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USING THE NEUTRON SCATTERING TECHNIQUE TO ASSESS THE IMPACT OF SOIL CONDITIONERS ON THE MOISTURE CONTENT AND PRODUCTIVITY OF SANDY SOIL

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ABSTRACT: Egypt's sustainable agriculture faces challenges from sandy soil, poor water retention, and nutrient deficiency. This study uses neutron scattering techniques to investigate the effects of two soil conditioners, compost and water treatment residues (WTR), on soil moisture dynamics and crop productivity in sandy soils. The Nuclear Research Centre in Egypt conducted field experiments for wheat (Triticum aestivum L., Gimmiza-11) and peanut (Arachis hypogaea, Giza 6) during the 2021/2022 winter season and the 2023 summer season, respectively. Treatments included three irrigation levels (100%, 80%, and 60% of field capacity) and two soil conditioners, arranged in a split-plot design. Soil moisture was assessed using a neutron moisture meter, allowing accurate monitoring at various soil depths. Results indicated that compost significantly improved soil moisture retention and crop yields across all irrigation regimes, particularly under water stress. At full irrigation (100% FC), compost-amended soil exhibited the highest post-irrigation soil moisture and yields for both crops. The WTR improved water retention, albeit less effectively than compost. Control plots consistently had the lowest moisture content and yield. The research demonstrates that integrating organic amendments, especially compost, alongside precision irrigation methods can significantly enhance water use efficiency and agricultural yield in sandy, arid soils.

Keywords: Compost, Irrigation levels, Moisture content, Sandy soil, Water treatment residues, Wheat, Peanuts production.

INTRODUCTION

Most newly reclaimed soils in Egypt are sandy. This soil is characterized by a lack of plant nutrients, loss of structure, low water retention, minimal organic matter, reduced microbial activity, and highly rapid permeability. Moreover, sandy soil is susceptible to climatic fluctuations due to its tendency to be prone to droughts, even during the wet season (National Center for Appropriate Technology, 2019). Sandy soils are defined by their composition, which includes less than 18% clay and more than 68% sand within the upper 100 centimeters of the soil profile (ISSS Working Group R.B., 1998). A soil organic amendment is defined as any substance incorporated into the soil to enhance its physical characteristics, including water retention, permeability, drainage, structural integrity, and nutrient availability. This improves the conditions for root development and overall plant growth (Davies *et al.*, 2004). Ideally, agricultural soils should have a minimum organic matter content of 4-5% to enhance soil characteristics and provide essential nutrients for plants and microorganisms (Brady and Weil, 2008). However, water treatment residual (WTR) refers to the byproduct generated during the treatment of drinking water. A noteworthy concept involves the concurrent application of WTR and agricultural residues to enhance the characteristics of sandy soil. Nonetheless, organic amendment applications on soil may improve the quality of sandy soils and provide a cost-efficient option for waste disposal. Both WTR and compost represent innovative alternative technologies for rehabilitating sandy soils (Hsu and Hseu, 2011). Egypt’s agricultural sector heavily relies on wheat, a vital grain for food security, economic stability, and rural

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livelihoods, making it one of the world's largest wheat importers. Both ancient and modern Egyptians relied heavily on wheat, which has remained a crucial component of their nutrition (Fadl *et al.,* 2013; CAPMAS, 2020; FAO, 2022). Egypt's wheat production is crucial for its economy and food security strategy, but it faces challenges in meeting domestic demand. Investments in research, infrastructure, and water management are needed. Egypt's sustainable agricultural expansion is crucial for its economy, but water supplies have declined due to factors such as arid terrain, climate change, and inefficient irrigation practices. Over-irrigation and farmers' reluctance to rationalize irrigation water are exacerbated by a lack of research on irrigation water management (Abdelazez *et al.,* 2024). The Egyptian government values wheat for its role in ensuring food security and social stability. State-run bakeries distribute bread, especially subsidized bread, to low-income residents. Egypt's social safety net has long included this state subsidy, and wheat supply disruptions could lead to political and social unrest, as seen during the 2008 food crisis, when rising wheat prices triggered protests and instability (FAO, 2022). Egypt's wheat production faces challenges due to limited areas of fertile soil, water scarcity, climate change, and global price fluctuations. The country's wheat cultivation reaches 3 million hectares annually, accounting for 12-15% of its arable land. The production is primarily concentrated in the Nile Delta, New Valley, Sinai, and Upper Egypt (World Bank, 2023). Despite Egypt's favorable climate and advanced irrigation techniques, wheat yields per hectare are below global averages due to traditional farming methods and soil degradation. The Egyptian Ministry of Agriculture is introducing new wheat varieties, improved irrigation systems, and modern farming equipment to enhance wheat productivity (Kishk Abd Elmageed *et al.,* 2019).

Peanuts, a nutritious and adaptable crop, are also gaining popularity in Egypt due to their economic value and ability to thrive in the country's varied soil conditions. Due to its high temperatures and ample sunlight, Egypt's hot summers are ideal for peanut farming, allowing for maximum growth and yields (Tugrul and Koca, 2014). Egypt's peanut crop is valuable for oil extraction, food products, and snacks. Peanut oil is a healthy alternative, and peanut butter is a popular choice. Egypt exports peanut products, including roasted peanuts and peanut oil (Samaras and Magoulas, 2015; FAO, 2022). Peanuts in Egypt are a low-water-demand crop due to their drought-tolerant nature and ability to improve soil health. They fix nitrogen, reduce the need for chemical fertilizers, and enhance fertility, making them crucial for Egypt's efforts to rehabilitate arid and semi-arid lands, despite water scarcity issues (Singh *et al.,* 2018; Kumar *et al.,* 2022). Peanuts are a crucial food source in Egypt, providing protein, fats, vitamins, and minerals, and are essential for maintaining food security and improving nutrition in low-income communities, according to the World Bank (2023), Ali *et al.* (2021), and Hassan *et al.* (2020). Egypt prioritizes agricultural diversification to improve resilience to climate change and market fluctuations. Promoting peanuts can boost output, increase export potential, and reduce pest pressure. Rotating peanuts with other crops can also increase farm productivity. These challenges have led to demands for enhanced water resource management and the development of arid agricultural regions, resulting in appeals for supplementary agricultural sandy soils (Omran *et al.,* 2025).

The neutron probe is a widely used method for measuring soil water content, based on the principle of neutron scattering. It emits fast neutrons into the soil, which interact with hydrogen atoms in water molecules and thermalize, indicating the soil's moisture content. This technique offers the advantage of measuring soil moisture at various depths without disturbing the soil, making it ideal for monitoring dynamic moisture changes over time (Robock, 2003). The neutron probe, despite its limitations due to safety precautions and high equipment and calibration costs, remains a standard in soil moisture measurement, especially in research and large-scale agricultural applications, despite its reliance on radioactive isotopes. (Hillel, 2004). The Neutron Moisture Meter effectively measures moisture content in sandy soils. It provides real-time, continuous measurements over various depths, enabling efficient irrigation management. This makes it useful for agricultural practices in arid regions without disturbing soil structure (Huisman *et al.*, 2003; Seneviratne *et al.*, 2010; Schwank *et al.*, 2015).

This study aims to assess the impact of applying compost and WTR as soil conditioners on specific properties of sandy soil, as well as on the production of wheat and peanut crops.

MATERIALS AND METHODS

Experimental Site

An experimental methodology was employed to evaluate the responses of wheat *(Triticum aestivum L.)*, Gimmiza-11 variety, and peanuts *(Arachis hypogaea)*, Giza 6 variety, to three irrigation water levels and two soil conditioner types (compost and WTR). This study was conducted as a field experiment during the two successive growing seasons: the winter season of 2021/2022 for wheat and the summer season of 2023 for peanut at the Experimental Farm of the Soil and Water Research Department, Nuclear Research Centre, Atomic Energy Authority, Egypt, located at Abu Zaabal, Quliobia Governorate. The site is located at a latitude of 30°24' N and a longitude of 31°35' E, with an altitude of 25 m above sea level.

The experimental area (12٠ m^2) was divided into three equal sections, representing the three added soil conditioners (compost, water treatment residues "WTR", and the control "no addition"). The compost was added according to El-Shony *et al.* (2019) at a rate of 26 tons/ha, which is equivalent to 4% of the soil volume. The same percentage of 4% WTR was added to the soil, corresponding to a rate of 33.5 tons/ha. Both compost and WTR were placed before tillage and were mixed with the top 25 cm of the soil surface. Each section was subsequently divided into three equal parts, corresponding to the three irrigation rates: 100, 80, and 60% of the soil field capacity (FC).

A drip irrigation system was implemented to irrigate wheat and peanut plants. Each treatment was conducted in triplicate, with each plot measuring 1.2 m² (0.6 m × 2 m). A one-meter strip was elevated between the plots to inhibit water interaction. The compost and WTR were placed in a trench (10 cm wide and 10 cm deep) in the soil next to the drip irrigation hose. These additions were made in conjunction with soil preparation throughout two growing seasons.

Cultivated Crops

This study was conducted on two crops

- **a- Wheat:** Seeds of wheat *(Triticum aestivum L.*, Gimmiza-11 variety) provided by the Wheat Department, Field Crops Research Institute, Agriculture Research Center, Giza, Egypt, were sown on 18 November 2021 and harvested on 8 April 2022. The space between rows was 30 cm, and the planting spacing within the same row was 15 cm—the amount of seeds required was 190.93 kg per hectare.
- **b- Peanuts:** Peanut (*Arachis hypogea*, Giza 6 variety) seeds were planted in each plot on June 4, 2023, and harvested on October 8, 2023. Each hectare necessitated 180 kg of pods, corresponding to 120 kg of seeds. These seeds were obtained from the Field Crop Institute Research, ARC, Egypt. Peanut seeds were sown in holes that were ten centimeters apart. The missing holes were replanted 10 days after planting. A drip irrigation system was installed in the two plots.

Physical and chemical analysis of the experimental soil

Before planting, as well as after the plants had grown, undisturbed and disturbed soil samples were collected from surface soil depths of 0–15 cm, 15–30 cm, 30–45 cm, and 45–60 cm to determine specific physical and chemical characteristics. These determinations were carried out according to the methodologies of Carter and Gregorich (2008); the data are listed in Tables 1 and 2.

Table 1: Physical properties of the experimental soil before cultivation.

Soil depth (cm)	Particle size distribution (%)			Texture class	Bulk density (g/cm^3)	Total porosity (%)	Moisture content* (volume %)		
	Sand	Silt	Clay				FC	WP	AW
0-15	97.6	1.9	0.5	Sand	1.7	35.0	7.3	3.5	3.8
15-30	97.3	1.6	1.1	Sand	1.7	36.0	7.0	3.3	3.7
30-45	98.1	1.1	0.8	Sand	1.7	35.0	6.9	3.1	3.8
45-60	98.4	1.3	0.3	Sand	1.7	35.0	6.8	3.0	3.8
Mean	97.9	1.5	0.6	sand	1.7	35.3	7.0	3.2	3.8

FC: Field Capacity, WP: Wilting Point, and AW: available water

Table 2: Chemical properties of the experimental soil before cultivation.

Soil depth (cm)	EC (dS/m)	pH (1:2.5) Susp.	Soluble anions (meq/L)				Soluble cations (meq/L)			
			Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
0 – 15	2.8	8.33	3.33	0.60	0.00	24.07	0.54	26.29	1.12	0.05
15 – 30	3.27	8.21	3.33	0.60	0.00	28.73	0.59	30.94	1.09	0.06
30 - 45	2.50	8.11	2.67	0.53	0.00	21.80	0.49	23.43	1.01	0.07
45 - 60	2.03	8.29	3.00	0.40	0.00	16.93	0.40	18.95	0.95	0.04
Mean	2.70	8.20	3.10	0.50	0.00	22.90	0.50	24.90	1.00	0.10

Soil conditioners

This field study examined two soil conditioners, compost and WTR, applied at specified rates. Samples of each soil conditioner were collected and analyzed for various physical and chemical properties as outlined by Klute (1986) and Page *et al.* (1982). The acquired data are documented in Tables 3 and 4.

Table 3: Physical and chemical properties of compost

Properties	Value
Moisture content (%)	18.00
pH (1: 5 soluble)	7.94
EC (1:10 extract), dS/m	2.85
Bulk density (g/cm^3)	0.52
Ammonium nitrogen (mg/kg)	177.00
Nitrate nitrogen(mg/kg)	47.00
Total nitrogen (%)	0.93
Organic matter (%)	21.43
C/N ratio (%)	13.36:1
Total phosphorus (P_2O_5), %	0.38
Total potassium (%)	0.18

Table 4: Physical and chemical properties of the WTR

Properties	Value
Moisture content (%)	2.95
Organic matter (%)	6.28
Bulk density (g/cm^3)	0.67
pH (1:2.5 suspension)	7.89
EC (1:5 extract), dS/m	1.43
Total N (%)	0.29
C/N ratio (%)	12.56:1
Soluble Na^+ (meq/L)	0.35
Soluble Ca^{2+} (meq/L)	6.80
Soluble Mg^{2+} (meq/L)	1.00
Soluble K^+ (meq/L)	1.50

Fertilization

Wheat *(Triticum aestivum L.)* fertilization was performed at the recommended doses of NPK fertilizers as mentioned by the Ministry of Agriculture and Land Reclamation, Egypt. Mineral fertilizers were applied at an amount of ammonium sulphate (20.6 %N) $(NH_4)_2SO_4$, which was added at a rate of 1380 kg/ha. This amount is divided into six parts before the flowering stage. Superphosphate (15% P_2O_5) was added at a rate of 480 kg/ha before planting, and potassium sulphate (48% K_2O) was added at a rate of 250 kg/ha. This quantity is partitioned into two segments: prior to and during flowering. In addition, micronutrients (zinc, manganese, and iron) in a ratio of (1:1:1.5) were added at a rate of 0.5 grams per liter, and each hectare requires 476.19 liters of spraying.

Due to varying water regimes, the plant matured at different times. As a result, the harvest was completed after maturity for various water regimes. Harvest dates were 8 April 2022 (142 days), 31 March 2022 (134 days), and 31 March 2022 (134 days), representing 100%, 80%, and 60% of volumetric field capacity, respectively.

Additionally, for peanuts (Arachis hypogaea), fertilization and all agronomic practices were performed as recommended by the Ministry of Agriculture and Land Reclamation. Mineral fertilizers were applied as superphosphate (15% P_2O_5) at a rate of 715 kg/ha before planting, potassium sulphate (48% K_2O) at a rate of 120 kg/ha, and an amount of nitrate at a rate of 33.5%. The addition of both N and K is divided into two parts: before and during flowering. The micronutrients (zinc, manganese, and iron) were applied in a 1:1:1.5 ratio at a rate of 0.5 grams per liter, with a hectare requiring 476.19 liters of spraying. The harvest took place 127 days after planting, on October 10, 2023.

Soil moisture content detection using Neutron Scattering Techniques

The gravimetric method was employed to obtain precise measurements of soil moisture contents in the surface layers (0-15 cm). The neutron moisture meter (50 MCi, Am 241 and B9), according to IAEA (2003), was used to estimate the soil moisture contents at deeper depths (30 and 60 cm). The neutron moisture meter is a well-established instrument for non-destructive measurement of soil water content, particularly at deeper soil depths. In this study, a neutron moisture meter with a radioactive source strength of 50 millicuries (MCi), utilizing Americium-241 (Am-241) and Beryllium-9 (Be-9), was employed to estimate soil moisture at depths of 30 cm and 60 cm. The device operates on the principle of neutron scattering, where fast neutrons emitted from the source are moderated primarily by hydrogen atoms, an abundant component of water molecules, within the soil matrix. The resulting thermal neutrons are then counted to estimate the volumetric water content.

The calibration and safe operation of such instruments are crucial due to the involvement of radioactive materials. The International Atomic Energy Agency (IAEA, 2003) provides comprehensive guidance on the use, calibration, and safety protocols associated with neutron moisture meters in soil physics and hydrology research.

This method is particularly effective for monitoring changes in soil water content over time, especially in field studies requiring repeated measurements at fixed depths without disturbing the soil structure.

RESULTS AND DISCUSSION

Effect of soil conditioners and irrigation level on SMC before and after irrigation

Table 5 illustrates the effect of different irrigation levels (100, 80, and 60% of FC) in the absence and presence of soil conditioners (compost and WTR) on the average values of SMC at 15, 30, and 60 cm during wheat cultivation in sandy soil. The amount of applied irrigation water was calculated based on 90% irrigation efficiency. The values are measured both before irrigation (BI) and one day before, allowing time to calculate SMC for the surface layer, and after irrigation (AI), one day after, to allow for water redistribution, using a neutron moisture meter.

Table 5: Soil moisture content along the soil profile at different treatments on the wheat plant.

Soil Conditioners		Control		Compost		WTR	
Irrigation level % FC	**Soil depth (cm)**	**SMC (%) BI**	**SMC (%) AI**	**SMC (%) BI**	**SMC (%) AI**	**SMC (%) BI**	**SMC (%) AI**
100%	15	4.2	11.0	6.0	14.6	6.1	14.3
	30	7.0	10.8	9.0	10.0	8.0	9.8
	60	6.8	8.4	11.7	7.8	6.2	7.6
	Mean	**6.0**	**10.0**	**8.9**	**10.8**	**6.8**	**10.6**
80%	15	3.0	11.0	7.4	13.8	6.0	12.6
	30	6.4	7.0	8.0	8.4	6.7	6
	60	6.1	8.0	8.1	6.2	5.0	7.7
	Mean	**5.17**	**8.7**	**7.8**	**9.5**	**5.9**	**8.9**
60%	15	4.0	8.0	6.2	12.0	5.9	7.8
	30	5.0	6.0	6.8	5.4	5.7	7.0
	60	4.9	5.0	7.5	4.3	4.0	5.0
	Mean	**4.6**	**6.3**	**6.8**	**7.2**	**5.2**	**6.6**

SMC: Soil Moisture Content, BI: Before Irrigation, AI: After Irrigation, WTR: Water Treatment Residues.

At 100% FC, the soil treated with compost showed the highest water content after irrigation, with a recorded average value of SMC of 10.8%. The SMC with the three irrigation levels, the soil amended with compost, was higher than with WTR at 80% FC, followed by 60% FC. This suggests that compost notably enhances water retention under full irrigation, likely due to its ability to improve soil structure and organic matter content. In addition to BI, plots with compost retained more moisture content than the other treatments. This trend highlights the effectiveness of compost in conserving moisture, even under mild water stress (Zhao *et al.*, 2013).

At the most stressed condition (60% FC), all treatments of soil conditioners showed reduced water content, where WTR performed better than compost after irrigation. This suggests that WTR may be particularly effective in enhancing short-term moisture retention during irrigation events in drier conditions. Also, WTR's fine particles and high metal oxides may reduce infiltration and improve FC in sandy soils (Makris *et al.*, 2004).

Table 5 clearly shows that, across all irrigation levels, the control treatment consistently exhibited the lowest water content in both the BI and AI stages, highlighting the limitations of unamended sandy soil in retaining water. In this regard, Omran *et al.* (2023) showed the relationships between SMC and soil water potential for different soil textures, including coarse-textured soils such as sand. The results showed very low water availability in such soil. These findings align with previous studies indicating that organic amendments such as compost can improve soil porosity and water holding capacity (Abdelraouf *et al.,* 2013), while industrial byproducts like WTR can improve physical properties of sandy soils, reduce leaching, and enhance water availability (Makris *et al.,* 2004; Ippolito *et al.,* 2011).

Data in Table 6 illustrate the effect of different irrigation levels (100, 80, and 60% of FC) in the absence and presence of soil conditioners (compost and WTR) on SMC during Peanut cultivation in sandy soil. The amount of applied irrigation water was calculated to be consistent with 90% irrigation efficiency. The values are measured at both BI and AI using the neutron moisture meter.

Table 6: Soil moisture content along the soil profile at different treatments on the peanut plant.

Soil Conditioners		**Control**		**Compost**		**WTR**	
Irrigation level % FC	**Soil depth (cm)**	**SMC (%) BI**	**SMC (%) AI**	**SMC (%) BI**	**SMC (%) AI**	**SMC (%) BI**	**SMC (%) AI**
100%	**15**	2.6	11.0	4.0	14.0	2.8	12.8
	30	4.9	9.8	6.0	11.0	5.4	10.8
	60	5.5	9.0	8.0	9.5	5.3	6.9
	Mean	**4.3**	**9.9**	**6.0**	**11.5**	**4.5**	**10.2**
80%	**15**	2.4	9.8	2.8	12.6	2.3	10.4
	30	5.7	8.8	7.6	11.0	6.0	11.4
	60	4.6	7.8	5.8	8.0	4.50	5.5
	Mean	**4.2**	**8.8**	**5.4**	**10.5**	**4.3**	**9.1**
60%	**15**	2.3	9.0	3.0	10.2	2.4	9.2
	30	4.8	8.0	7.0	9.5	6.1	8.5
	60	4.4	6.0	4.6	6.7	3.6	6.0
	Mean	**3.8**	**7.6**	**4.9**	**8.8**	**4.0**	**7.9**

SMC: Soil Moisture Content, BI: Before Irrigation, AI: After Irrigation, WTR: Water Treatment Residues.

At 100% FC, the mean values of SMC at AI were highest in the soil treated by compost treatment (11.5%), followed by WTR (10.2%), and then the control (9.9%). Similarly, before irrigation, compost maintained the highest soil moisture (6%), compared to WTR (4.5%) and control (4.3%). This confirms that compost significantly improves soil water retention under full irrigation, consistent with findings that organic matter enhances soil structure and moisture retention (Abdelraouf *et al.,* 2013).

The trend remained consistent at 80% FC sandy soil treated, with compost exhibiting the highest AI value (10.5%), followed by that found in treated with WTR (9.1%) and the control

(8.8%). Furthermore, amended soils exhibited elevated BI values, with compost demonstrating an advantage. This illustrates that compost can retain moisture even in the presence of mild water stress.

At 60% FC, the benefits of conditioners became even more pronounced. Although the overall water content decreased, the compost exhibited a slightly higher AI (8.8%) compared to the WTR (7.9%) and the control (7.6%). This suggests that compost may perform better under deficit irrigation due to its fine particles and metal oxides, which reduce infiltration and promote short-term water retention (Makris *et al.,* 2004). The BI values followed the same trend but at lower levels, with compost and WTR both outperforming the control.

Within all treatments of soil conditioners and irrigation levels, control plots consistently recorded the lowest water content, highlighting the poor water-holding capacity of untreated sandy soils. These findings align with previous studies, which have shown that soil amendments can significantly enhance water use efficiency and mitigate the effects of water stress (Ippolito *et al.,* 2011). Therefore, FC represents the maximum amount of soil water that can be retained after gravitational drainage, providing a water reservoir for plant uptake (Irmak, 2015). When water is applied up to this level, the soil is optimally recharged without causing leaching or deep percolation losses. Furthermore, irrigation scheduling manuals emphasize that applying more than ETc may be necessary when soil water is below FC and must be refilled to ensure healthy crop development (Shock *et al.,* 2007).

Effect of soil conditioners and irrigation level on wheat productivity

Table 7 indicates the individual and combined effects of different irrigation levels (100, 80, and 60% FC) and soil conditioners (compost, WTR, and control) on wheat growth, including plant height (cm) and yield (kg/hectare) under sandy soil conditions.

Table 7. Effect of irrigation level and soil conditioners on wheat plant production

Irrigation level, % FC	Conditioners	Plant height (cm)	Yield (kg/ha)	Statistical analysis	
100	Compost	94.6	5170.6	Plant height	Irrigation
	WTR	94.2	5063.2	P= 0.206	P= 0.000*
	Control	90.4	4302.3	ns	LSD= 678
80	Compost	93.8	4554.9	Conditioners	Conditioners
	WTR	93.6	3964.6	P= 0.399	P= 0.001*
	Control	90.3	3856.7	ns	LSD= 546
60	Compost	90.3	3886.5	Interaction	Interaction
	WTR	88.5	3194.1	P= 0.969	P= 0.417
	Control	88.5	3166.7	ns	ns

P-value (significance level, the significance value is ≤ 0.05); LSD: Least Significant Difference.

Water availability plays a critical role in wheat production, particularly in sandy soils characterized by limited water-holding capacity (Haddadin *et al.,* 2020). The data indicate that the 100% FC irrigation level resulted in the highest plant height and grain yield across all treatments. Under this condition, compost-amended soil produced the tallest plants (94.6 cm) and the highest yield (5170.6 kg/ha), followed by WTR (water treatment residue) at 94.2 cm and 5063.2 kg/ha, and the control treatment at 90.4 cm and 4302.3 kg/ha. These findings are consistent with those of Omran (2013), who reported that deficit irrigation strategies can help conserve water in Medicago sativa grown in sandy soils of arid regions. A positive linear correlation was observed between crop yield and the amount of available soil water.

The significant effect of irrigation on yield is supported by a P-value of 0.000 and an LSD of 678, emphasizing that adequate water supply is essential for optimal wheat production. This aligns with previous findings that wheat is susceptible to water stress, particularly during critical growth stages (Sadras and Lawson, 2011).

When irrigation was reduced to 80% FC, a decline in both plant height and yield was observed. Nevertheless, compost-amended plots still achieved relatively high yields (4554.9 kg/ha) and plant height (93.8 cm), indicating that compost mitigated moderate water stress. In contrast, WTR (3964.6 kg/ha) and the control (3856.7 kg/ha) experienced more substantial reductions, highlighting the role of organic amendments in maintaining soil moisture and supporting plant growth under stress conditions (Gopinath *et al.,* 2008; Lamlom *et al.,* 2025).

At 60% FC, all treatments exhibited a significant reduction in both yield and plant height. The compost treatment maintained a height of 90.3 cm and yield of 3886.5 kg/ha, while WTR (88.5 cm, 3194.1 kg/ha) and the control (88.5 cm, 3166.7 kg/ha) showed the lowest performance. The interaction between irrigation levels and soil conditioners was not statistically significant (P = 0.417, ns), suggesting that irrigation has a more substantial influence on yield than conditioners alone under severe drought stress.

Soil conditioners significantly affected wheat yield (P = 0.001), although their influence on plant height was not significant (P = 0.399). Compost consistently outperformed both WTR and the control, likely due to its ability to improve soil structure, enhance nutrient availability, and increase water retention in sandy soils (Koishi *et al.,* 2020).

Although WTR improved the yield relative to the control, it was less effective than compost. This may be attributed to compost's higher organic matter content and its more sustained benefits to soil physical and biological properties (Ibrahim *et al.,* 2015). These findings are supported by previous research indicating that compost applications can enhance wheat growth in sandy soils by improving moisture retention and promoting microbial activity (Zhang *et al.,* 2018).

Effect of soil conditioners and irrigation level on peanut production

Table (8) illustrates the effects of varying irrigation levels (100, 80and 60% of FC) and soil conditioners (compost and WTR) on peanut yield (kg/ha). Statistical analysis displays the importance of irrigation, conditioners, and their interaction. The experiment conducted in sandy soil underscores the importance of adequate water and soil management practices in enhancing crop productivity. The interaction between irrigation levels and conditioners was insignificant (P = 0.417, ns). This suggests that water availability is the primary limiting factor for wheat growth under severe drought conditions, even when soil conditioners are used (Kumar *et al.,* 2022).

Table 8. Effect of irrigation amount and soil conditioners (Compost and WTR) on peanut production.

Irrigation levels % FC	Conditioners	Seeds (Kg/ha)	Statistical analysis
100	Compost	5716.7	Irrigation
	WTR	5100	P= 0.000*
	Control	4266.7	LSD= 678
80	Compost	6083.3	Conditioners
	WTR	4426.7	P= 0.000*
	Control	3733.3	LSD= 546
60	Compost	4063.3	Interaction
	WTR	3276.7	P= 0.153

	Control	3176.7	ns

P-value (significance level, the significance value is ≤ 0.05); LSD: Least Significant Difference, ns: Not significant.

Table 8 shows that the highest peanut yield (seeds) was recorded under 100% FC irrigation levels, with a compost application value of 5716.7 kg/ha, followed by the WTR treatment (5100.0 kg/ha) and the control (4266.7 kg/ha). The significant P-value (0.000) and LSD = 678 indicate that irrigation is critical to peanut productivity. The results show a significant effect of irrigation (P = 0.000), with LSD = 678, implying that higher irrigation levels increase yield.

The results align with research by Ogbodo (2011), who found that compost application in sandy soils significantly improves water retention, leading to increased crop yields under limited irrigation.

Reducing the irrigation level to 80% FC resulted in a yield decline in the WTR and control treatments. However, notably, the compost treatment yielded even higher (6083.3 kg/ha) than at 100% FC, possibly due to compost's role in enhancing soil moisture retention and nutrient availability, all of which are crucial for plant growth, especially in sandy soils (Diacono and Montemurro, 2015; Somasundaram *et al.*, 2020). In this regard, Ladányi *et al.* (2021) stated that water availability is a crucial factor in crop production, especially in sandy soils characterized by low water-holding capacity and high infiltration rates.

At 60% FC, all treatments experienced a significant decrease in yield, with compost being 4063.3 kg/ha, followed by WTR (3276.7 kg/ha) and control (3176.7 kg/ha). The P-value (0.000), with LSD = 546, indicates a significant effect of conditioners, implying that compost application is critical for maintaining high peanut yield even under moderate water stress. However, both WTR (4,426.7 kg/ha) and the control (3,733.3 kg/ha) showed significant reductions, highlighting the importance of organic amendments in mitigating moderate water stress. This suggests that, while WTR may improve soil structure and water retention, it is less effective than compost, possibly due to lower organic matter content (Singh *et al.*, 2019). Statistical analysis reveals that the interaction effect of irrigation and conditioners was not significant (p = 0.153), implying that their combined effect was ineffective. This finding aligns with studies indicating that under extreme drought conditions, crop productivity in sandy soils becomes more dependent on water availability than on soil conditioners alone (Kumar *et al.*, 2022).

Consequently, irrigation has a significant impact on peanut yield, with higher irrigation levels yielding better productivity. Soil conditioners significantly improve yield, with compost being the most effective treatment across all irrigation levels. At moderate irrigation stress (80% FC), compost helps maintain high yield, suggesting its potential use in water-saving agricultural practices. Under severe water stress (60% FC), yields decline significantly. The study emphasizes the significance of compost as a sustainable soil amendment for improving peanut production, particularly under varying irrigation conditions. Studies by Liu, Y., *et al.* (2025) confirm that peanut yield decreases significantly under water-deficit conditions, particularly in sandy soils with rapid moisture depletion, limiting root water uptake.

Conclusion

In conclusion, the obtained data reveal that soil conditioners are crucial for improving water maintenance in low-water-holding sandy soil, particularly in arid regions. Irrigation significantly affects wheat and peanut yields, with 100% FC producing the highest yield. Compost is the most effective soil amendment for both crops, significantly improving yield across all irrigation levels. At 80% FC, compost maintains a high yield, making it an ideal practice for water-saving strategies in the sandy soil. Under severe drought stress (60% FC), wheat and peanut yields decline drastically, with no significant interaction between irrigation and conditioners. These findings underscore the importance of integrated water and soil management strategies for sustainable wheat and peanut production in sandy soils. The study recommends applying compost and optimized irrigation scheduling to enhance wheat productivity while conserving water resources in sandy soils.

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استخدام تقنية التشتت النيترونى في تقييم تأثير محسناتا لتربة على المحتوى الرطوبى وإنتاجية التربة الرملية

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الملخص العربى

تتناول هذه الدراسة تأثير الكمبوست ومخلفات معالجة المياه على محتوى الرطوبة وإنتاجية التربة الرملية مع التركيز على محاصيل القمح والفول السوداني. تواجه التربة الرملية في مصر التي تتميز بضعف قدرتها على الاحتفاظ بالماء ونقص العناصر الغذائية، تحديات كبيرة في الزراعة المستدامة. أُجريت التجربة في المزرعة التجريبية الخاصة بقسم بحوث الأراضي والمياه –مركز البحوث النووية – هيئة الطاقة الذرية– جمهورية مصر العربية لتقييم تأثير ثلاث مستويات من الري١٠٠ و٨٠ و٦٠% من السعة الحقلية واثنين من مصلحات التربة (الكمبوست ومخلفات معالجة المياه) تم قياس محتوى الرطوبة في التربة باستخدام جهاز قياس الرطوبة النيوترونى على أعماق مختلفة. أظهرت النتائج أن الكمبوست حسن بشكل كبير من قدرة التربة على الاحتفاظ بالرطوبة عبر جميع مستويات الري خاصة تحت الري الكامل ١٠٠% من السعة الحقلية بينما أظهرت مخلفات معالجة المياه أيضًا فوائد في احتباس المياه، خصوصًا تحت الري المحدود. تم ملاحظة أعلى العوائد لمحاصيل القمح والفول السوداني في التربة المضاف إليها الكمبوست، حيث تفوق الكمبوست على مخلفات معالجة المياه من حيث إنتاجية المحاصيل. كما انخفضت غلة القمح والفول السوداني تحت الري المحدود مع دعم السماد العضوي لزيادة العوائد مقارنةً بالكنترول. تسلط الدراسة الضوء على فعالية السماد العضوي كإضافة مستدامة للتربة لتعزيز الاحتفاظ بالرطوبة وزيادة إنتاجية المحاصيل في التربة الرملية خاصة في ظل استراتيجيات الري الموفرة للمياه. تشير النتائج إلى أن دمج المواد العضوية وإدارة الري الفعالة يمكن أن تحسن بشكل كبير النتائج الزراعية في المناطق الجافة.