Research Article

Effect of Organic Conditioners on the Physical Properties of Sandy Soil under Drip Irrigation Conditions

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Abstract | Sandy soils are characterized by poor physical properties, low water and nutrient retention capacity, which limits their agricultural productivity. Numerous studies have shown that adding organic matter can induce significant changes in their physical properties. This study was conducted to determine the extent of the impact of organic conditioners- Animal waste (bovine and ovine manure) and plant waste (wheat and rice straw), as well as their combination- on some of the physical properties of sandy soils after planting (*Solanum tuberosum* L.) under a drip irrigation system. The experiment was carried out in a randomized complete block design (RCBD) with three replicates and three concentrations (5%, 10%, and 15%) of each conditioner, individually or in combination. The results showAed that all treatments significantly improved soil bulk density. The treatment with a 15% Bovine and ovine manure mixture recorded the lowest value, 1.394 mg.cm^{-3}, compared to the control (0%) value of 1.635 mg.cm^{-3}. Using a rice and wheat straw mixture also reduced bulk density to 1.458 mg.cm^{-3} at the same concentration. In terms of total porosity, organic conditioners contributed to a gradual increase with increasing concentration. Porosity reached 47.40% when using a 15% animal manure mixture, compared to 38.30% in untreated soil. Saturated hydraulic conductivity decreased gradually with increasing concentrations, due to the increase in micropores that slow water movement. Conductivity decreased to 0.463 cm.min-1 when the soil was treated with a 15% Bovine and ovine manure mixture, compared to a control coefficient of 0.786 cm.min^{-1} in the soil. Soil moisture content also improved significantly across all treatments, with the highest recorded moisture content of 39.46% in the 15% animal waste mixture treatment, compared to the initial value of 14.6%. These results demonstrate that the use of organic conditioners, especially at high concentrations, represents an effective and sustainable means of improving the physical properties of sandy soils. The use of a mixture of animal and plant waste is recommended for optimal results as part of sustainable soil management strategies.

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Introduction:

Sandy soils present significant challenges for agriculture due to their weak physical properties, including low water and nutrient retention, limited porosity, and high permeability. These characteristics impair soil structure and hinder plant growth. Recent studies have shown that the addition of organic conditioners, whether from animal or plant sources, can significantly improve the physical properties of sandy soils, enhancing their productivity and agricultural sustainability (Liu *et al*., 2024b). The agricultural sector in some countries around the world suffers from a continuous decline in its economic contribution due to constraints that hinder investment, such as water scarcity, soil degradation, weak infrastructure, and a lack of government support (Drebee *et al*., 2021; Drebee *et al*., 2022). Sandy soils are among the most prominent marginal soil types, facing physical problems that limit their productivity. The use of organic amendments, in conjunction with drip irrigation techniques, contributes to improving the properties of these soils and increasing their agricultural efficiency.

In this context, several studies have been conducted that demonstrate the positive effects of using organic wastes like manure, poultry manure, straw, and compost. Applying these materials enhances the soil's organic matter content, structure, and porosity, lowers its bulk density, and increases the moisture retaining capacity (Yuan *et al*., 2022; El-Mahrouk *et al*., 2023). As for the plant residues, rice and wheat reduce the salt build-up while enhancing the soil's aeration. Animal and plant residues also offer abundant macro and micro nutrients (Hundi *et al*., 2025; Jafaar *et al*., 2022).

Combining organic residues, e.g., mixing straw with manure or composting with poultry manure, yields greater results as opposed to just one type of organic waste. The diversity in the compounds improves soil nutritional balance and microbial activity, which is vital in the decomposition of organic matter and ameliorating the soil's physical and chemical properties (Zhao *et al*., 2018; Jawad *et al*., 2019).

The application of both animal and plant sourced organic conditioners improves soil structure, reduces the soil's bulk density, and raises the water retention level (Sulok *et al*., 2021; Xuan *et al*., 2023). The application of organic matter improves the physical characteristics of the soil by increasing total porosity, and the bond, cohesion of particles are reduced. These changes foster better microbial activity and aeration. Moreover, organic matter aids in enhancing the distribution of pore size, which further helps in improving the soil's hydraulic properties (Kandra *et al*., 2024). In light of this, the type composition of the amendments has been noted as the greatest deciding factor regarding how useful these additions are and as a result the effectiveness stems from applying animal manure in contrast to applying plant residues which have a differing rate of decomposition, along with the fiber and nutritional content (Al-Juthery *et al*., 2019; Sapkota *et al*., 2025).

Additionally, irrigation methods play an important role in having control over the soil performance after manipulating its attributes, so the way water is given to the soil surface dictates how organic matter and nutrients are distributed vertically and laterally in the soil. In terms of sandy soils, drip irrigation is the most advanced technique in arid and semi-arid regions as it is water-conserving and cuts down on evaporation/surface runoff. With regards to organic residues, drip irrigation increases their effectiveness in the root zone (Yuan *et al*., 2022; Hassan *et al*., 2022). The integration of multiple amendment types into a methodical approach of an organic amendment is important as it offers a better balance between nutrient content and rate of decomposition, thereby enhancing the soil properties more sustainably and efficiently (García-Orenes *et al*., 2020; Akol *et al*., 2021).

Similarly, organic amendments are coherent with an irrigation system as they affect the soil structure too. Improved sandy soils are more adept at conserving moisture and inhibiting deep-seated water loss, thus enhancing water use efficiency, particularly in agriculture systems that employ drip (Hamid, 2025a; Essien, 2011). The lack of agricultural development in several countries, especially those with arid or semi-arid climates, is in part explained by the declining soil fertility coupled with the poor physical structure of the soil, dominated by sandy or degraded soil (Mohammed and Suliman, 2023). Agricultural productivity and resource use efficiency, especially water, suffer greatly from low organic matter, weak moisture retention, and excess deep infiltration (Hassan *et al*., 2023). In this context, enhancing soil structure using low-cost, locally available organic conditioners represents a strategic solution to address these problems. This also contributes to supporting food security and reducing reliance on costly chemical inputs, positively impacting the long-term sustainability of the agricultural sector (Al-Hadethi and Almashhadani, 2019).

Therefore, this study aims to understand the impact of adding these residues, either individually or as mixtures, on the physical properties of sandy soils, including bulk density, total porosity, Saturated hydraulic conductivity, and moisture content. This will pave the way for providing scientific recommendations to enhance the use of these materials in managing degraded soils and increasing their productivity within sustainable agricultural practices.

Materials and Methods

This experiment was conducted using Loamy Sand soil to study the effect of adding organic plant waste (rice straw and wheat straw) and animal waste (Bovine manure, Ovine manure), either individually or as mixtures, on some physical properties of sandy soil cultivated with potatoes (Solanum tuberosum). The experiment was conducted by adding three different levels of organic conditioners (5, 10, and 15%) of the soil weight, individually and in combination for each type.

The field soil was prepared for planting and then planted with potato tubers. Immediately after planting, organic waste was added to the soil according to the quantities specified for each treatment, individually or as a mixture of plant and animal waste.

The basic physical properties of sandy soils were analyzed, including:

- Bulk density
- Porosity
- Moisture Content
- Saturated Hydraulic Conductivity

To conduct physical and chemical analyses, soil samples were oven dried and sieved using a 2 mm hole diameter sieve. The results of these analyses are shown in Table 1.

Drip irrigation was also used during the experiment, with the drippers spaced 30 cm apart to ensure even moisture distribution around the plant roots. It enables precise control of water quantities and reduces losses through evaporation and runoff. Daily water requirements are calculated based on scientific equations that take into account reference evapotranspiration (ET_0), crop coefficient (Kc), coverage area, and system efficiency.

Table 1: *Some chemical and physical properties of the studied soil.*

Parameters	Unit	Value
Physical properties		
Bulk density	$Mg.m^{-3}$	1.635
particle density	$Mg.m^{-3}$	2.651
Total porosity	%	38.30
Field capacity	%	14.60
Saturated Hydraulic Conductivity	$cm.min^{-1}$	0.786
Particle size distribution		
Sand	gm.kg-1	850.00
silt	gm.kg-1	105.00
Clay	gm.kg-1	45.00
Chemical properties		
pH $(1:1)_{sups}$	———	8.42
EC $(1:1)_{Ext}$	$dS.m^{-1}$	1.42
$CaCO_3$	%	0.98
OM	%	0.23

The daily water requirements of the potato crop were estimated based on the scientific equations shown below, with detailed results shown in Table 2, which reflect the estimated values for each growth stage according to specific climatic conditions and a drip irrigation system.

$$ET_c = ET_o * K_c \text{ .... (1)}$$

$$\text{Water}_{daily} = \frac{ETc * A}{Ei} \text{ ... . (2)}$$

ETc= Actual crop requirement (mm.day-1)
ETo = Reference Evapotranspiration ($mm.day^{-1}$)
K_c = Crop Coefficient (variable depending on the growth stage)
$Water_{daily}$ = Amount of water required (L.plant.day-1) A = Plant area (m^2.plant)
Ei= Drip irrigation system efficiency

Experimental design and statistical analysis

The field experiment used a randomized complete block design (RCBD) with two factors and three replicates each. The first factor included the type of bio-amendment (Animal waste: Bovine manure, ovine manure, and plant waste: wheat straw and rice straw).

While the second factor included four different levels of organic condition (0%, 5%, 10%, and 15%) of the soil weight, individually and in combination for each type. Soil volume and mass were calculated to determine the quantities of the added amendment. The results were statistically analyzed using Sas software to test for significant differences at a probability level of ≤ 0.05 using the least significant difference (LSD) (Sas, 2001).

Table 2: *Daily water requirements of potatoes according to growth stages and ET_0.*

Growth Stage	Duration (Day)	Kc	Approximate water requirement (L Plant^{-1} D^{-1}) Et_0 = 5 (Mm)
Germination	0-15	0.4-0.5	0.4 – 0.6
Vegetative Growth	15-30	0.7-0.85	0.7-1.0
Onset Of Tuber Formation	30-60	1.0	1.1-1.4
Fullness Of Tubers	60-85	1.1-1.05	1.3-1.6
Maturity	85-100	0.7-0.75	0.8-1.0

Soil physical properties

Soil particle size distribution: The distribution of primary soil particles (sand, silt, and clay) was determined using the pipette method (Black, 1965).

Bulk density: It was measured using the core sampling method with a metal cylinder, following the procedure outlined by Black (1965).

Total porosity: It was calculated based on the measured values of bulk and particle densities, as described in (Black, 1965).

$$P\% = (1-(pb/ps))\times100 \quad .... \quad (3)$$

Saturated hydraulic conductivity: Saturated hydraulic conductivity was determined using the constant head method as described by Klute and cited in (Black, 1965). A constant water head of 2 cm was maintained above the soil column, and the volume of water percolating through the soil was recorded over set time intervals. Once a steady flow rate was achieved—i.e., when the outflow volume remained constant over time—the saturated hydraulic conductivity was calculated accordingly.

Soil moisture content: Soil moisture content was estimated by the gravimetric method, following the procedure outlined in (Black, 1965). Fresh soil samples were weighed, then oven-dried at 105 °C for 24 hours to determine their dry weight. The moisture content was then calculated using the following formula:

$$\text{Moisture content (\%)}=(\text{Wet weight}-\text{Dry weight} / \text{Dry Weight})\times100 \quad ...... \quad (4)$$

Estimating the chemical properties of the soil

Soil pH: The soil pH was determined in a 1:1 soil-to-water suspension using a pH meter, following the procedure described by (Page, 1982).

Electrical conductivity (EC): Electrical conductivity was measured 1:1 soil-to-water extract using a conductivity meter, according to (Page, 1982).

Organic matter content: Organic matter content was estimated using the wet oxidation method (Walkley-Black method)as described in (Page, 1982).

Results and Discussion

Effect of organic conditioner types on the bulk density of sandy soil

Figure 1 shows that the bulk density of sandy soil gradually decreased with increasing concentrations of organic conditioners, whether of animal, plant, or a combination of both. When comparing the effects of different types of conditioners, it was observed that the animal waste mixture (Bovine and ovine manure) was the most effective, recording the lowest bulk density value at the highest concentration (15%), reaching 1.394 mg.cm^{-3}, compared to the control (0%), which was 1.635 mg.cm^{-3}, which is lower than the other treatments.

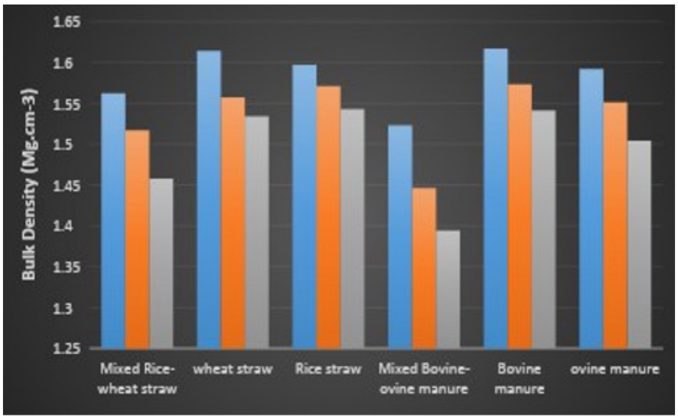

Figure 1: *Effect of organic conditioner types on the bulk density (mg.cm^{-3}) of sandy soil.*

This decrease is a positive indicator of improved soil physical structure, as bulk density is one of the most important physical indicators that reflect the cohesion of particles and the soil's efficiency in aeration and water retention. When bulk density decreases, porosity increases, improving conditions for root growth and increasing microbial activity in the root zone (Kok *et al*., 2023). The cumulative integrated impact is due to the combined characteristics of both types of manure. Bovine manure helps enhance soil structure due to its fibrous nature, while sheep manure has a high organic matter content with rapid decomposition. These two properties together will be able to improve soil elevation, enhance aeration potential, reduce cohesion, and promote biological activity (Sapkota *et al*., 2025). As for plant residues, a mixture of rice straw and wheat straw at 15% concentration is more effective in diminishing bulk density than either one of the straws on its own, reaching 1.458 $mg.cm^{-3}$ rather than 1.467 $mg.cm^{-3}$and 1.494 $mg.cm^{-3}$, respectively. This is related to the synergistic effects of rice straw's high silica, which aids disintegration and enhances drainage, and wheat straw's moderate organic matter and fiber contribution to soil. A balance of innovative soil's physical structure and strength equilibrium of these straws promotes and improves soil structure. (Akinremi *et al*., 2006). It's also important to point out how applying a drip irrigation system significantly enhances the impact of organic conditioners with even moisture distribution around roots while minimizing erosion or the clumping of fine particles. Moreover, drip irrigation sustains moderate moisture levels around organic matter, enhancing microorganism activity, thus accelerating the decomposition of organic matter. As a result, soil structure, as well as bulk density, is improved more than with traditional irrigation methods. The synergy with organic conditioners and irrigation systems indicates the need to fine-tune agricultural practices alongside sophisticated water management practices to attain optimal soil physical properties (Al Hasnawi *et al*., 2020).

Overall, results validated the hypothesis formulated regarding the effectiveness of organic Conditioners, particularly those with higher concentrations (15%), in enhancing the bulk density of sandy soils. This is consistent with numerous studies that have indicated that adding organic matter reduces particle cohesion, increases pore space, improves soil water retention, and provides a suitable environment for microorganism activity. Therefore, it is recommended to apply this concentration of improvers within agricultural management practices, especially when using drip irrigation, due to its complementary role in enhancing soil efficiency and achieving higher productivity (Kok *et al*., 2023; Hamid, 2025b).

Effect of organic conditioner types on the Total porosity of sandy soil

Figure 2 shows that the addition of organic conditioner, whether animal or plant waste, or a combination of both, significantly increased the total porosity of sandy soils as concentrations increased from 5% to 15%. Total porosity increased from 38.98% to 47.40% when using a Bovine and ovine manure mixture, and from 39.09% to 44.98% when using a rice and wheat straw mixture, compared to the control laboratory concentration of 38.30%.

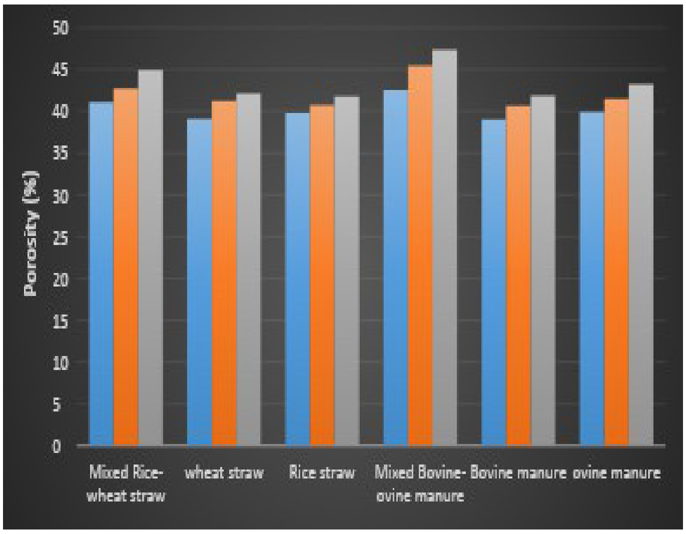

Figure 2: *Effect of organic conditioner types on the Total porosity (%) of sandy soil*

This increase is attributed to the improvement of soil structure through increased organic matter, which promotes the formation of stable soil aggregates and increases air and water voids within the soil (Abedi-Koupai *et al*., 2008). These results are consistent with (Abdel-Motaleb *et al*., 2025), which showed that adding organic fertilizer to sandy soils significantly increased total porosity and improved pore size distribution, enhancing soil water retention and reducing bulk density. Xuan *et al*. (2023) also validated the earlier finding that combined organic conditioners such as compost and biochar enhanced total porosity as a soil physicochemical property due to increased structural stability and pore size distribution.

This also corroborates the work of Ho *et al.* (2021), who showed that the inclusion of agricultural waste such as plant residues and compost to sandy soils enhanced the physical structure, including the porosity, which improved the performance and growth of the plants. In addition, Zhang *et al.* (2014) also showed that adding straw to the soils improved the water holding capacity and reduced the rate of evaporation, which suggested enhanced pore properties, distribution, and structural materials in the soil.

Furthermore, it should also be noted that the applications of organic conditioners at the highest concentrations of 15% were most successful in total porosity increment, which suggests that there is a logical connection between the volume of organic matter added and the soil structure improvement. This concurs also other investigations done on sandy soils, which showed a remarkable increase in pore spaces, soil hydrodynamics, and physical properties such as soil structure were responsive to organic matter conditioners (Xuan *et al.*, 2023; Abdel-Motaleb *et al.*, 2025). The use of a drip irrigation system in the present work substantially contributed to increasing the effect of organic conditioner on soil total porosity. This system supplies the root zone with steady and even moisture; it can prevent the root from being suddenly dried up and decrease water loss through evaporation and transpiration. The method of drip irrigation also promotes the consumption of the organic substance and the provision of a water-air balance in the pores, contributes to microbially enhanced activity and a better spread of moisture in the soil. Studies such as Kok *et al.* (2023) reported that locally drip-irrigated organic conditioners were effective in improving moisture conditions and soil structure. Thus, organic conditioners combined with drip irrigation is a positive response towards achieving these results.

Based on these results, it can be concluded that the use of organic conditioners, especially at higher concentrations, represents an effective and sustainable strategy for improving sandy soil properties, particularly total porosity. A combination of animal and plant waste is recommended for optimal results, while ensuring a balance between decomposition rate and organic content to ensure sustainable improvement in soil structure and fertility (Sulok *et al.*, 2021; Akol *et al.*, 2024).

Effect of organic conditioner types on the saturated Hydraulic conductivity of sandy soil

The data in Figure 3 indicate that the addition of organic conditioners, whether animal or plant waste, or a combination of both, significantly affects the Saturated hydraulic conductivity of sandy soils. A gradual decrease in Saturated hydraulic conductivity values was observed as the amendment concentration increased from 5% to 15%. Saturated hydraulic conductivity decreased from 0.674 cm/min to 0.582 cm.min-1 when using a rice and wheat straw mixture, and from 0.631 cm/min to 0.463 cm/min when using a Bovine and ovine manure mixture.

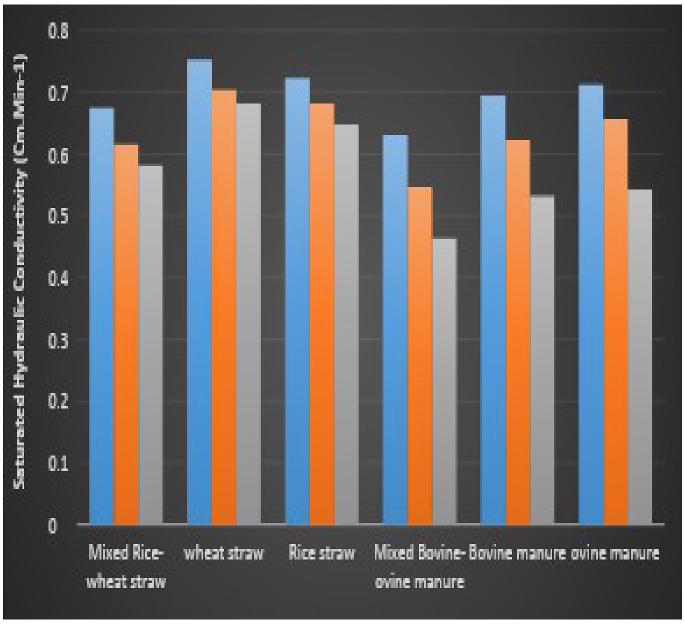

Figure 3: *Effect of organic conditioner types on the saturated Hydraulic conductivity (cm.min^{-1}) of sandy soil*

This decrease in Saturated hydraulic conductivity can be explained by several factors associated with adding organic matter. First, organic matter improves soil structure by increasing the proportion of micropores and decreasing macropores, which reduces the speed of water movement through the soil (Botková *et al.*, 2024). Second, fine particles resulting from the decomposition of organic matter can clog macropores, reducing Saturated hydraulic conductivity (Demir & Demir, 2015). Thirdly, some organic materials may constrain soil wettability, thereby making water movement increasingly difficult (Wang *et al.*, 2009). The results align with Essien (2011), who documented that organic materials cause pore changes within sandy soils, thus decreasing Saturated hydraulic conductivity. Nemes *et al.* (2005) also showed that the increase in organic content with oil is directly proportional to the decrease in conductivity due to changes in pore droplet distribution. It is important to mention that the influence of organic matter on the conductivity of saturated water will differ depending on the kind and quantity of organic matter added. In the case of calcic and suilo soils, wheat straw is likely to have a different influence than Bovine manure due to their contrasting chemical and physical compositions, as Botková *et al.* (2024) observed in their study on the properties of organic matter and their effect on sandy soils. Also, the adoption of drip irrigation systems has increased overall water management efficiency in organic fertilized sandy soils. This method provides water directly to the root zone in small incremental amounts, minimizing wastage through surface runoff or deep infiltration and offsetting the drop in Saturated hydraulic conductivity. Drip irrigation also contributes to maintaining soil moisture at optimal levels for plant growth and provides a stable environment for microbial activities that decompose organic matter, enhancing absorption efficiency and improving soil properties. Kok *et al.* (2023) indicated that combining organic matter with drip irrigation leads to an effective improvement in soil hydrological properties, while reducing water waste and maximizing the utilization of the added organic matter.

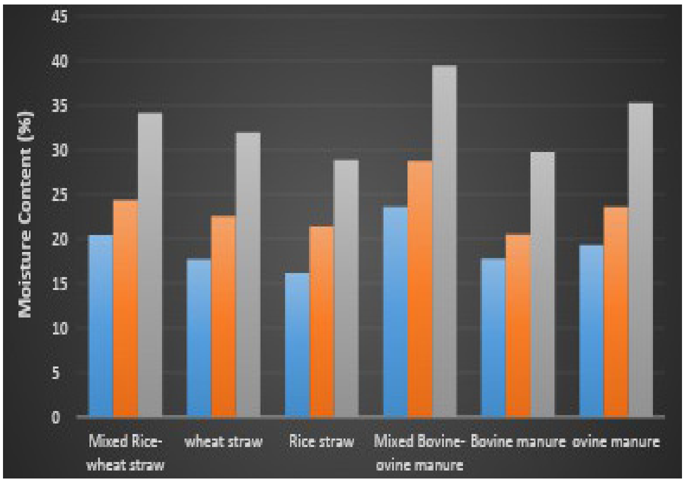

Figure 4: *Effect of organic conditioner types on the Moisture content (%) of sandy soil.*

Effect of organic conditioner types on the Moisture content of sandy soil

The results presented in Figure 4 showed a clear effect of animal and plant waste, whether added individually or as mixtures, on the moisture content of the sandy soil, compared to the initial concentration of 14.6%. The addition of organic matter was shown to gradually increase moisture content with increasing addition ratios (5%, 10%, 15%). When comparing the types of other waste used, it was found that animal waste outperformed plant waste in improving soil moisture. This was evident in the higher values recorded by animal manure, particularly the Bovine and ovine manure mixture, which reached a moisture content of 39.46% at its highest concentration (15%), compared to the straw mixture (wheat and rice straw), which recorded 34.17% at the same concentration.

These differences may be explained by the fact that animal organic matter is often richer in nitrogenous compounds and contains decomposable materials that are easier for microorganisms to break down, enhancing soil activity and improving its structural composition.

This was indicated by Wang *et al.* (2023). Animal waste, especially when mixed with organic matter, also provides a balance of nutrients necessary for microorganism activity, leading to improved biological fixation of organic matter and the formation of more stable soil aggregates capable of retaining water for longer periods. This nutritional balance, particularly in the carbon to nitrogen (C: N) ratio, is a key factor in controlling the rate of organic decomposition and its impact on soils.

As for plant waste, it also significantly contributed to improving soil moisture content, although it was less effective than its animal counterpart. This is attributed to the nature of its fibrous components, such as cellulose and lignin, which decompose relatively slowly. However, a study by Liu *et al.* (2024a) found that straw recycling reshapes the pore structure of sandy soils, contributing to increased moisture retention.

Remarkably, the cumulative effect of mixed residues both animal and plant was most pronounced at the highest addition rate (15%), reflecting the importance of the added concentration in achieving tangible improvements in soil properties. In this context, Zhang *et al.* (2023) study confirmed that mixing green manure and plant residues improves sandy soil properties more effectively than using organic matter alone.

The use of a drip irrigation system also helped maximize the benefits of adding organic matter by reducing water loss and increasing the efficiency of moisture distribution within the root zone. Drip irrigation supplies precise amounts of water regularly and directly to the root zone, reducing evaporation and runoff and improving soil utilization of available water. Kok *et al.* (2023) study also indicated that concluded that combining drip irrigation with organic conditioners enhances soil moisture and improves the water-air balance in the root zone, which supports plant growth and increases moisture content stability for longer periods, even in highly conductive soils such as sandy soils. Maintaining a constant moisture level also helps stimulate the biodegradation of organic matter and promotes the development of microporous structures.

Based on the above, these results highlight the importance of using organic waste, especially when mixed thoughtfully, as a sustainable method for improving moisture in sandy soils. They also support the trend toward reusing agricultural and animal waste to enhance soil properties and reduce reliance on chemical inputs, in line with sustainable agriculture principles.

Conclusions and Recommendations

The results of the current study showed that the use of animal and plant organic conditioners, individually or as a combination, led to a significant improvement in the physical properties of sandy soil, especially at the highest concentration (15%). These treatments contributed to a reduction in bulk density, an increase in total porosity, and a significant increase in moisture content, with a gradual decrease in Saturated hydraulic conductivity due to the increase in micropores. The drip irrigation system also helped enhance the effectiveness of these conditioners by reducing water loss and improving moisture distribution in the root zone. Based on these results, the study recommends the adoption of organic conditioners, particularly animal waste or mixed fertilizers, as an effective and sustainable option for improving the quality of sandy soils, with the highest concentration (15%) being preferred for optimal results. It is also recommended to combine these conditioners with drip irrigation, which has proven its effectiveness in improving moisture utilization and reducing evaporation, supporting sustainable agriculture and reducing reliance on chemical inputs.

Novelty Statement

The article is distinguished by its focus on addressing a real soil problem using natural, sustainable, and environmentally friendly materials.

Author's Contribution

We carried out all the work for the article, including preparing the soil, planting the crop, collecting samples, analyzing and interpreting the results, and writing the article.

Conflict of interest

There is no conflict of interest among the authors regarding the publication of this research work.

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