PAN POLSKA AKADEMIA NAUK
JOURNAL OF WATER AND LAND DEVELOPMENT
e-ISSN 2083-4535
ITP-PIB
Polish Academy of Sciences (PAN) Institute of Technology and Life Sciences – National Research Institute (ITP – PIB)

JOURNAL OF WATER AND LAND DEVELOPMENT
DOI: 10.24425/jwld.2026.158719
2026, No. 69 (IV–VI): 216–224

Enhancing soil properties and barley yield using organic amendments in a semi-arid Algerian steppe

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RECEIVED 18.09.2025 ACCEPTED 10.02.2026 AVAILABLE ONLINE 16.06.2026

Abstract: Sustainable management of soils with low organic matter in semi-arid regions remains a major agricultural challenge. Organic amendments can improve soil structure and increase productivity. This study evaluated the effects of poultry manure (PM) and palm compost (PC) on soil physical properties at two depths (0–20 cm and 20–40 cm) and on the yield of barley (*Hordeum vulgare* L. 'Rihane 03') in El-Maadher, Algeria. A randomised complete block design with three replications was used, comprising three treatments: T1 (control), T2 (PM), and T3 (PC). The amendments significantly improved soil physical properties, with the effects most pronounced in the 0–20 cm layer. At maturity, PM reduced bulk density by 7% and increased porosity by 15% and permeability by 82% compared with the control. PC also improved these properties, although it was less effective than PM. Both amendments significantly ($p < 0.05$) increased yield components. PM produced the highest grain yield (11.2 $Mg \cdot ha^{-1}$), followed by PC (9.8 $Mg \cdot ha^{-1}$), both of which were considerably higher than the control (5.3 $Mg \cdot ha^{-1}$). Overall, the study indicates that poultry manure is the most effective organic amendment for improving soil hydro-physical properties and increasing barley yield. These findings highlight the importance of selecting appropriate organic amendments to achieve successful agricultural outcomes. For farmers, the results provide a clear, evidence-based recommendation: poultry manure can deliver rapid soil improvement and maximise productivity. This research presents a practical approach to advancing sustainable agriculture in semi-arid areas by enhancing soil health, improving water-use efficiency, and contributing to food security.

Keywords: barley, palm compost, poultry manure, semi-arid area, soil amendment, soil depth

INTRODUCTION

Algerian soils, like many Mediterranean soils, are typically characterised by low organic matter (OM) content, owing to the prevailing climate and to agricultural practices that do not favour the accumulation of organic reserves in the soil (Dridi and Toumi, 1999). Intensive cultivation and poor soil management practices, including excessive agrochemical use, deep tillage, and over-irrigation, have resulted in soil degradation, increased gas emissions, and water-resource pollution, ultimately reducing soil fertility and productivity through the loss of stable organic matter (Montemurro *et al.*, 2015). The organic matter removed by crops from already poor soils is not adequately replaced (Grosbellet *et al.*, 2011). This practice, together with land pressure, has exacerbated soil impoverishment. Consequently, the availability of arable land, its degradation, and its restoration have become major national concerns (Koull and Halilat, 2015). Given their characteristics, these soils have poor physical quality (Dridi and Toumi, 1999; Koull and Halilat, 2015). To improve them, it is important to maintain soil organic matter levels ($3\% \leq OM \leq 4\%$)

(Grosbellet *et al*., 2011), because organic matter directly affects soil physical properties and its loss is directly responsible for soil-quality degradation (Lal, 2004; Lal, 2006).

Barley (*Hordeum vulgare* L.) is an essential crop in semi-arid regions because of its drought tolerance and ability to grow in marginal soils (El-Khalifa, El-Gamal and Zahran, 2022; Ali El-Bosily and Agwa, 2023; Sarğın and Karaca, 2023). In Algeria, where 80% of arable land is classified as arid or semi-arid, barley is a crucial staple crop for both human consumption and livestock feed (Salih *et al*., 2022). However, the prevalence of calcareous soils in areas such as M'Sila creates substantial agronomic challenges. These soils usually have an alkaline pH (7.8–8.2), low organic matter content (less than 1%), and poor water retention (Al-Hasn, Younes and Othman, 2022; Sarğın and Karaca, 2023). These factors limit nutrient availability, inhibit root development, and ultimately reduce crop productivity, thereby aggravating food-security risks in vulnerable agroecosystems (Al-Hasn, Younes and Othman, 2022; El-Khalifa, El-Gamal and Zahran, 2022).

To address these challenges, organic amendments such as poultry manure (PM) and palm compost (PC) have emerged as sustainable solutions. Research has shown that manure-based amendments improve soil fertility and increase crop yield in organic agricultural systems (Geng *et al*., 2019). In particular, PM and composted lignocellulosic waste, such as palm residues, improve microbial activity and nutrient cycling, helping to reduce the adverse effects of calcareous soils (Scotti *et al*., 2015; Supriatna *et al*., 2022; Ouali *et al*., 2025). Rotary drum composting systems further optimise this process by accelerating the decomposition of recalcitrant materials such as palm waste and achieving maturity within 20 days (Kalamdhad and Kazmi, 2009; Ouali *et al*., 2025). In addition, combined PM and palm-waste fertilisers have been shown to increase soil electrical conductivity (*EC*) and cation exchange capacity (*CEC*) (Agbede *et al*., 2020; Badawi, 2022).

Organic amendments such as poultry manure (PM) and palm compost (PC), the latter comprising PM and date-palm residues, represent promising alternatives for soil improvement. These materials not only recycle local agricultural waste but also improve soil structure, increase microbial activity, and promote nutrient cycling (Supriatna *et al*., 2022; Mahmoud *et al*., 2023; Agbede, 2025; Ouali *et al*., 2025).

Similar trends have been observed in Egypt, where mixtures of PM and compost have improved soil characteristics and nutrient availability in both sandy and clay soils (Makhlof, El-mawla Mohammeda and Ahmed, 2019; Khalifa *et al*., 2022). Barley grain production increased by 27–62%. Internationally, organic-amendment strategies in Pakistan and Ethiopia have increased soil organic carbon (SOC) by 45–69% and nitrogen availability by 169%, demonstrating their cross-regional applicability (Girma, Zeleke and Getachew, 2020; Agbede, 2025; Shabir *et al*., 2026). For instance, vermicompost-PM integration in Ethiopia increased barley yield by 4.2 $Mg \cdot ha^{-1}$ by restoring degraded Nitisols (Girma, Zeleke and Getachew, 2020).

This study evaluates the comparative efficacy of poultry manure and palm-poultry compost in improving soil fertility and barley productivity in the calcareous soils of El-Maadher, Algeria, drawing on methodologies from Ouali *et al*. (2025) and Kalamdhad and Kazmi (2009). The research quantifies the effects of the amendments on barley growth across four stages.

This research addresses a significant knowledge gap in the sustainable management of soils in North African semi-arid regions. The comparative efficacy of these amendments, particularly their influence on soil physical properties at different depths and their subsequent impact on crop yield, remains insufficiently documented. This study therefore aimed to bridge this gap by evaluating the effects of poultry manure and palm compost on soil hydro-physical properties at two depths (0–20 cm and 20–40 cm) and on the yield of barley, a staple crop in a semi-arid Algerian agroecosystem.

In this context, we hypothesised that a single application of either poultry manure (PM) or palm-poultry compost (PC) would improve the hydro-physical characteristics of calcareous soil and barley productivity compared with an unamended control. We further hypothesised that PM would provide immediate benefits for crop growth because it is likely to mineralise more rapidly, whereas PC, with its higher organic content, would contribute to longer-term improvements in soil structure. Accordingly, the current study was designed to answer the following research questions: (i) what are the comparative effects of PM and PC on key soil hydro-physical properties (bulk density, porosity, and permeability) at two soil depths (0–20 cm and 20–40 cm) throughout the barley growing season?; (ii) how do these organic amendments influence barley growth, yield, and yield components (plant height, number of ears per m^2, number of seeds per ear, and grain and straw yield)?; (iii) to what extent do the initial chemical characteristics of the amendments (e.g. nutrient content, C:N ratio, and *EC*) drive changes in soil chemistry (pH and *EC*) and subsequent plant performance?; and (iv) what are the practical implications for farmers in semi-arid regions such as Algeria when choosing between these amendments for short-term productivity and long-term soil health?

MATERIALS AND METHODS

EXPERIMENTAL SITE

The field experiment was conducted at El-Maadher, Maarif commune, M'Sila province, Algeria (35°20'33.7"N, 4°19'37.8"E), during the 2023–2024 growing season (Fig. 1).

Based on NASA POWER Project data (2014–2024), the study area has a semi-arid climate. Annual rainfall is low, averaging 297 mm, and temperatures vary markedly. The dry season, from May to September, often brings temperatures above 40°C, generating severe water deficits. These conditions make crop production difficult and underline the need for soil management practices that retain water in the soil and improve crop resilience.

SOIL AND AMENDMENT CHARACTERISATION

The experimental soil was loam in the upper 20 cm and sandy clay loam in the lower layer (20–40 cm). In accordance with the World Reference Base for Soil Resources (WRB, 2022), it is classified as Calcic Cambisol; further soil and amendment properties are presented in Table 1. Palm compost contained higher concentrations of organic matter (38.07%), phosphorus (3,175.47 $mg \cdot kg^{-1}$ P_2O_5), and electrical conductivity (18.73 $dS \cdot m^{-1}$) than poultry manure, which contained 27.98%, 1,091.57 $mg \cdot kg^{-1}$, and 6.87 $dS \cdot m^{-1}$, respectively. The nitrogen

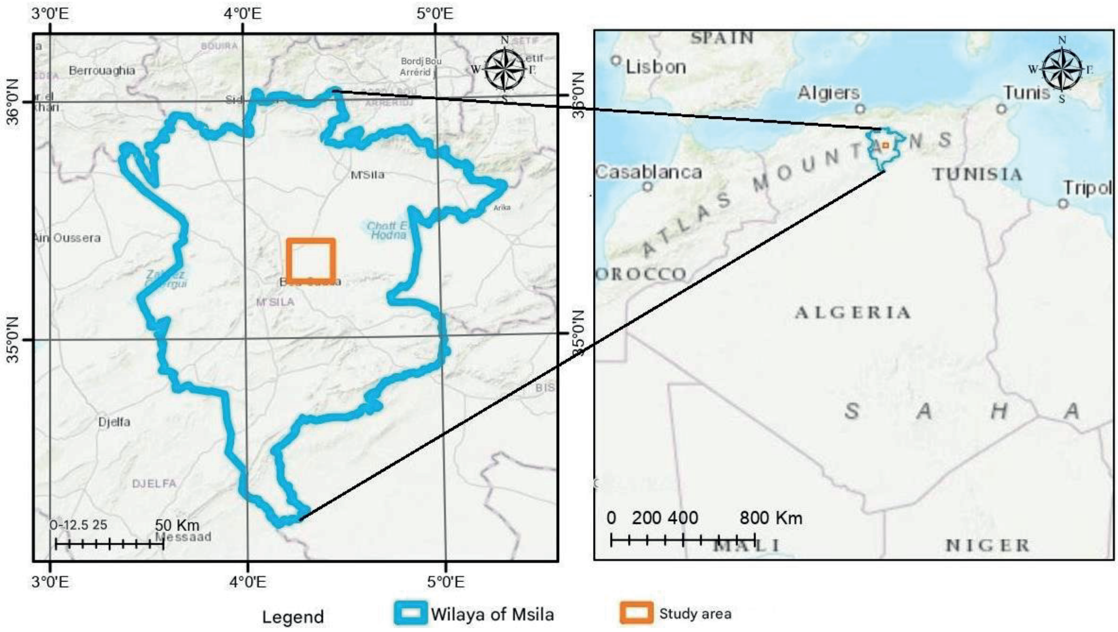

Fig. 1. Geographical location of the study area; source: excerpt from ArcGIS online basemaps

Table 1. Characteristics of the initial soil and the organic amendments used

Parameter	Soil layer (cm)		Poultry manure	Palm compost
	0–20	20–40		
pH	8.18	8.21	6.10	7.12
EC ($dS \cdot m^{-1}$)	0.79	0.75	6.87	18.73
OM (%)	2.18	0.92	27.98	38.07
Total organic carbon (%)	1.27	0.54	16.27	22.13
Total N ($g \cdot kg^{-1}$)	1.40	0.40	3.15	3.71
P_2O_5 ($mg \cdot kg^{-1}$)	86.26	66.41	1,091.57	3,175.47
Clay (%)	25.08	22.53	–	–
Silt (%)	32.41	22.64	–	–
Sand (%)	42.50	54.84	–	–
Soil texture	loam	sandy clay loam	–	–

Explanations: *EC* = electrical conductivity, OM = organic matter.
Source: own elaboration.

content of poultry manure (3.15 $g \cdot kg^{-1}$) was lower than is often reported for fresh manure, probably because of ammonia volatilisation losses during storage before application.

EXPERIMENTAL DESIGN

A randomised complete block design was used with three treatments (Fig. 2): T1, control (unamended soil); T2, poultry manure (soil amended with poultry manure at a rate of 45 $Mg \cdot ha^{-1}$); and T3, palm compost (soil amended with compost produced using the method described by Ouali *et al.* (2025)). This method involved a rotary drum system and a maturation period of 20 days. The compost, which consisted of palm-tree waste mixed with poultry litter, was applied at a rate of 45 $Mg \cdot ha^{-1}$. This rate was selected for both amendments because it represents a common high agronomic rate used in regional studies to ensure a clearly measurable effect on soil properties and crop yield in degraded soils (Hartl, Putz and Erhart, 2003; Burcea *et al.*, 2024; Salis *et al.*, 2024). Applying the same mass allowed a direct comparison of amendment types. The organic amendments were applied once, two weeks before sowing. The materials were broadcast by hand onto the soil surface and incorporated into the top 20 cm of soil during final seedbed preparation.

Each treatment was replicated three times, with individual plots measuring 3 × 2 m and a spacing of 1 m between plots. Barley (*Hordeum vulgare* L. 'Rihane 03') was sown at a rate of 100 $kg \cdot ha^{-1}$ on 3 November 2023 and harvested at physiological maturity on 20 May 2024. Grain moisture content at harvest was approximately

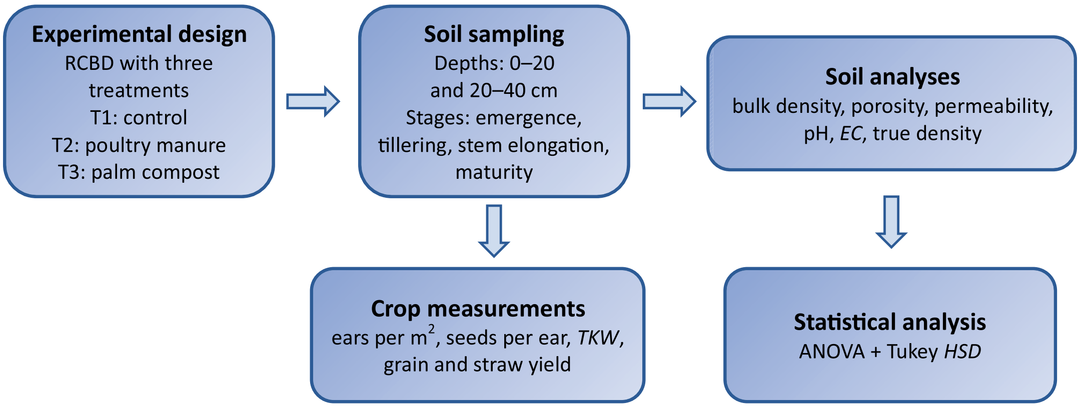

Fig. 2. Workflow of the experimental study; RCBD = randomised complete block design, *EC* = electrical conductivity, *TKW* = thousand kernel weight, *HSD* = honest significant difference; source: own elaboration

14%. Irrigation was applied using a sprinkler system to ensure even water distribution across all plots. Soil moisture was monitored in the control plots at a depth of 15 cm. Irrigation was triggered when soil moisture fell below 50% of field capacity. A uniform volume of 30 mm was applied to all plots at approximately 7-day intervals, early in the morning to minimise evaporation, in order to maintain comparable soil moisture conditions across treatments and avoid confounding water stress with amendment effects.

SAMPLING AND ANALYSES

Soil samples were collected at two depths (0–20 cm and 20–40 cm) across four barley growth stages: emergence, tillering, stem elongation, and maturity. Using standard methods (Klute, 1986), soil physical properties (particle density, bulk density, porosity, and permeability) were assessed. The chemical traits soil pH and electrical conductivity (*EC*) were measured in 1:2.5 and 1:5 soil-to-distilled-water suspensions, respectively, using a pH meter and a conductivity meter (Hanna Instruments). Agronomic measurements were conducted at the same growth stages. Plant height was recorded, and the assessed yield components included the number of ears per m^2, the number of seeds per ear, thousand kernel weight (*TKW*), and both grain and straw yield.

Data for both soil and plant parameters were subjected to analysis of variance (ANOVA) using a randomised complete block design. Mean comparisons were performed using Tukey's honest significant difference (*HSD*) test at a 5% probability level ($p < 0.05$).

RESULTS AND DISCUSSION

GENERAL INFORMATION

The results demonstrate that the application of organic amendments, namely poultry manure and palm-poultry compost, significantly improved soil physical properties and barley productivity under the semi-arid conditions of El-Maadher, Algeria. These improvements reflect both immediate and cumulative effects on soil structure, nutrient availability, and plant development. The dynamics of soil physical properties are critical indicators of soil health because they directly influence water infiltration, root growth, and erosion resistance.

SOIL HYDRO-PHYSICAL PROPERTIES

Particle density, defined as the density of soil solids excluding pores, showed minimal variation between treatments at both depths (0–20 cm: T1, 2.19 ±0.03 g·cm^{-3}; T2, 2.18 ±0.02 g·cm^{-3}; T3, 2.16 ±0.04 g·cm^{-3}; 20–40 cm: T1, 2.21 ±0.02 g·cm^{-3}; T2, 2.20 ±0.03 g·cm^{-3}; T3, 2.19 ±0.02 g·cm^{-3}) (Fig. 3a). This stability was expected because particle density is primarily determined by the mineral composition of the soil (Hillel, 2004), which is consistent with previous studies showing that organic amendments affect mainly porosity and bulk density (Rees *et al.*, 2015; Rizzo *et al.*, 2022). The measured values (2.16–2.21 g·cm^{-3}) are lower than the typical value for pure quartz sand (2.65 g·cm^{-3}). Such values are characteristic of calcareous soils, where complex pedogenic processes and the formation of stable, low-density organo-mineral associations on carbonate-rich parent material reduce soil particle density (Kowalska *et al.*, 2019). The existing soil organic matter in this Calcic Cambisol further contributes to this effect.

A significant interaction between treatment, depth, and growth stage was observed. At maturity, in the 0–20 cm layer, both amendments significantly reduced bulk density compared with the control (T1, 1.15 ±0.09 g·cm^{-3}; T2, 1.07 ±0.11 g·cm^{-3}; T3, 1.11 ±0.08 g·cm^{-3}). Consequently, total porosity, calculated from bulk density measurements, followed an inverse pattern and increased most strongly in T2 (51.0 ±4.5%) compared with T3 (48.9 ±4.1%) and T1 (47.7 ±3.4%) (Tab. 2, Fig. 3). This improvement in soil structure can be attributed to the added organic matter, which acts as a soil-particle binding agent and promotes the formation of stable aggregates (Celik, Ortas and Kilic, 2004; Bot and Benites, 2005). The more pronounced effect of poultry manure is probably due to its more favourable biochemical composition, which promotes faster microbial activity and aggregate formation than the more stable, lignin-rich palm compost. These findings are consistent with the work of Ojeniyi, Awodun and Odedina (2007), who observed that organic amendments reduce soil compaction by increasing organic matter, thereby improving aggregate stability and pore space. The compost treatment (T3), with the highest organic matter content (38.07%), also improved porosity relative to the control at maturity, suggesting sustained improvement in soil structure.

Soil permeability, a key factor for water management in semi-arid regions, was highly variable but showed clear treatment

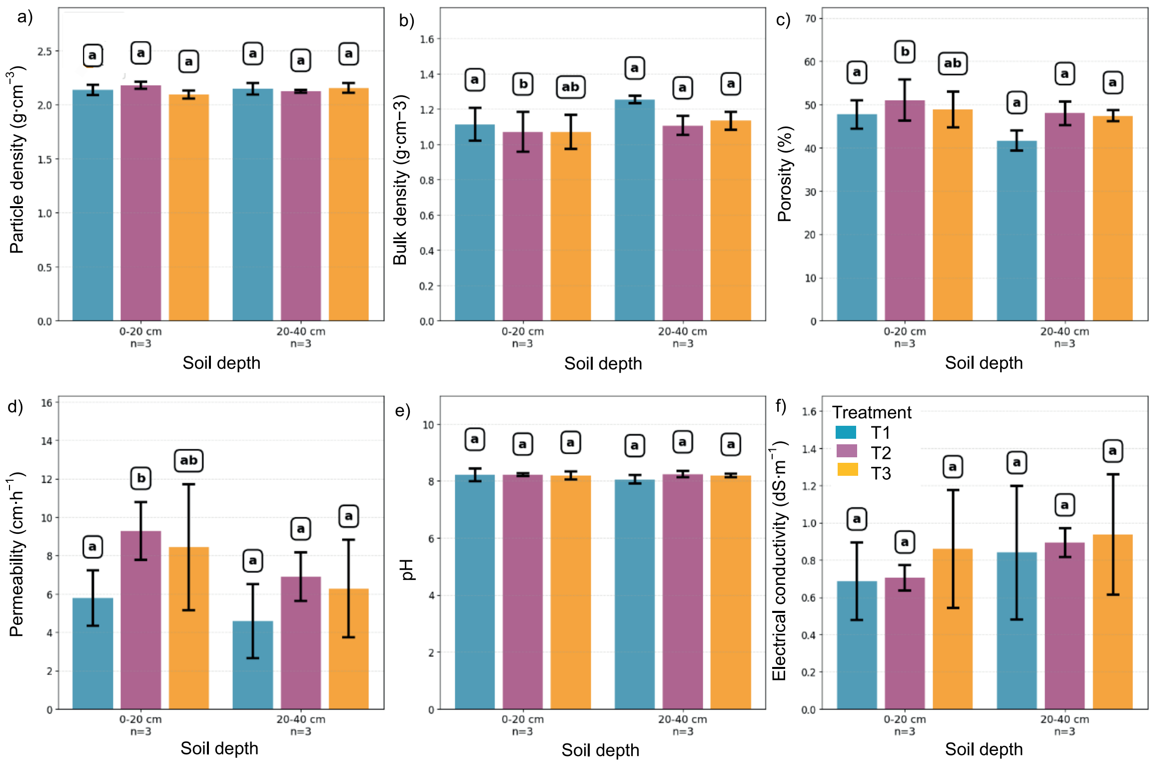

Fig. 3. Soil physical properties at maturity by treatment and depth: a) particle density, b) bulk density, c) porosity, d) permeability, e) pH, and f) electrical conductivity; treatments as defined in the "Experimental design" section; n = number of samples; different lowercase letters (a, b, ab) above the bars indicate statistically significant differences at $p \leq 0.05$ according to Tukey's honest significant difference test; bars marked "ab" are not significantly different from bars marked "a" or from bars marked "b"; source: own study

Table 2. Effect of organic amendments on soil physical properties at maturity (0–20 cm depth)

Treatment	Bulk density (g·cm^{-3})	Porosity (%)	Permeability (cm·h^{-1})
T1 (control)	1.15 ±0.09 a	47.7 ±3.4 a	5.1 ±1.5 a
T2 (poultry manure)	1.07 ±0.11 b	51.0 ±4.5 b	9.3 ±1.4 c
T3 (palm compost)	1.11 ±0.08 ab	48.9 ±4.1 ab	7.1 ±2.9 b
p-value	0.032	0.047	0.001

Explanations: treatments are defined in the "Experimental design" section; means within a column followed by different letters are significantly different at $p < 0.05$ according to Tukey's honest significant difference test. Source: own study.

effects. By the maturity stage, mean permeability in the 0–20 cm layer was highest in T2 plots (9.3 ±1.4 cm·h^{-1}), representing an 82% increase over the control (5.1 ±1.5 cm·h^{-1}). An intermediate value (7.1 ±2.9 cm·h^{-1}) was recorded for T3 plots (Tab. 2, Fig. 3d). This enhanced permeability under organic amendments reduces surface runoff and increases water infiltration, thereby improving crop water-use efficiency, which is a crucial advantage in water-limited semi-arid environments (Blanco and Lal, 2010). Although this study did not directly measure soil water-holding capacity, the significant improvements in porosity and permeability are strong indicators of enhanced water infiltration and potential retention, both of which are critical for mitigating drought stress. Most investigated soil parameters reached their maximum values after poultry manure application (Fig. 3), consistent with enhanced water flow in amended soils (Agbede, 2025). At 20–40 cm, treatment effects persisted but were less pronounced than in the 0–20 cm layer.

Soil pH values remained stable and alkaline across all treatments and depths (pH 7.88–8.52). As expected, none of the amendments caused a notable change in soil pH. This stability can be attributed to the buffering capacity of the calcareous soil, and the high inherent pH of the palm compost amendment itself would not be expected to acidify the soil. Electrical conductivity was more dynamic. Although no significant build-up was detected, the T3 (palm compost) plots showed a slightly higher, but not statistically significant, average *EC* value in the surface layer at maturity (0.86 dS·m^{-1}) compared with T2 (0.70 dS·m^{-1}) and T1 (0.69 dS·m^{-1}). This trend is noteworthy because it corresponds to the initial characterisation of the amendments, which showed that palm compost had a much higher EC (18.73 dS·m^{-1}) than poultry manure (6.87 dS·m^{-1}) (Tab. 1). Although not conclusive in this short-term study, this result suggests a potential risk of salinisation with repeated applications of palm compost, which must be carefully managed (Khaliq, Abbasi and Hussain, 2006).

BARLEY YIELD AND YIELD COMPONENTS

Plant height

Plots treated with poultry manure and palm compost exhibited taller and more uniform plants (Fig. 4), indicating better root development and overall crop vigour throughout the season. The difference in final plant height reflects the combined influence of enhanced soil moisture retention, increased porosity, and improved N supply from the amendments (Wahab *et al.*, 2018;

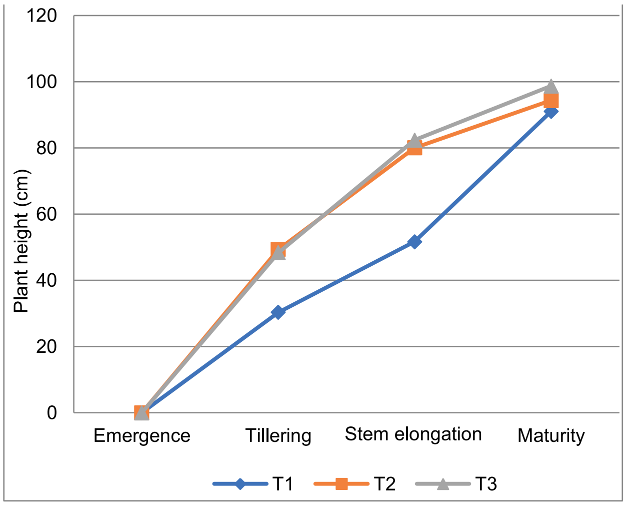

Fig. 4. Barley plant height at different growth stages; treatments as defined in the "Experimental design" section; source: own study

Agbede, 2025). The slightly superior performance of T3 (palm compost) at maturity may be linked to its higher phosphorus content (3,175.47 mg·kg^{-1} P_2O_5 compared with 1,091.57 mg·kg^{-1} in T2; Tab. 1).

Yield components

The organic amendments had a strong and significant effect on all yield parameters (Fig. 5), underscoring their role in alleviating nutrient deficiencies in these impoverished soils.

The thousand kernel weight (*TKW*) was comparable across treatments (approximately 42–47 g) (Fig. 5e), aligning with the genetic potential of the 'Rihane 03' cultivar (Mazid, Aw-Hassan and Salahieh, 2007; Guetteche *et al.*, 2023).

The organic amendments significantly enhanced barley growth, as shown by increases in the number of ears per m^2 and the number of seeds per ear. Poultry manure (T2) produced the highest grain-yield components, with mean values of approximately 474 ears·m^{-2} and 52.9 seeds per ear (Fig. 5), probably because of faster mineralisation and the release of nitrogen and phosphorus (Abou El-Magd, El-Bassiony and Fawzy, 2006). Rapid nutrient availability is critical during key growth stages such as tillering and grain filling. It is noteworthy that this significant yield response was achieved despite the relatively low nitrogen content of poultry manure (3.15 g·kg^{-1}), suggesting that even a moderately nitrogen-rich amendment can provide substantial benefits in these highly

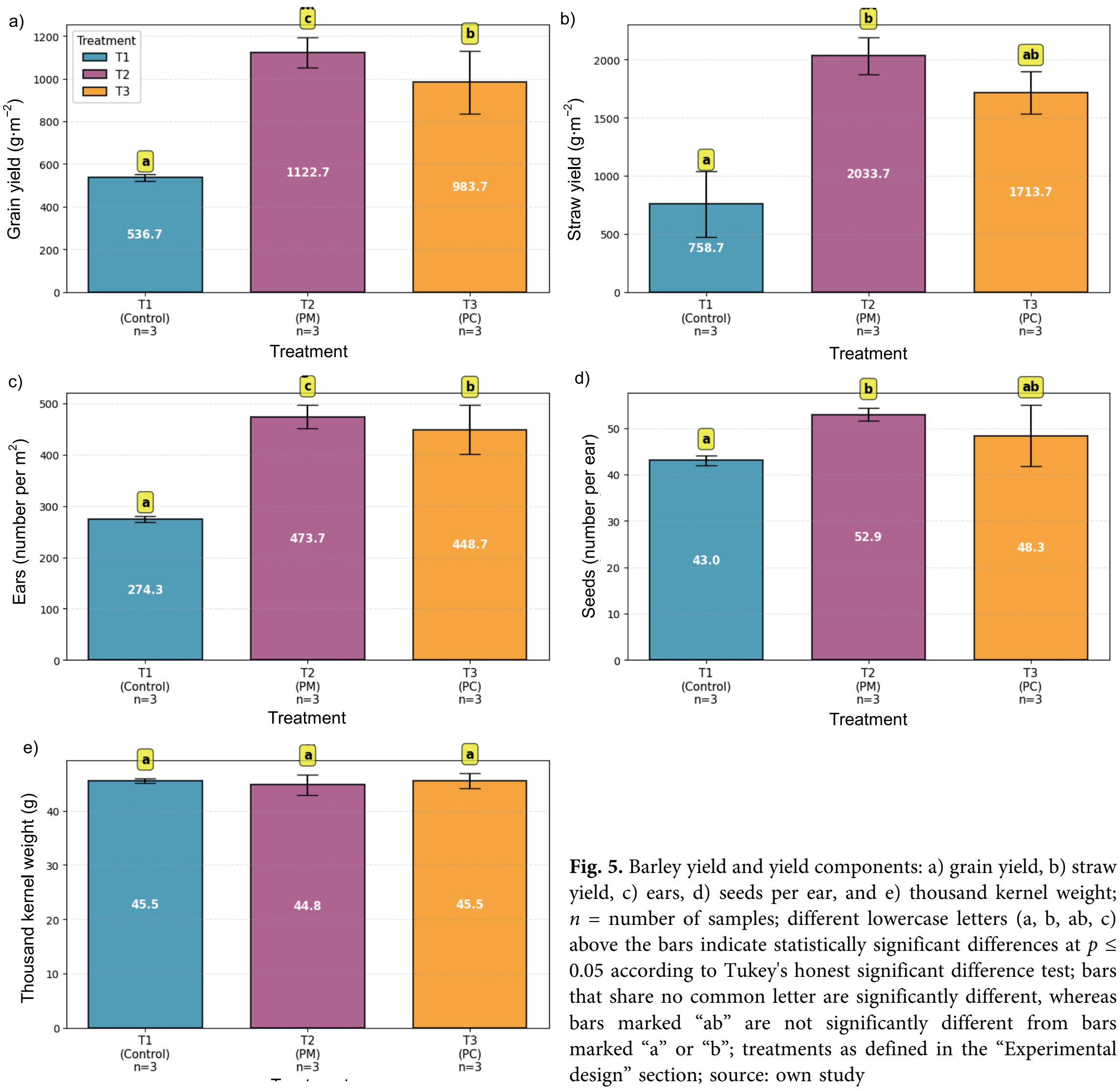

Fig. 5. Barley yield and yield components: a) grain yield, b) straw yield, c) ears, d) seeds per ear, and e) thousand kernel weight; n = number of samples; different lowercase letters (a, b, ab, c) above the bars indicate statistically significant differences at $p \leq 0.05$ according to Tukey's honest significant difference test; bars that share no common letter are significantly different, whereas bars marked "ab" are not significantly different from bars marked "a" or "b"; treatments as defined in the "Experimental design" section; source: own study

nutrient-poor soils and that its positive effects on soil structure played a crucial role.

Treatment T2 produced the highest values for the number of ears per m^2 and the number of seeds per ear, resulting in the highest grain and straw yields and significantly outperforming T3 and T1 (Fig. 5). The marked yield response, with PM and PC increasing grain yield by 109% and 83%, respectively, compared with the control, is also a direct consequence of the improved soil physical properties described above (Fig. 3). Reduced bulk density and increased porosity and permeability create a more favourable rooting environment, enhancing access to water and nutrients. This improvement is then reflected in robust yield components (ears per m^2 and seeds per ear) and final biomass production (Bot and Benites, 2005; Blanco and Lal, 2010).

Direct comparison indicates that poultry manure provided an advantage in grain and straw yield, probably because of its lower C:N ratio and faster mineralisation (Adediran, Taiwo and Sobulo, 2003). This rapid nutrient availability is particularly valuable in semi-arid systems, where crop cycles are short and rainfall is limited.

Palm compost, however, supplied higher organic matter and P_2O_5, improved soil porosity, and contributed to greater plant height. Its slower nutrient release can support long-term fertility, making it valuable for sustainable soil management. The trade-off between immediate productivity and long-term soil quality is well documented (Ayeni, 2010).

Palm compost increased organic matter but produced lower grain and straw yields than poultry manure (Rees *et al*., 2015; Wahab *et al*., 2018; Rizzo *et al*., 2022; Agbede, 2025; Guyader Le *et al*., 2025).

This finding is consistent with global research showing the effectiveness of organic fertilisers for barley and other cereals in arid areas. Previous studies highlight the critical roles of amendment type and application depth in optimising soil health and crop productivity (Courtney and Mullen, 2008; Abera *et al*., 2018; Wahab *et al*., 2018; Rizzo *et al*., 2022; Agbede, 2025; Guyader Le *et al*., 2025).

The present study clearly illustrates the advantages of poultry manure and palm compost, although one limitation should be noted. The chemical characterisation of the amendments focused on organic matter, nitrogen, and phosphorus. Data on other important nutrients, such as potassium (K), magnesium (Mg), and micronutrients, were not available. Including these elements could have provided a more comprehensive explanation of the observed plant physiological responses and soil chemical dynamics. Future research should therefore include complete elemental analysis to better elucidate nutrient cycling and the long-term fertility effects of these organic amendments.

CONCLUSIONS

This study demonstrated that organic amendments, specifically poultry manure and palm compost, significantly improved soil physical properties and increased barley (*Hordeum vulgare* L. 'Rihane 03') productivity in the semi-arid region of El-Maadher, Algeria. The results address the research questions as follows.

With respect to soil hydro-physical properties, both amendments significantly improved soil structure in the critical 0–20 cm layer by the maturity stage. Poultry manure (PM) was the most effective treatment, significantly reducing bulk density and increasing total porosity and permeability compared with the control, thereby enhancing water infiltration and the rooting environment. These effects were markedly weaker in the 20–40 cm layer.

With respect to barley yield, both amendments markedly increased all yield components. PM was superior, producing the highest number of ears per m^2 and seeds per ear and resulting in a 109% increase in grain yield compared with the control. Palm compost (PC) also performed well, increasing grain yield by 83%, but its effect was statistically lower than that of PM, probably because of its slower nutrient mineralisation.

With respect to amendment composition, the initial chemical properties were highly influential. The faster mineralisation of PM, inferred from its properties, drove immediate yield gains. The high electrical conductivity (*EC*) of PC did not cause significant salinisation after a single application, but it indicates a potential long-term risk that requires monitoring. The high phosphorus content of PC may have contributed to plant development but did not translate into a higher yield than PM in this study; this issue requires long-term investigation.

From a practical perspective, poultry manure is the recommended amendment for farmers seeking immediate productivity gains in water-limited environments because of its rapid nutrient release and superior yield response. Palm compost is a valuable option for building soil organic matter and providing a slower-release nutrient source, although its higher salinity warrants careful management.

In conclusion, although PM is recommended for immediate yield enhancement, integrating both amendments in rotation could provide a strategic approach for balancing short-term productivity with long-term soil sustainability.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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