clay soil at 2% addition rates after adding calcium nitrate fertilizer. The ECO.WRP treatment recorded the highest average value of nitrate leached from soil, reaching 6.02 mg L-1, compared to the control, gum arabic, and bentonite treatments, which reached 5.51, 5.36, and 4.93 mg L-1, respectively, representing increases of 9.27%, 12.45%, and 22.07%, respectively. As for the compaction treatments, the results indicate that the highest value of nitrates washed from the soil was in the compaction treatment C1, which amounted to 6.79 mg L-1. No significant difference was recorded for C0 and C2, in which the value of nitrates washed from the soil amounted to 4.51 and 5.07 mg L-1, respectively. As for the binary interaction treatment, the results showed that treatment C1A0 recorded the highest value of nitrates washed from the soil, as it amounted to 8.20 mg L-1, while treatment C0A1 recorded the lowest value of nitrates washed from the soil, as it amounted to 4.000%, with a decrease rate of 51.21%.

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Table 6. Effect of compaction levels and amendment type on nitrate leached from soil (mg L-1.(

Compaction levels (C)	Type of amendments (A)				Mean (C)
	A_0	A_1	A_2	A_3	
C_0	4.17 e	4.00 e	5.10 cde	4.77 de	4.51 B
C_1	8.20 a	7.10 ab	6.63 abc	5.23 cde	6.79 A
C_2	4.17 e	4.97 cde	6.33 bcd	4.80 de	5.07 B
Means (A)	5.51 AB	5.36 AB	6.02 A	4.93 B	

Means with the same letter for each factor or the interaction between them are not significantly different (P ≤ 0.05) according to Duncan's multiple range.

Conclusions

This study concludes that the chemical properties of the improved soil are improved compared to the unimproved soil. The addition of gum arabic also increased organic matter and available nitrogen, which is important for improving soil fertility. The addition of ECO.WRP fertilizer played an important role in increasing the cation exchange capacity .

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