Research Article

Comparison of Organic and Chemical Soil Amendments in Semi-Arid Barley Cultivation: A Comprehensive Analysis of Soil Dynamics and Yield Responses

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Abstract | In semi-arid regions, sustainable soil management practices are essential for counteracting soil degradation and maintaining crop productivity. This study evaluated the efficacy of organic amendments compared to chemical fertilization to improve soil properties and barley performance under semi-arid Mediterranean conditions. A field experiment was conducted using a randomized block design with three treatments: chemical fertilizer, sheep manure (45 t ha^{-1}), and palm compost (45 t ha^{-1}). The physical and chemical properties of the soil were analyzed at two depths during four barley growth stages, and the performance components were evaluated at maturity. The results showed that organic amendments significantly improved soil hydro-physical properties, reducing bulk density by up to 8% and increasing porosity and permeability by up to 18% and 51%, respectively, relative to chemically fertilized plots. Chemically fertilized soils showed higher pH and EC but had minimal structural improvement. Agronomically, sheep manure produced the highest grain and straw yields (5,79 t ha^{-1} and 11,02 t ha^{-1}, respectively) surpassing chemical fertilizer and palm compost. These results highlight the potential of locally available organic amendments, particularly sheep manure, to enhance soil resilience and barley productivity in semi-arid Mediterranean environments.

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Introduction

Soil nutrient management is considered one of the cornerstones of sustainable agriculture, particularly in semi-arid climates where nutrient depletion and soil degradation threaten agricultural productivity (Kavvadias *et al.*, 2024; Oueriemmi *et al.*, 2025). Semi-arid climates face a complex set of problems resulting from limited natural water resources and climate changes. Water scarcity is one of the key agricultural constraints in semi-arid regions, which leads to soils (and vegetation) that typically exhibit unstable site characteristics, and have low levels of soil organic carbon, poor soil structure, reduced soil biodiversity, and a high rate of soil erosion via wind (Naorem *et al*., 2023). Soil nutrient depletion, with respect to soil degradation, is one of the main constraints to the sustainability of agriculture in semi-arid zones, as they contain calcareous soils, and have low organic matter resulting in the inability for agricultural production (El-Khalifa *et al*., 2022; Mahmoud *et al*., 2023). This suggests the need to develop areas where we have not significantly altered land productivity. In this respect, the large soil resources of arid regions provide a potential agricultural habitat and comprise around 16% of the planet's land surface (Husein *et al*., 2019). Fertilizers, both chemical and organic, play a vital role in improving soil properties and enhancing crop productivity (Titirmare *et al*., 2023). Chemical fertilizers provide readily available nutrients, while organic fertilizers improve soil structure, water retention, and microbial activity (Emdad *et al*., 2023; Widjajanto *et al*., 2023). Traditional reliance on chemical fertilizers exacerbates salinity and structural decline (Makhlof *et al*., 2019). Organic amendments such as compost and manure have been shown to enhance soil physical properties and enhance crop performance (Hlisnikovský *et al*., 2024; Ojeniyi *et al*., 2007).

The integration of organic amendments (manure, compost) alongside or in place of chemical fertilizers is increasingly recognized for its role in improving soil structure, nutrient availability, and long-term productivity (Tefera *et al*., 2022; Wang *et al*., 2025).

Previous research has established that while chemical fertilizers can lead to improved crop production, they can have negative consequences, such as soil acidification, nutrient imbalances, and environmental pollution (Dikr, 2023; Titirmare *et al*., 2023). whereas organic fertilizers, such as animal manure and compost, enhance soil structure, improve water-holding capacity, and increase microbial activity (Verma *et al*., 2024; Zha *et al*., 2024). A study by Kumawat *et al*. (2016) showed that in a semi-arid location in Rajasthan, that vermicompost with the application of biofertilizer resulted in improved barley yields and improved soil biochemical properties. A further study conducted in Tunisia found that amendments of compost and biochar improved soil fertility and increased barley biomass under saline conditions (Oueriemmi *et al*., 2025).

In Algeria, barley is a dominant cereal crop, yet few studies have documented the impact of fertilization strategies on its production in local semi-arid conditions. This study investigates the effects of chemical fertilizer, sheep manure, and palm compost on soil physical properties at two depths (0–20 cm and 20–40 cm) and their subsequent impact on barley growth and yield. Our aim is to provide evidence-based recommendations for sustainable soil management that enhances productivity and contributes to regional food security.

Materials and Methods

Study area and data

A field experiment was conducted over a growing season (2023-2024) at El-Maadher, Maarif commune, in the province of M'Sila, Algeria (Figure 1). The precise GPS coordinates of the experimental site are 35°20'33"N 4°19'37"E. This region has a semi-arid steppe climate.

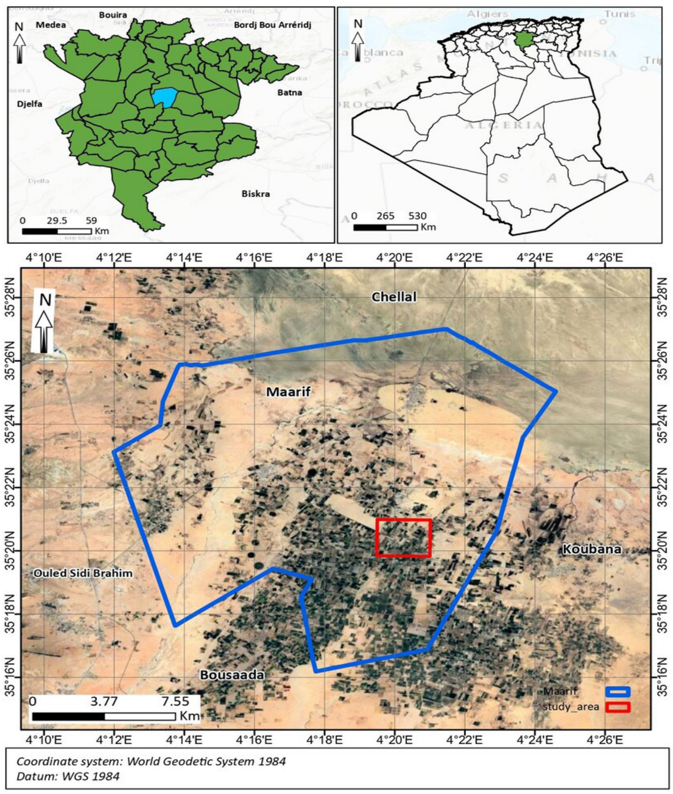

Figure 1: *Localization of the study area.*

Climatic data were sourced from the NASA POWER database (NASA Power Project, 2024). The long-term climatological assessment, based on a ten-year period (2014-2024) indicates that the location receives approximately 296 mm of precipitation per year, with a very irregular pattern of distribution. There are peaks in precipitation in May (41,35 mm), September (34,34 mm), and March (31,52 mm), while summer is characterized by extreme dryness, with less than 3 mm recorded in July. The mean annual temperature is 19.74 °C, with an average of 9,61 °C in January and over 30,88 °C in July. Average wind speeds are 2,74 m/s, with winds highest in spring (approximately 3 m/s).

The Bagnouls and Gaussen ombrothermic diagram, based on climatic averages from 2014 to 2024 (Figure 2), clearly displays a long dry season, peaking in July and August, demonstrates the extent of water deficit in the region further confirming the arid to semi-arid nature of the study area, which is crucial for developing adaptive soil and water management practices to sustain barley yield.

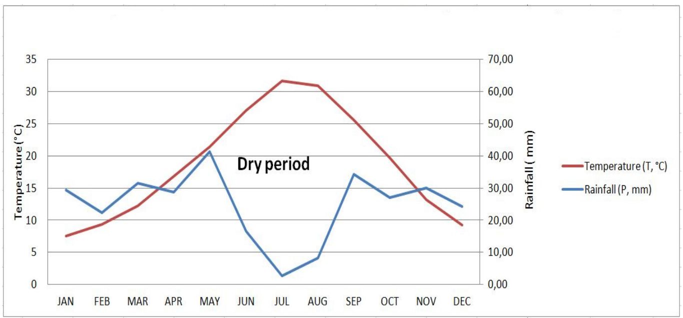

Figure 2: *Ombrothermic diagram of the study area (2014-2024) (NASA Power Project, 2024).*

Experimental design and agronomic management

The experiment was conducted using a randomized block design featuring three treatments and three replications (Figure 3). The treatments were: "T1" Chemical fertilizer PK 20-25 (100 kg P/ha, 125 kg K/ha) combined with Urea 46 (120 N kg/ha applied in three equal; 1/3 at sowing, 1/3 at tillering, 1/3 at bolting), The nitrogen was applied in three equal splits (40 kg N/ha each) at sowing, tillering, and bolting to minimize nitrogen losses through leaching and volatilization, a common practice in semi-arid environments (Sajjad *et al.*, 2024; Dikr 2023). «T2» Sheep manure (45 t/ha), «T3» Palm compost (45 t/ha). The fertilizer dosage of 45 t/ha for organic amendments was selected based on local farmer practices and previous studies in the region (e.g., Ouali *et al.*, 2025) to ensure a substantial input of organic matter for improving soil structure. Individual plots measured 3 × 2 m, with 1 m spacing between plots. Barley (*Hordeum vulgare* L., cultivar 'Rihane 03') was sown at a rate of 100 kg/ha. Irrigation was done using a sprinkler system to ensure even water distribution across all plots. Soil moisture was checked in the control plots at a depth of 15 cm. Irrigation started when the soil moisture dropped below 50% of field capacity. A uniform amount of 30 mm was applied to all plots roughly every 7 days, during the early morning to reduce evaporation. This helped keep soil moisture levels similar across treatments and prevented mixing up water stress with the effects of the amendments.

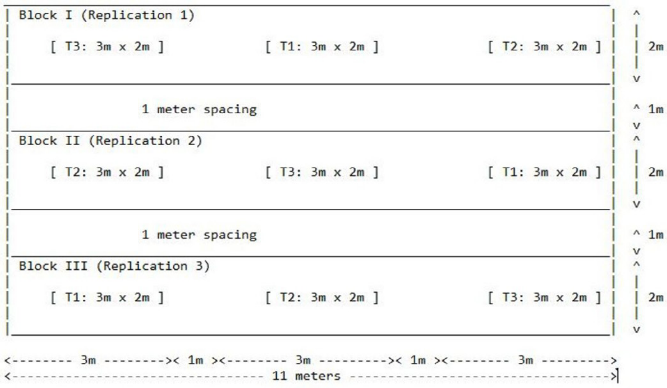

Figure 3: *Schematic of the experimental design.*

Table 1: *Physico-chemical properties of the experimental soil before treatments.*

Parameters	**Value**	
Profile horizon	**H1**	**H2**
Depth cm	0-20	20-40
Clay (%)	25.08	22.53
Silt (%)	32.41	22.64
Sand (%)	42.50	54.84
Soil texture	**Loam**	**Sandy Clay Loam**
pH (1/5)	8.18	8.21
EC dS m^{-1} (1/5)	0.79	0.75
Organic matter (%)	2.18	0.92
Total organic carbon (%)	1.27	0.54
Total nitrogen ‰	1.41	0.39
$CaCO_3$ Total (%)	18.50	14.88
$CaCO_3$ Active (%)	11.40	8.42
CEC (meq /100 g)	12.49	10.39
P_2O_5 ppm	86.26	66.41

Soil and fertilizer characterization

The experimental soil is defined as loam in the surface horizon (H1: 0–20 cm) and sandy clay loam in the subsurface horizon (H2: 20–40 cm) (Table 1). The soil reaction is alkaline (pH ≈ 8,2) and has low electrical conductivity (0,75–0,79 dS m^{-1}), as such is non-saline soil. Organic matter is low, particularly in the subsurface layer (2,18% in H1 and 0,92%

in H2), together with low total nitrogen (0,14% in H1 and 0,04% in H2). Available phosphorus levels are moderate (86,26–66,41 ppm), whereas the soil contains high levels of total calcium carbonate (18,5–14,9%) and active $CaCO_3$ (11,4–8,4%), confirming the calcareous nature of the soil. The cation exchange capacity is moderate (10,39–12,49 meq/100 g), indicating a low capacity to retain nutrients. Overall, the soil is calcareous, alkaline and low in organic matter and nitrogen, indicating the importance of applying organic amendment and balanced fertilizer to improve soil productivity.

The chemical characteristics of the fertilizer are summarized in Table 2 (sheep manure and palm compost). The compost used in this experiment is 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 sheep manure and was established at 45 tons/ha. The analyses conducted on organic amendments indicated that sheep manure and palm compost are only slightly alkaline, with resulting pH values of 8 for sheep manure and 8,19 for palm compost and moderately saline, with an electrical conductivity (EC) of 6,8 to 7,6 dS m^{-1}. The analysis indicated that the sheep manure had a moderate organic matter content (15.48%). The relatively low value can be attributed to the high mineral (ash) content of the samples, likely resulting from soil and bedding material mixed with the manure during collection. In addition, the manure was partially decomposed, which reduces organic carbon through mineralization. total carbon (9%), and total nitrogen (1,54%), though sheep manure is a notably good source of phosphorus (2183 ppm). The palm compost outperformed manure as an organic amendment in terms of organic matter (41,17%), carbon (23,93%), total nitrogen (2,91%), and phosphorus (2282 ppm) and is an overall better source of nutrients. While sheep manure is an excellent source of phosphorus, the palm compost presents a more sound and balanced organic amendment due to its organic matter and total nitrogen and would be best for fertility and structure improvements long-term.

Table 2: *Characteristics of experimental poultry manure and palm compost.*

Amendment	pH (1/10)	EC (dS m^{-1}) (1/10)	OM %	Total C %	Total N ‰	P_2O_5 ppm
Sheep manure	8.00	6.83	15.48	9	1.54	2183.13
Palm compost	8.19	7.60	41.17	23.93	2.91	2282.37

Barley cultivation

Seeds of the barley (*Hordeum vulgare* L.) cultivar Rayhan 03 were sown at a rate of 100 kg/ha. The characteristics of this barley variety are summarized in Table 3.

Sampling and analyses

Soil samples were collected from two depths (H1: 0–20 cm and H2: 20–40 cm) for four barley growth stages: Emergence, tillering, stem stretching and maturity. Using standard methods (Klute, 1986; Blake and Hartge, 1986), we assessed the soil's physical properties (particle and bulk density, porosity, and permeability) and chemical traits, Soil pH and electrical conductivity (EC) were measured in a 1:2,5 and 1:5 soil-to-distilled water suspension using a pH meter and a conductivity meter (Hanna Instruments), respectively. Agronomic measurements were conducted at the same growth stages. During these stages, plant height was recorded, while yield components assessed included the number of ears per plant, the number of seeds per ear, the thousand kernel weight (TKW), and both the grain and straw yields.

Statistical analysis

Data were subjected to a two-way analysis of variance (ANOVA) considering treatment and depth as factors, using R software (v 4.3.0). Treatment means were separated using Tukey's Honest Significant Difference (HSD) test at a 5% probability level (*p* < 0,05).

Table 3: *Pedigree, origin and agronomical parameters of the barley variety "Rihane03" used in the current study (Guetteche et al., 2023).*

Pedigree	Origin	Year of release	Heading (days)	Height (cm)	Maturity (days)	Spikes/ m2	Kernels/ Spike	Thousand kernel weight (g)	Grain yield (g/ha)
deriving from Atlas46/ Arivat //Athenais	ICARDA (Syria)	1995	98	96	118	198	72	46	38.2

Results

Soil characteristics

The use of organic amendments to the soil resulted in a major change in soil properties as compared to the application of chemical fertilizers (Figure 4, Table 4). Relative to the chemical fertilizer treatment, organic amendments positively influenced soil physical structure. At the maturity stage, the soil bulk density in the topsoil layer (0-20 cm) of the plots amended with sheep manure (1,12 g cm^{-3}) and palm compost (1,13 g cm^{-3}) was significantly lower when compared to the chemically fertilized plots (1,20 g cm^{-3}), representing an 8% reduction. Along with this, an increase in total porosity was also noted with the organic treatments having a value of 47,3% which was significantly higher than 44,0% that was obtained in the chemical treatment, an 8% increase. These changes in the soil composition were reflected by a considerable increase in the saturated hydraulic permeability. The topsoil permeability rate for sheep manure was found to be 7,40 ml s^{-1} while for palm compost it was 7,06 ml s^{-1} as against 4,89 ml s^{-1} for the chemical fertilizer treatment- a 51% increase. The variations in the bulk density and porosity were noticed to be more significant in the surface layer (0-20 cm) from where the effects were also visible in the subsurface layer (20-40 cm) albeit at a lower degree.

The influence of different fertilization treatments on soil chemical parameters was very clear. At harvest, the pH of the topsoil was still alkaline for all treatments, However, the observed differences were not substantial, with a value of 8,23 for chemical fertilization compared to a range of 8,11 to 8,28 for organic amendments. For electrical conductivity (EC),The topsoil values were most elevated in the sheep manure treatment (1,01 dS m^{-1}), with chemical fertilizer (0,83 dS m^{-1}). Notably, the palm compost treatment resulted in a lower EC (0,59 dS m^{-1}) than the chemical fertilizer, suggesting a potential benefit for mitigating salinity. All the values were lower than the threshold limit of 2 dS m^{-1}, thus, an absence of saline stress condition was inferred.

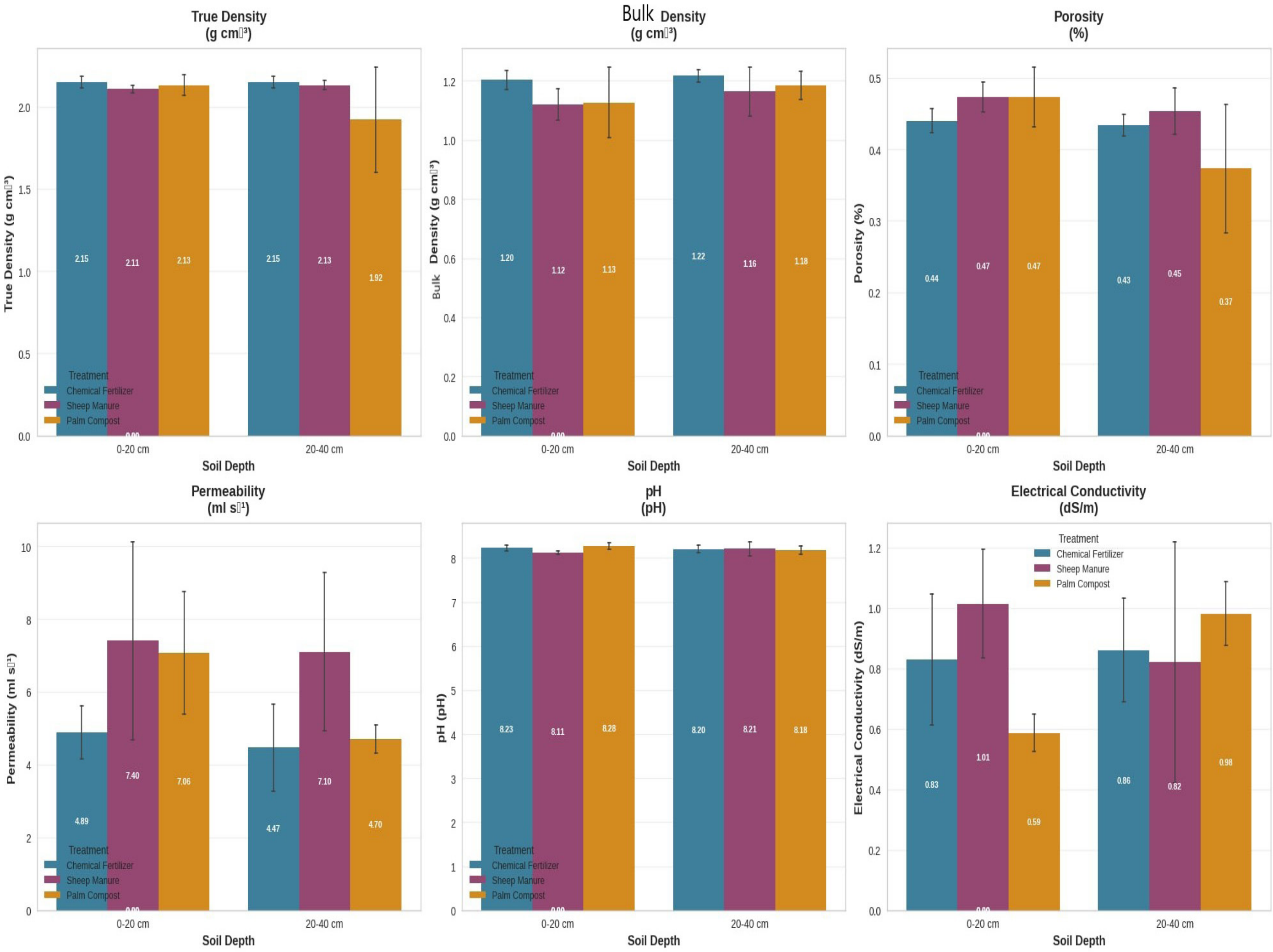

Figure 4: *Effect of organic and chemical amendments on soil properties at maturity (depth 0-20 cm and 20-40 cm).*

Links Researchers

Table 4: *Impact of chemical and organic amendments on soil properties across depth.*

Parameter	Depth (cm)	T1 (Chemical Fertilizer)	T2 (Sheep Manure)	T3 (Palm Compost)	Key Trend
Porosity (%)	0–20	43.0±1.2[b]	49.0±1.5[a]	44.0±2.1[b]	T2 > T3 ≈ T1 (topsoil)
	20–40	42.0±0.8[b]	44.0±1.1[a]	44.0±1.3[a]	T2 = T3 > T1 (subsoil)
Bulk density ($g\ cm^{-3}$)	0–20	1.31±0.03[a]	1.22±0.05[b]	1.28±0.07[ab]	T2 < T1 (improved structure)
	20–40	1.30±0.02[a]	1.28±0.04[a]	1.26±0.05[a]	NSD (subsoil less responsive)
EC ($dS\ m^{-1}$)	0–20	0.60±0.05[b]	0.91±0.07[a]	0.64±0.12[b]	T2>T1=T3 (salinity concern)
	20–40	0.75±0.03[b]	0.87±0.06[a]	0.82±0.09[ab]	T2 ≈ T3 > T1 (subsoil)
Permeability ($ml\ s^{-1}$)	0–20	4.30±0.8[b]	7.85±2.1[a]	6.78±1.5[a]	T2=T3>T1 (faster infiltration)
	20–40	5.85±1.0[b]	7.61±1.3[a]	4.66±0.9[b]	T2>T1≈T3(depth interaction)

(Mean ± Standard Deviation; Different letters indicate significant differences at p<0,05 within each depth)

Barley growth and yield

Plant growth, measured as final plant height, was greatest in plots receiving sheep manure (104,3 cm), compared to chemical fertilizer (87,0 cm) and palm compost (85,3 cm) (Figure 5).

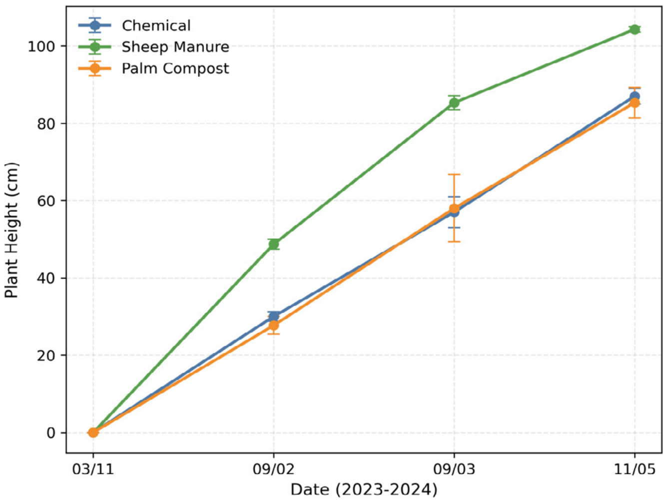

Figure 5: *Effect of organic and chemical amendments on plant height (cm).*

Agronomic performance was strongly influenced by the fertilization strategy (Figure 6, Table 5). Yield component analysis revealed that the number of ears per m^2 was the primary factor driving yield differences. The sheep manure treatment produced significantly more ears per m^2 (2564) than the chemical (1493) and palm compost (1382) treatments. The thousand kernel weight (TKW) showed no significant differences among treatments, ranging from 45,9 to 48,3g.

Consequently, grain yield was highest in the sheep manure treatment, reaching 5,79 t ha^{-1}. This was significantly greater than the yield obtained with chemical fertilizer (3,43 t ha^{-1}) and palm compost (2,99 t ha^{-1}). A similar trend was observed for straw yield, with sheep manure producing 11,02 tha^{-1}, substantially outperforming the other treatments. In summary, the use of sheep manure significantly enhanced both soil physical properties and barley yield components compared to chemical fertilizer and palm compost.

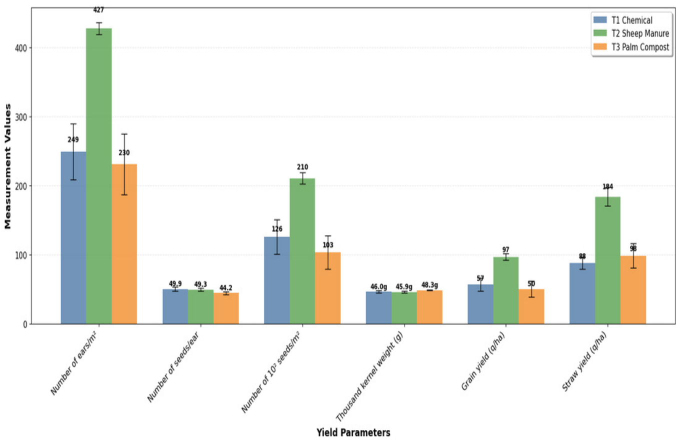

Figure 6: *Effect of organic and chemical amendments on components of barley yield.*

Discussion

Soil physical responses

Our findings demonstrate that organic amendments, particularly sheep manure, significantly enhanced soil physical properties compared to chemical fertilization. Bulk density decreased markedly with sheep manure and palm compost, reaching 1,08 g cm^{-3} at 0–20 cm during stem elongation and maturity. Conversely values increased at 20–40 cm, indicating greater compaction and reduced organic matter with depth (Wang *et al*., 2019; Yaşar *et al*., 2016). Sheep manure and palm compost markedly reduced bulk density at 20 cm, enhancing porosity and hydraulic conductivity throughout barley growth.

Table 5: *Barley yield components vs. critical soil properties by treatment.*

Treatment	Grain yield (g/m^2)	Straw yield (g/m^2)	TKW (g)	Linked soil property (0–20 cm)	Linked Soil property (20–40 cm)
T1 (Chemical)	3426 ± 583	5246 ± 583	46.0 ± 1.7	Low porosity (43%) • High bulk density (1,31 g cm^{-3})	Moderate permeability (5.85 ml s^{-1})
T2 (Sheep Manure)	5788 ± 283	11018 ± 789	45.9 ± 1.4	High porosity (49%) • Low bulk density (1.22 g cm^{-3})	High permeability (7.61 ml s^{-1})
T3 (Palm Compost)	2994 ± 706	5889 ± 1048	48.3 ± 0.6	High organic C (23,93%) • Moderate porosity (44%)	High organic C (23.5%) • Low permeability (4,66 ml s^{-1})

This structural improvement facilitated deeper rooting and improved water fluxes corroborating evidence from arid soils where organic amendments improved soil physical structure and reduced compaction (Oueriemmi *et al*., 2021).

Porosity declined with depth, restricting water infiltration and root penetration, but increased markedly under organic amendments, sheep manure plots reaching porosity values up to 49% at (0–20 cm) at maturity, This was significantly greater than the porosity observed in chemically fertilized plots. Conversely, chemical fertilizers plots exhibited lower porosity, particularly at 40 cm, likely due to compaction and salt accumulation, processes known to reduce enzymatic activity and microbial diversity essential for soil structural stability (Kumar *et al*., 2020; Sharma *et al*., 2023).

Permeability showed a significant increase with organic amendments, with the highest value of 7,61 ml s^{-1} in sheep manure plots at maturity, compared to chemical fertilizer plots which peaked at 5,85 ml s^{-1}. This result demonstrates that water infiltration dynamics were improved in organically amended soils.

Soil chemical responses

Soil pH exhibited a small alkaline trait at both depths, with a slight decrease observed at 20–40 cm, which is typical of semi-arid soils (Xiao *et al*., 2025; Zhang *et al*., 2022). Organic amendment generally produced slight increases in pH, especially at 20 cm depth and during the early growth period, which supported the previous conclusion that organic fertilizer mitigated acidity and supports soil chemical equilibrium (Wang *et al*., 2025). On the other hand, chemical fertilizer tended to maintain or lead to a slight decrease in pH, showing the acidifying effects from the inorganic nitrogen source.

Electrical conductivity (EC) was highest at the surface and fell with depth, indicating that salts accumulated in the upper layer because of evaporation. Chemical fertilizer resulted in a modest increase in EC, which reflects a higher concentration of ionic solutes. By contrast, organic manure reduced EC, thereby mitigating salinity accumulation. These results corroborate findings in maize systems where organic substitution decrease soil salinity and enhanced soil health (Xing *et al*., 2024).

Depth-dependent effects revealed more pronounced improvement in physical properties within the upper 20 cm under organic amendments, including increased in porosity and reduced bulk density. At a depth of 40 cm, the impacts of amendments were reduced but still higher than amendments with chemical fertilizer. This reinforces the notion that organic amendments are mostly engaging the topsoil through direct incorporation of organic matter and stimulating microbial activity, whereas changes in the subsurface layers would presumably occur much slower.

The results of these studies support previous research that organic amendments improve soil health through improving soil structure, enhancing microbial activity, and improving nutrient availability (Kumawat *et al*., 2016). In comparison, while chemical fertilizers provide rapid nutrient supply, they often contribute to soil acidification and lower long-term fertility (Khan *et al*., 2024). Similar patterns have reported in Iranian barley systems, where soil properties such as EC, pH, and water-holding capacity significantly influenced biomass and grain yield (Ayoubi *et al*., 2009). Organic fertilizers also increase soil organic carbon, microbial biomass and enzyme activities, especially within the upper 20 cm, and furthermore in deeper soil (20–40 cm) after repeated applications (Herencia and Maqueda 2016; Wang *et al*., 2025). Over the long-term organic inputs will maintain fertility and soil properties, while chemical fertilizers alone may lead to continuous deterioration of soil quality (Wang *et al*., 2025).

Agronomic and yield effects

Regarding barley yield characteristics, the plant height in the sheep manure plots reached a maximum of 105 cm, compared to approximately 90 cm with chemical fertilizer, demonstrating improved vegetative growth. This verifies with earlier observations of significant improvements in plant height with increasing levels of fertilization (Ramadhan, 2013; Rashid and Khan, 2008).

The highest number of ears per plot was obtained in the sheep manure and chemical treatments, which was then followed by the palm compost treatment. This improvement was due to an improved availability of nutrients supplied in the fertilizers to the plants, promoting expanded flag leaf levels that enhanced photosynthesis and tillering to sustain growing conditions. The results were consistent with the results reported by Zarina and Konosonoka (2019).

With respect to the count of seeds per Ear, the chemical fertilizer plots were observed to have marginally increased numbers as a result of application, however, these changes were not significant in most cases. Notably, the treatment (T1) yielded highest number of seeds per ear. This trend is consistent with previous findings (Ryan *et al*., 2009), indicating the yield gains from fertilization are driven by both increased ear density and a higher number of seeds per ear. Similarly, Sher *et al*. (2003), reported significant yield improvements with chemical fertilizer application compared to unfertilized controls.

Thousand Kernel Weight (TKW) increased under organic amendments, indicating improved grain filling. This observation aligns with Megh and Saniay (2004), who reported that nitrogen deficiency in cereals limits carbohydrates translocation to the grains, resulting in smaller grain size and reduced weight. Conversely, adequate nitrogen availability enhance grain filling, thereby increasing TKW.

Organic treatments particularly palm compost, produced grain yields comparable to or exceeded those achieved with chemical fertilizer consistent with finding reported in similar agro-climates conditions (Kumawat *et al*., 2016; Tefera *et al*., 2022).

Straw yield was higher under organic treatment, particulary with sheep manure and palm compost, compared to chemical fertilizer (Oueriemmi *et al*., 2025). Both chemical and organic amendments enhance vegetative growth by stimulating green foliage development. The direct absorption of potassium through increases leaf K concentration, improving photosynthetic efficiency through enhanced CO_2 uptake and metabolism, and facilitating assimilate translocation throughout the plant. As a result, this process contributes to weight gain in the plant (Calinski *et al*., 1981; Steer and Hocking, 1984).

Similary, Hussein (2022) reported that higher organic fertilizer rates increase tillering due to greater nutrient availability, particularly nitrogen, during critical growth stages, thereby supporting greater biomass accumulation.

In terme of yield Response, evidence from Rajasthan and Ethiopia demonstrates that organic amendments, such as vermicompost, farmyard manure, can enhance barley grain yield by 20–30% compared to untreated controls. when applied alone or in conjunction with biofertilizers or at optimal rates (Kumawat *et al*., 2016; Mestawut *et al*., 2020; Tefera *et al*., 2022). The increased grain and straw yields with sheep manure applications in this study are in line with (Guetteche *et al*., 2023), and emphasizes the importance of organic amendments in sustaining productivity in similar agro-climatic zones. In Ethiopia, it has been shown that nitrogen and phosphorus fertilization significantly improved grain and biomass yields in barley (Tigre, 2014).

Implications for sustainable management

The results of this work are encouraging and support the core sustainable soil management approach based on the application of locally available organic materials, in particular sheep manure, in semi-arid areas such as those of Algeria. Chemical fertilizers deliver nutrients that are readily available, but because they have a very low influence on the soil's physical and biological properties and are known to contribute to increasing soil salinity, they have certain limitations in terms of sustaining soil health. In contrast, sheep manure had a more pronounced effect on the physical quality of the soil, an aspect that is regarded as a decisive factor for water retention in areas susceptible to drought, and at the same time it supplied nutrients, which enabled the obtaining of the best results.

Furthermore, it reinforcing food security by providing actionable recommendations for farmers in arid and semi-arid regions to ensure stable barley production under resource-limited conditions. For policymakers, it underscores the value of integrating livestock and crop production systems within a circular economy framework. Subsequent studies should focus on optimizing application rates, improving local composting techniques, and monitoring the long-term effects of these amendments on soil carbon sequestration and ecosystem health.

Conclusions

This study demonstrates that locally sourced organic amendments, particularly sheep manure, are a superior alternative to chemical fertilizers for enhancing soil health and barley productivity in semi-arid Mediterranean environments. Sheep manure significantly improved key soil physical properties, which included lowering soil bulk density by 8% and increasing permeability by 51% compared to using chemical fertilizer. These changes in soil directly impacted positively in terms of agronomical performance, where sheep manure produced the maximum yields in terms of grain and straw weights at 5,79 tons per hectare and 11,02 tons per hectare, respectively.

Besides other contributions, this work is also a marked point in the evaluation of palm compost as a potential valuable amendment for areas with date palm residues. Despite the fact that palm compost had a positive effect on soil properties, its impact on agricultural practices was significantly lower than that of sheep manure, which points to the need for adjusting the processes of composting and getting deeper insights into nutrient release profiles of different organic inputs for future agronomic use.

In summary, the adoption of organic amendments, such as sheep manure, represents a sustainable and effective means of restoring ground quality, increasing barley yield, and strengthening resilience against climate variability in semi-arid environments. Agricultural policy and farming communities are strongly encouraged to promote these practices as the basis for sustainable land management and rural development. By integrating scientific evidence, local resources, and farmers' experience, it is possible to promote food safety and environmental administration for the future of agriculture in regions with water limits.

Future studies should focus on improving composting techniques for palm waste and conducting long-term monitoring of soil health and yield stability. Investigating integrated nutrient management strategies that combine organic and mineral fertilizers could further optimize resource-use efficiency.

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Novelty Statement

This study provides an integrated field evaluation of sheep manure, palm compost, and chemical fertilization, assessing their effects on soil hydro-physical properties and barley performance across multiple growth stages and soil depths under semi-arid Mediterranean conditions. The findings demonstrate that locally available sheep manure simultaneously restores soil physical quality and maximizes crop yield, offering a practical and sustainable alternative to synthetic fertilizers in degradation-prone dryland agroecosystems.

Author's Contribution

Abderrazak Mabrouki: Conceived the study, designed and conducted the field experiment, collected and analyzed the data, and wrote the original manuscript.
Fatima Hiouani: Contributed to the conceptualization of the research idea, assisted in data interpretation, and reviewed and edited the manuscript.
Abdelouahad Ouali: Participated in field experiment management and provided critical feedback throughout the study.
Djamila Madani: Contributed to the statistical analysis of the data and manuscript correction.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI-assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

References

Ayoubi, S., Farhad, K. and Kanwar, L.S., 2009. Relationships of barley biomass and grain yields to soil properties within a field in the arid region: Use of factor analysis. Acta Agric. Scand., B Plant Soil Sci., 59(2): 107–117. https://doi.org/10.1080/09064710801932417

Blake, G.R. and Hartge, K.H., 1986. Bulk density. In: SSSA book series, 1st ed., edited by Arnold Klute, vol. 5. Wiley. https://doi.org/10.2136/sssabookser5.1.2ed.c13

Calinski, T., Steel, R.G.D. and Torrie, J.H., 1981. Principles and procedures of statistics: A biometrical approach. Biometrics, 37(4): 859. https://doi.org/10.2307/2530180

Dikr, W., 2023. Effect of long-term chemical fertilizer application on soil chemical properties: A review. J. Biol., 13(5):11.

El-Khalifa, Z.S., El-Gamal, E.H. and Zahran, H.F., 2022. Evaluation of barley cultivated areas actual status in Egyptian newly reclaimed lands. Asian J. Agric. Rural Dev., 12(3): 164–172. https://doi.org/10.55493/5005.v12i3.4532

Emdad, M.R., Tafteh, A. and Nejad, S.A.G., 2023. The effect of organic fertilizer on the changes of soil physical properties in different rotations cultivation in permanent plots. Water Soil Manage. Model., 4(2): 121–132.

Guetteche, H., Jarrar, A.K., Khiyel, I., Narimane D., Leila R., Abdelkader R., Abdelkader B. and Peter N. 2023. The popular algerian barley landraces saïda and tichedrett are autochthonous evidence from RAPD, SSR and Agrophenological Markers. Copyright © The Author(s), 2023. Published by Cambridge University Press on Behalf of National Institute of Agricultural Botany, no. 20 (May): 394–405. https://doi.org/10.1017/S1479262123000291

Herencia, J.F. and Maqueda, C., 2016. Effects of time and dose of organic fertilizers on soil fertility, nutrient content and yield of vegetables. J. Agric. Sci., 154(8): 1343–1361. https://doi.org/10.1017/S0021859615001136

Hlisnikovský, L., Zemanová, V., Roman, M., Menšík, L. and Kunzová, E., 2024. Long-term study of the effects of environment, variety, and fertilisation on yield and stability of spring barley grain. Plants, 13(19): 2745. https://doi.org/10.3390/plants13192745

Husein, H.H., Mousa, M., Sahwan, W., Bäumler, R. and Lucke, B., 2019. Spatial distribution of soil organic matter and soil organic carbon stocks in semi-arid area of northeastern Syria. Natl. Resour., 10(12): 415–432. https://doi.org/10.4236/nr.2019.1012028

Hussein, A.A., 2022. Effect of foliar nitrogen and number of cutting on yield of green forage and quality of barley. Ijar Iraqi J. Agric. Res., 26(1): 13–27.

Kavvadias, V., Guyader, E.L., El-Mazlouzi, M., Maxime G., Belkacem B., Mohamed M., Hafouda L., Mahtali S., Ines R. Z., Kamel G., Aissa T., Abid A., Beatrice M., and Xavier M. 2024. Using date palm residues to improve soil properties: The case of compost and biochar. Soil Syst., 8(3): 69. https://doi.org/10.3390/soilsystems8030069

Khan, M.T., Aleinikovienė, J. and Butkevičienė, L-M., 2024. Innovative organic fertilizers and cover crops: Perspectives for sustainable agriculture in the era of climate change and organic agriculture. Agronomy, 14(12): 2871. https://doi.org/10.3390/agronomy14122871

Klute, A., 1986. Methods of soil analysis: Part 1 physical and mineralogical methods. 1st edn. Vol. 5. SSSA Book Series. Wiley. https://doi.org/10.2136/sssabookser5.1.2ed

Kumar, A., Singh, S., Gaurav, A.K., Srivastava, S. and Verma, J.P., 2020. Plant growth-promoting bacteria: Biological tools for the mitigation of salinity stress in plants. Front. Microbiol., 11(July): 1216. https://doi.org/10.3389/fmicb.2020.01216

Kumawat, S., Sharma, S.R., Rundala, S.R. and Dogra, P., 2016. Organics and fertility levels influences barley yield and soil properties in semi-arid region of Rajasthan. Annals of Agricultural Research. 37(1): 66–71.

Mahmoud, E., Ghoneim, A.M., Seleem, M., Zuhair, R., El-Refaey, A. and Khalafallah, N., 2023. Phosphogypsum and poultry manure enhance diversity of soil fauna, soil fertility, and barley (*Hordeum aestivum* L.) grown in calcareous soils. Sci. Rep., 13(1): 9944. https://doi.org/10.1038/s41598-023-37021-3

Makhlof, H., Hassan, A.L., Mohammeda, A.E-M. and Ahmed, G.L., 2019. Effect of organic (biochar, compost and chicken manure) and mineral fertilization on available NPK on sandy soil. J. Pure Appl. Sci., 17: 86–91.

Megh, S. and Saniay, A., 2004. Interaction effect of zink and nitrogen on growth and yield of barley (*Hordeum vulgare* L.) on typic ustip samments. Asian J. Plant Sci., 3(1): 101–103. https://doi.org/10.3923/ajps.2004.101.103

Mestawut, A., Abebe, M. and Getachew, A., 2020. Effect of combined organic and inorganic fertilizer on yield and yield components of food barley (*Hordeum vulgare* L.). Food Sci. Qual. Manage., 95 (March).

Naorem, A., Jayaraman, S., Dang, Y.P., Ram C. Dalal, Nishant K. S., Ch. Srinivasa R. and Ashok K.P. 2023. Soil constraints in an arid environment challenges, prospects, and implications. Agronomy, 13(1): 220. https://doi.org/10.3390/agronomy13010220

NASA. 2024. 'The NASA POWER Project's Data Access Viewer (DAV)'. https://power.larc.nasa.gov/data-access-viewer/

Ojeniyi, S.O., Awodun, M.A. and Odedina, S.A., 2007. Effect of animal manure ammended spent grain and cocoa husk on nutrient status growth and yield of tomato. Int. J. Agric. Res., 2(4): 406–410. https://doi.org/10.3923/ijar.2007.406.410

Ouali, A., Hiouani, F., Beribeche, K. and Madani, D., 2025. Optimized date palm waste composting: Accelerating maturity via C:N ratio and moisture adjustments using a rotary drum system. J. Ecol. Eng., 26(8): 120–131. https://doi.org/10.12911/22998993/203810

Oueriemmi, H., Kidd, P., Trasar-Cepeda, C., Beatriz R.G., Rahma Z., Kaouther A., Ángeles P.F., and Mohamed M. 2021. Evaluation of composted organic wastes and farmyard manure for improving fertility of poor sandy soils in arid regions. Agriculture, 11(5): 415. https://doi.org/10.3390/agriculture11050415

Oueriemmi, H., Zoghlami, R.I., Guyader, E.L., Fatma M., Yosra S., Ali B., Mohamed M., Mahtali S., Sarra S., Xavier M., and Mohamed O. 2025. Addressing soil fertility challenges in arid agriculture: A two-year evaluation of combined soil organic amendments under saline irrigation. Soil Syst., 9(1): 16. https://doi.org/10.3390/soilsystems9010016

Ramadhan, M.N., 2013. Tillage systems and seeding rate effect on yield components, seed yield and biological yield of barley cultivars. J. Basrah Res., 39(1): 33–46.

Rashid, A. and Khan, R.U., 2008. Comparative effect of varieties and fertilizer levels on barley. Int. J. Agric. Biol., 10(1): 124–126.

Ryan, J., Monem, M.A. and Amri, A., 2009. Nitrogen fertilizer response of some barley varieties in semi-arid conditions in Morocco. J. Agric. Sci. Technol., 11: 227–236.

Sajjad, M., Hussain, K., Wajid, S.A. and Saqib, Z.A., 2024. The impact of split nitrogen fertilizer applications on the productivity and nitrogen use efficiency of rice. Nitrogen, 6(1): 1. https://doi.org/10.3390/nitrogen6010001

Sharma, S., Gupta, N., Chakkal, A.S., Neha S., Saud A., Manzer H. S., and Fasih U.H. 2023. Changes in enzyme activities in salt-affected soils during incubation study of diverse particle sizes of rice straw. Agriculture, 13(9): 1694. https://doi.org/10.3390/agriculture13091694

Sher, A., Fayaz, A., Faridullah, F. and Munir, H., 2003. Effect of different NPK levels on the growth and yield of kohlrabi (*Brassica canloraoa* L.) at Northern areas of Pakistan. Asian J. Plant Sci., 2(3): 336–338. https://doi.org/10.3923/ajps.2003.336.338

Steer, B.T. and Hocking, P.J., 1984. Nitrogen nutrition of sunflower (*Helianthus annuus* L.): Acquisition and partitioning of dry matter and nitrogen by vegetative organs and their relationship to seed yield. Field Crops Res., 9(January): 237–251. https://doi.org/10.1016/0378-4290(84)90029-7

Tefera, T., Hameso, H. and Tontosha, H., 2022. Performance of barley (*Hordeum vulgare* L.) varieties to organic and inorganic fertilizers on yield, yield components and soil characteristics. 10 (September).

Tigre, W., 2014. Effects of nitrogen and phosphorus fertilizer levels on growth and development of barley (*Hordeum vulgare* L.) at Bore District, Southern Oromia, Ethiopia. Am. J. Life Sci., 2(5): 260. https://doi.org/10.11648/j.ajls.20140205.12

Titirmare, N.S., Ranshur, N.J., Patil, A.H., Patil, S.R. and Margal, P.B., 2023. Effect of inorganic fertilizers and organic manures on physical properties of soil: A review. Int. J. Plant Soil Sci., 35(19): 1015–1023. https://doi.org/10.9734/ijpss/2023/v35i193638

Verma, S., Pradhan, S.S., Singh, A. and Kushuwaha, M., 2024. Effect of organic manure on different soil properties: A review. Int. J. Plant Soil

Sci., 36(5): 182–187. https://doi.org/10.9734/ijpss/2024/v36i54515

Wang, S., Guo, L., Zhou, P., Xuejie Wang, Ying S., Huifang H., Tangyuan N., and Kun H. 2019. Effect of subsoiling depth on soil physical properties and summer maize (*Zea mays* L.) yield. Plant, Soil Environ., 65(3): 131–137. https://doi.org/10.17221/703/2018-PSE

Wang, X., Wei, J., Duan, J., Sanwei Y., Tingting M., Mingrui L., Fangchi W., and Shengmei Y. 2025. Effects of organic fertilizer replacing chemical fertilizer on organic carbon mineralization and active carbon fractions in yellow paddy soil of Guizhou Province V1. Preprint, Springer Science and Business Media LLC, February 27. https://doi.org/10.17504/protocols.io.ewov1dr27vr2/v1

Widjajanto, D., Somba, B.E., Rois, Uswah H., Abdul R., Rachmat Z., Rezi A., Rully A. P. D., Rizki P., and Desi R. 2023. High-carbon organic fertilizer effects on soil physical properties of sandy loam soil and corn growth. In: Proceedings of the 2nd international interdisciplinary conference on environmental sciences and sustainable developments 2022 environment and sustainable development (IICESSD-ESD 2022), edited by Nur Edy, Anshary Alam, Syamsu Rijal, Rahadian Pratama, Agung Wibowo, and Anita Ahmad Kasim, vol. 36. Advances in Biological Sciences Research. Atlantis Press International BV. https://doi.org/10.2991/978-94-6463-334-4_27

Xiao, Y., Ye, M., Zhang, J., Yamin C., Xinxin S., Xiaoyan L., and Xiaodong S. 2025. Significant changes in soil properties in arid regions due to semicentennial tillage a case study of Tarim River Oasis, China. Sustainability, 17(9): 4194. https://doi.org/10.3390/su17094194

Xing, Y., Li, Y., Zhang, F. and Wang, X., 2024. Appropriate application of organic fertilizer can effectively improve soil environment and increase maize yield in loess plateau. Agronomy, 14(5): 993. https://doi.org/10.3390/agronomy14050993

Yaşar, K., Selma and Korkanç, M., 2016. Physical and chemical degradation of grassland soils in semi-arid regions: A case from Central Anatolia, Turkey. J. Afr. Earth Sci. 124(December): 1–11. https://doi.org/10.1016/j.jafrearsci.2016.08.021

Zarina, L. and Konosonoka, I.H., 2019. Cereal species effect on protein content in pea grains in legume cereal mixtures depending cropping system. Environment. technologies. resources. Proceedings of the International Scientific and Practical Conference 1 (June): 349. https://doi.org/10.17770/etr2019vol1.4179

Zha, Y., Liu, A., Lai, W., Jianrong W., Xiaoyuan L., Hong Y., and Wenfei X. 2024. Sheep manure organic fertilizer is an effective strategy to promote strawberry growth by improving soil physicochemical properties and microbiota. Front. Environ. Sci., 12(May). https://doi.org/10.3389/fenvs.2024.1414010

Zhang, L., Chang, Y., Gao, W., Xiaojia Li, Hongtao J., Ruiping Z., Jun M., Xiaoming W., Chunxing H., and Yunhu X. 2022. Assessment of the quality indices of soils irrigatedby groundwater in a typical semi-arid steppe ecoregion. Polish J. Environ. Stud., 31(2): 1951–1961. https://doi.org/10.15244/pjoes/143302