# The Role of Soil Amendments in Reducing the Bulk Density of Calcareous Soils under Different Textures

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## Abstract
This study investigated the quantitative relationship between organic matter content and improvements in soil physical and chemical properties using medium and fine textured Iraqi soils. Corn cobs, barley straw, and rice husks were applied at rates of 0–2% of soil dry weight. The mixtures were incubated for 20 weeks at field capacity (33 k pa) and ambient temperature. Results showed that adding organic matter reduced bulk density by 10–15%. Available nitrogen, phosphorus, and potassium levels increased with higher organic matter additions. The 1.5% application rate was the most effective across all organic matter types. This treatment improved soil fertility and structure. Overall moderate organic additions enhance soil productivity and sustainability.
**Keywords**: Soil organic matter, Bulk density, Nutrient availability, Soil fertility, texture.

# دور محسنات التربة في خفض كثافة الترب الكلسية الظاهرية تحت نسجات مختلفة

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## الخلاصة
هدفت هذه الدراسة إلى تحديد العلاقة الكمية بين محتوى المادة العضوية وتحسين الخصائص الفيزيائية والكيميائية للتربة باستخدام ترب عراقية متوسطة وناعمة النسجة. استُخدمت ثلاثة أنواع من المواد العضوية: قشور الذرة، وقش الشعير، وقشور الرز، بنسب 0–2% من الوزن الجاف للتربة. تم تحضين الخلطات لمدة 20 أسبوعًا عند السعة الحقلية (33 كيلو باسكال) ودرجة الحرارة المحيطة. أظهرت النتائج أن إضافة المادة العضوية خفّضت الكثافة الظاهرية بنسبة 10-15%. كما ازدادت تراكيز النيتروجين والفوسفور والبوتاسيوم الجاهزة بزيادة كمية المادة العضوية. وكانت نسبة الإضافة 1.5% هي الأكثر فعالية لجميع أنواع المواد العضوية. أدت هذه المعاملة إلى تحسين واضح في خصوبة وتركيب التربة . بصورة عامة، تُظهر النتائج أن الإضافة المعتدلة للمادة العضوية تعزز إنتاجية التربة واستدامتها.
**الكلمات المفتاحية:** المادة العضوية في التربة ، الكثافة الظاهرية ، جاهزية العناصر الغذائية ، خصوبة التربة.

## Introduction

Studies indicate that organic matter plays a detrimental role in enhancing both the physical and chemical properties of soil, hence increasing soil production and reducing deterioration (Farouk *et al.,* 2024). The formation and decomposition of soil organic matter are critical processes that sequester and liberate energy derived from photosynthesis (Ghoneim *et al.,* 2020). Soil organic matter predominantly arises from the microbiological and faunal decomposition of plant residues (Shabtai *et al.,* 2023). The decomposition of plant residue results in the formation of humic substances, which comprise 70 to 80% of the organic matter in most soils (Ghoneim *et al.,* 2020). Soil organic matter primarily results from the microbiological and faunal breakdown of plant leftovers (Shabtai *et al.,* 2023). The decomposition of plant residue results in the formation of humic substances, which comprise 70 to 80% of the organic matter in most soils (Ennab *et al.,* 2023).

Soil organic matter has the capacity to retain nutrients through cation exchange. Dietary cations, including ammonium ($NH_4$), calcium (Ca), magnesium (Mg), and potassium (K), are preserved on the cation exchange sites of organic matter (Ciric *et al.,* 2023). Additionally, the concentrations of essential plant elements, such as trace elements, in organic matter are sufficient (Bashir *et al.,* 2021).

The cation exchange capacity of soil organic matter may account for 20 to 70% of the soil's total cation exchange capacity. Soil organic matter synthesis integrates nutrients such as nitrogen (N) and phosphorus (P) into the soil matrix, enabling the soil to function as a reservoir for these and other nutrients (Cotrufo & Lavallee, 2022).

The intensive farming system reduced soil organic matter through a substantial increase in the rate of decomposition and a measurable reduction in the rate of organic matter accumulation (Bedolla-Rivera *et al.,* 2023). On the other hand, an adequate level of organic matter in soils is also essential for maintaining soil physical conditions and markedly reduces water erosion (Demir *et al.,* 2022),

(Lombardi *et al.,* 2022) Found that on a weight basis, the organic fraction is the highest effective fraction of soils.
Reviewing the literature revealed that organic matter is typically added to soil as animal manure, farm waste, and crop residues at rates of application as high as 25 tons per hectare (Humphries *et al.,* 2023). Others (Unagwu *et al.,* 2023) suggested that adding 12.5 to 15.0 Tons per hectare is as practical as the higher rates. (Oelbermann *et al.,* 2023), Moreover, Wei *et al.* (2024) found that higher or lower rates of applications are not important in terms of improving soil physical and chemical conditions, and in return, promoting plant growth.

Apparently, there is a conflicting report in the literature concerning the effective rate of organic matter in soils. Furthermore, the role of organic waste, which is most abundant in Iraq, such as corn cobs, straw, and rice husks, has not been thoroughly investigated for its effectiveness in soils. Therefore, the objectives of this work are to determine the most efficient rate of Organic matter application to soils. Corn cob, Rice Husks and wheat straw were included in this study.

## Materials and Methods

The Study was carried out in the laboratory using fine and medium textured soils. fine textured soil obtained from the Tuwaitha area, 30 km southeast of

Baghdad and medium textured soils obtained from the Jaderia farm, southern suburb of Baghdad. These two types of soil are the most common in the entire Lower Mesopotamian Plain of Iraq. Relevant characteristics of both soils are given in Table 1. Soil samples were collected at a depth of 0 to 20 cm, air-dried, thoroughly mixed, and ground to pass through a 2 mm sieve. Soils in 10 kg lots were transferred into a top-open plastic box. Barley straw, Rice husks, and well-decomposed corn cobs were used as sources of organic matter. Organic matter from each source was added to the soil in the box at ratios of 0%, 0.5%, 1.0%, 1.5%, and 2.0%. Three boxes of each soil type were assigned to each level of organic addition. Soils and organic matter were thoroughly mixed and homogenized, then incubated at a (33 K Pa) moisture content for 20 weeks. After the incubation period, the soils were air-dried, thoroughly ground through a 2 mm sieve for evaluation of the effect of rate and type of organic matter content on the soils under investigation. The bulk density of the soil was determined using the core method, in which undisturbed soil samples were collected using a metal cylinder of known volume. The samples were oven-dried at 105°C for 24 hours and then weighed after cooling (Batjes, 2020). Soil organic matter was determined using the Walkley–Black wet oxidation method (Walkley and Black, 1934). Total nitrogen was estimated by the Kjeldahl digestion method as described by Bremner (1965). Available phosphorus was extracted using the Olsen method and measured spectrophotometrically (Olsen *et al.*, 1954). Cation exchange capacity (CEC) was determined using the ammonium acetate method at pH 7 following the procedure outlined by Chapman (1965). Soil pH was measured in a soil–water suspension using a pH meter according to the method described by Jackson (1973). Soil electrical conductivity of the saturated paste extract (ECe) was determined using a conductivity meter according to the method described by Richards (1954).

## Results and Discussion

Analyses of both soils (Table 1) clearly indicate that they contain appreciable levels of salts, as indicated by the relatively high electrical conductivity of the soil paste extract (>5.0 $dSm^{-1}$). However, this is the case with most soils of the lower Mesopotamian plain in Iraq these days, due to severe water shortages that necessitate considering the leaching fraction portion.

**Table 1. Some chemical and physical composition properties**

| Properties | Unit | Tuwaitha Soil (fine soil) | Jadria Soil (medium soil) |
|---|---|---|---|
| Sand | $g\ kg^{-1}$ soil | 320 | 580 |
| Silt | | 300 | 150 |
| Clay | | 380 | 270 |
| Soil texture | | Clay loam | Sandy Clay loam |
| Bulk density | $Mg\ m^{-3}$ | 1.50 | 1.45 |
| pH | | 7.4 | 6.8 |
| Ece | $dS\ m^{-1}$ | 16.3 | 10.4 |
| O.M | $g\ kg^{-1}$ soil | 6.0 | 4.0 |
| CEC | $C\ mol\ kg^{-1}$ soil | 24.2 | 18.2 |
| Available elements | | | |
| N | $mg\ kg^{-1}$ | 100 | 75.0 |
| P | | 13.8 | 10.3 |
| K | | 28.0 | 24.8 |

**Effect of Organic Matter on Soil Bulk Density**

The results of the study revealed that the addition of the three organic materials—rice husks, barley straw, and corn cobs to both the fine - and medium textured soils led to an apparent reduction in bulk density values compared with the control treatment (0%), and that this reduction increased progressively with higher application rates up to 2.0%.

In the fine textured soil, the bulk density in the control treatment was 1.50 g $cm^{-3}$, while it decreased to 1.37 g $cm^{-3}$ with the application of rice husks, 1.35 g $cm^{-3}$ with corn cobs, and reached the lowest value of 1.30 g $cm^{-3}$ with barley straw at the 2.0% rate. In the medium-textured soil, the initial bulk density was 1.45 g $cm^{-3}$, and it decreased progressively with increasing organic matter addition rates. At the 2.0% application level, bulk density values reached 1.32 g $cm^{-3}$ with rice husks, 1.30 g $cm^{-3}$ with corn cobs, and the lowest value of 1.28 g $cm^{-3}$ with barley straw. This represents a reduction of approximately 10–15% from the original bulk density, indicating that even in medium textured soils, organic amendments enhance soil porosity and reduce compaction (Table 2).

**Table (2): Bulk density of treatments for two types of soil.**

| Treatment | Type of soil | |
|---|---|---|
| | fine soil | Medium soil |
| Control | 1.50 | 1.45 |
| Rice husks | 1.37 | 1.32 |
| corn cobs | 1.35 | 1.30 |
| barley straw | 1.30 | 1.28 |

This reduction provides clear evidence of the beneficial influence of organic matter on improving soil physical structure, primarily through the enlargement of pore spaces and the attenuation of interparticle cohesion among mineral components (Skic *et al.,* 2023). Owing to its comparatively low specific gravity, organic matter effectively enhances total porosity, thereby promoting aeration and water transmission within the soil matrix. Such effects are particularly pronounced in fine-textured soils, which are inherently characterized by high bulk density and restricted permeability (Robinson *et al.,* 2022).

The chemical makeup and rate of degradation of the three organic components account for their variations. The higher decrease in bulk density observed with barley straw can be explained by the material's relatively rapid decomposition, which encourages microbial activity and the creation of biopolymers that stabilize soil aggregates (Piotr *et al.*, 2022) .Corn cobs, on the other hand, enhance soil porosity more gradually but steadily over time, as they break down more slowly (Zou *et al.,* 2021).In contrast to the other two organic sources, rice husks have a minimal impact on bulk density reduction, as they break down more slowly due to their high silica content (Bazuhair, 2023).

Results (Figure 1) showed that the residual organic matter content increased in both soils with the increase in the level of organic matter addition, irrespective of the type of organic matter added. Apparently, there is a linear increase in residual organic matter content with an increase in the level of addition. The rate of increase, averaged across all types of organic matter added, is 0.408 and 0.399 in Tuwatha and Jaderia soils, respectively. These results suggest that a low level of organic matter content is primarily attributed to an extremely low level of addition, rather than a high rate of decomposition. This suggests adapting farming practices in Iraq that contribute to increasing the level of organic matter of soils.

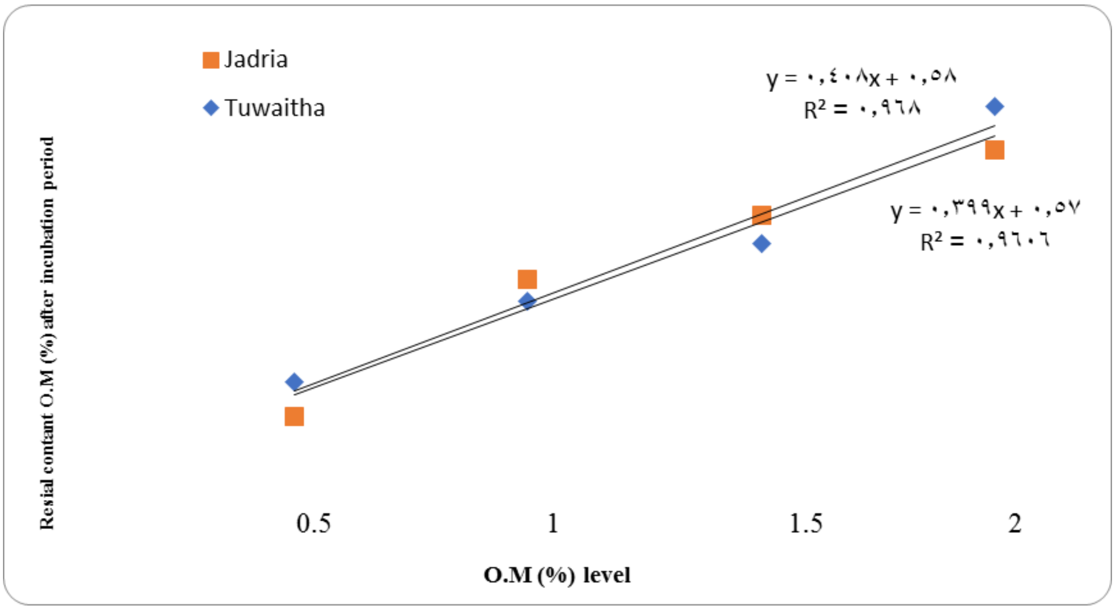


**Fig.1. Effect of the organic matter level added to soil (%) on total Organic matter after incubation for 20 weeks at room temperature.**

## Total Nitrogen

The nitrogen content of both soils increases significantly with the addition of organic matter at all levels. Regression analysis revealed that the regression coefficient for the N level and total nitrogen content of both soils, averaged across all types of organic matter added, is highly significant. The rate of total N increase was 0.049 and 0.018 for Tuwatha and Jaderia soils, respectively. This confirms previous reports that the total nitrogen content of soils increases with the increase in organic matter content (Figure 2). These findings align with (Chen *et al.*, 2025) results, which confirming that higher organic matter inputs substantially enhance total nitrogen levels in soil systems. A recent study published in soil and tillage Research reported that optimal nitrogen fertilizer management increased soil organic carbon (SOC) density by increasing the proportion of plant-derived carbon and particulate organic matter in the topsoil, which is closely associated with elevated soil organic matter and total nitrogen content. Additionally, long-term organic amendments combined with nitrogen fertilization have been shown to significantly increase soil organic carbon fractions and promote soil carbon sequestration, highlighting the role of continuous organic matter inputs in improving soil nutrient pools and biological functioning (long-term organic amendment study; organic materials increased SOC by up to 119.8%) (Ye *et al.*, 2025). These results further support the positive relationship between organic matter addition and total nitrogen enrichment observed in the current study.

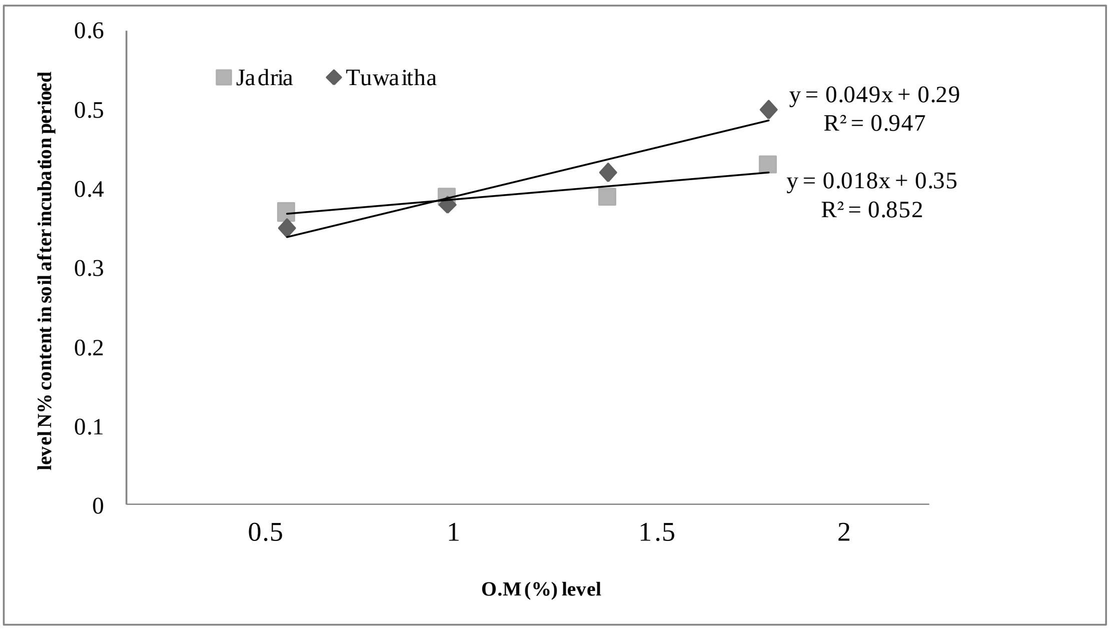


**Fig.2. Effect of the organic matter level added to soil (%) on total Nitrogen after incubation for 20 weeks at room temperature.**

## Available Phosphorus ($NaHCO_3$ extractable)

The highest level of available phosphorus (P) in Tuwatha and Jaderial soils was 25.8 and 21.5 ppm, respectively, under a 2.0% level of Corn cob addition. These levels of available P are twice that of soil P before addition. The available P in both soils incubated with Barley straw and Rice husks is relatively equal. However, in both soils, Available Phosphorus (P) increases with the addition of organic matter (Figure 3). These results agree with recent research showing that organic amendments significantly enhance soil available phosphorus by increasing labile P fractions and stimulating microbial processes that mobilize P from organic and inorganic pools. For example, a global synthesis study found that organic amendments (including compost, straw, and manure) significantly increased available P in amended soils compared with non-amended controls, highlighting the role of organic matter in releasing phosphorus into plant-available forms (Liu *et al.*, 2025). Additionally, incubation and field experiments have demonstrated that the application of manure and crop residues increased soil labile phosphorus fractions and promoted microbial phosphatase activity, leading to higher available P compared with soils without organic amendments (Zhang, *et. al.*, 2023).

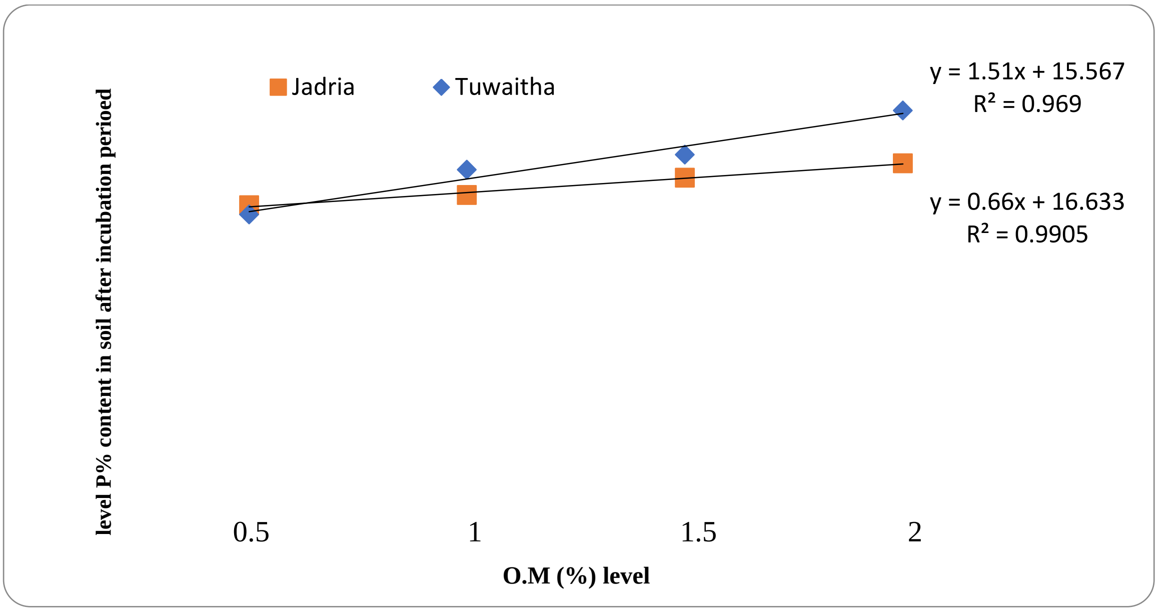


**Fig.3. Effect of the organic matter level added to soil (%) on Available phosphorus after incubation for 20 weeks at room temperature.**

**Potassium (K)**

Extractable Potassium is, in fact, similar to that of P, being the highest under the highest Corn cob treatment in both soils (Novak *et al*., 2021). Potassium content also increases with an increase in the level of organic matter addition, irrespective of the type of organic matter added. The rate of increase, however, depends on the type of organic matter added (Xu, J., *et al*., 2025) (Figure 4). These results are consistent with recent research showing that organic amendments significantly enhance soil available potassium by increasing the release of potassium ions and improving nutrient cycling processes. For example, studies on maize soils amended with organic manure reported that the addition of organic matter increased available potassium concentrations compared with unamended controls, indicating that organic materials facilitate the release of K into the soil solution (Bader *et al.*, 2021). Likewise, controlled experiments with biochar and other organic amendments found that increasing levels of organic amendments led to higher extractable potassium due to enhanced microbial activity and nutrient mineralization, confirming the positive influence of added organic matter on soil potassium availability (Tao *et. al.*, 2024).

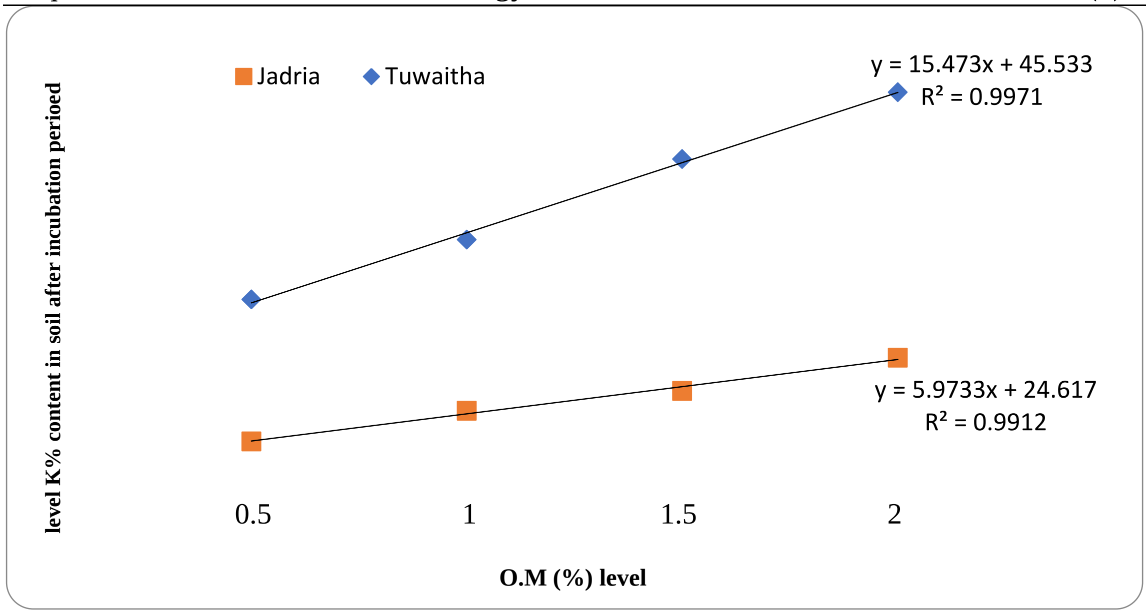


**Fig.4.Effect of the organic matter level added to soil (%) on available Potassium after incubation for 20 weeks at room temperature.**

## Conclusion

The incorporation of organic residues led to clear improvements in soil physical condition and nutrient status across both soil textures. A moderate application level (1.5%) produced the most consistent response among all treatments. These results indicate that judicious use of organic inputs contributes to better soil performance and supports sustainable soil management practices.

## Recommendation

Moderate application (1.5%) of organic residues is recommended for calcareous soils to enhance performance, promoting the use of local agricultural wastes and long-term field studies to validate the results.

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