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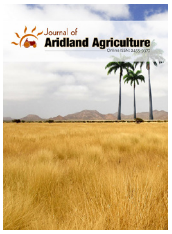

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The impact of compost and expanded perlite on soil physical properties and water productivity under different irrigation practices

Saadi Sattar Shahadha[1]*, Mohammed Al-Dharob[1], Mohammed Al-Jubouri[2], Riyadh Salih[3]

[1]College of Energy and Environmental Sciences, Al-Karkh University of Science, Baghdad 10081, Iraq, [2]College of Sciences, Al-Karkh University of Science, Baghdad 10080, Iraq, [3]Ministry of Water Resources, Baghdad 10085, Iraq

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***Corresponding author:**
Saadi Sattar Shahadha
E-mail: saadishahadha@kus.edu.iq

ABSTRACT

Finding an appropriate field management strategy for improving crop and water production becomes an imperious necessity because of the irrigation water deficiency in most of the agricultural fields in Iraq. Studying the response of soil properties to the applied soil amendments represents one of the critical parameters in agricultural field management for improving crop production and water use efficiency of Iraqi strategic crops. The effect of soil amendments (compost = 7.5 t/ha and perlite/0.1% Polyvinyl alcohol = 0.25 t/ha) on the water use efficiency and crop production under three levels of water depletion (30, 50, and 70%) of the available soil water was examined for wheat and barley crops. The study was applied under the sprinkler irrigation system. The experimental design was RCBD within 6 treatments and 3 replications for each wheat and barley. The results show that the soil amendments of expanded perlite and compost exhibit an improvement in the soil properties of soil bulk density and soil water content. Soil amendments, especially, the expanded perlite improved the crop yield and water use efficiency under all irrigation levels. The effect of expanded perlite shows the maximum effect on barley production under the 50% irrigation level with 3500 kg/ha. The irrigation level of 70% could be a worth-able management strategy if it is associated with the soil amendments of compost and expanded perlite. As a result, the effectiveness of expanded perlite increased with the increase in the drought of Iraqi soil.

KEYWORDS: Compost, Expanded perlite, Soil properties, Water use efficiency, Wheat and Barley

INTRODUCTION

Recently, the demand for freshwater has increased dramatically due to the increase in population growth and thus the increase in economic and agricultural activity (Hoekstra & Chapagain, 2011). Iraq consumes 85% of its renewable freshwater resources in the agricultural sector (Al-Ansari, 2013). Water is the main factor that determines the quantity and quality of crop productivity, so it has become necessary to develop more efficient resources and methods to produce "more crop per drop"; In other words, the least amount of water required for photosynthesis to occur, and thus crop production (Hoekstra & Mekonnen, 2012; Zahra *et al.*, 2021).

Sustainability is the main focus of most of the authorities and research nowadays (Anaz *et al.*, 2023). Improving the sustainability and productivity of the soil becomes indispensable for increasing crop production and water use efficiency (Adugna, 2016; Sayara *et al.*, 2020; Adhab & Alkuwaiti 2022; Oyetunji *et al.*, 2022). Organic matter such as compost plays an important role in the soil's physical, chemical, and biological properties. Which indeed, makes the greatest contribution to soil sustainability and productivity. It provides nutrients and linkage materials to the soil, which improves its structure, bulk density, and aeration and as a result, it improves the water holding capacity and crop water use efficiency (Edwards & Hailu, 2011; Duong, 2013; Scotti *et al.*, 2015; Bhunia *et al.*, 2021; Shahadha & Wendroth, 2022).

Many researchers explained the effect of perlite on the total soil characteristics because of its high porosity, which could be with a mean value of 88.09% out of which 27.9% belong to water porosity. In addition, perlite has a very high air capacity with a mean value of 60.2%. Hence, expended perlite has an appropriate retention capacity of water and air whose application can act as a betterment for the increase of soil water capacity (Markoska *et al.*, 2018a; Lim *et al.*, 2021). Thus, perlite can influence plants directly in their roots when they need a stable supply of water and air (Papadopoulos *et al.*, 2008; Pająk *et al.*, 2022). The physical and chemical properties of perlite make it a very useful medium for plant growth. It is considered a feature of enjoying a balance between the strength of soil water retention on the one hand and soil aeration on the other hand (Morrison *et al.*, 1960). Expanded perlite can reduce the compressive strength to much lower values. In addition, due to its porous structure, it improves the physical properties of the soil, especially, air and water capacity, and therefore, it improves crop production (Ennis, 2011; Jamei *et al.*, 2011; Mercan, 2021).

Polyvinyl alcohol (PVA) is an environment-friendly, water-soluble, and degradable polymer. PVA is also called a soil stabilizer (Liu *et al.*, 2017). Adding PVA to the soil leads to a decrease in the dispersion rate, while it leads to an increase in the overall stability and water permeability. In addition, when the concentration of PVA rises, the value of pH rises, and electrical conductivity can decrease (Khan *et al.*, 2021).

Soil water holding capacity is an important hydraulic property of the soil (Shahadha *et al.*, 2019; Shahadha *et al.*, 2023). Improving soil water holding capacity is of great significance for heavy soils. This is about the fact that the soil is not holding water to supply the plant with enough water when it is dry regarding its field capacity (Masood & Shahadha, 2021; Shahadha *et al.*, 2021). The water of the soil depends on the soil's physical properties, which means enhancing the soil's physical properties can supply sufficient water to the plant during the dry seasons, and thus improve water use efficiency. The objective of this study is to observe the influence of soil amendments (compost and expanded perlite with PVA) and their interaction with different irrigation levels on soil properties, crop yield, and water use efficiency for wheat and barley crops.

MATERIALS AND METHODS

The study was conducted at Al-Raieed Research Station, which is a specialized research station affiliated with the Environmental Studies Department/National Center for Water Resources Management. The station is located 20 km west of Baghdad, at longitude 44° 24' North, latitude 22° 33' East, and at an altitude of 34 meters above sea level. The soil of the study site in the station is classified as Typic Torrifluvents according to the 2010 Soil Taxonomy, USDA. The field study took place in a 0.1 ha. The soil properties were determined by opening a soil profile in the study site (Table 1 & 2). The groundwater level was between 200 - 220 cm during the crop growing season.

The wheat (Bhooth22) and barley (IPa 99) were planted on 18 November 2020 and harvested on 5 May 2021. Crops were grown in plots of 5 m by 5 m. Experimental treatments included two groups; The first group was the soil amendments which were (1) compost (7.5 t/ha) which is the natural aerobic decomposition of the wheat straw; (2) expended perlite (0.25 t/ha); this treatment also included applying dissolved 1g of PVA/10 liter of distilled water to the soil surface. The soil amendment treatments were applied to the soil two days before the planting date and mixed at a soil depth of 15 cm.

The second treatment group includes three irrigation levels. The irrigation levels were to apply the required water at three levels of irrigation water depletion, which were 30, 50, and 70% of available soil water using a sprinkler irrigation system. The total water amount applied during the crop growing season was 541, 520, and 504 mm/season for the irrigation level of 30, 50, and 70%, respectively. The total irrigation scheduled events during the crop growing season were 16, 12, and 9 for the 30, 50, and 70% irrigation levels, respectively. The statistical design of the experimental treatments was a randomized complete block design with three replications.

Chemical fertilization was split across two applications regarding the local fertilization cultural practice. The first application occurred one week before the planting date with diammonium phosphate (DAP); It includes 18% nitrogen and 46% Phosphorus. The second fertilizer application was applied two months after planting with urea 46% N.

The soil water content and soil bulk density were measured four times for a depth of 0-20 cm during the wheat and barley growing season. Soil electrical conductivity was measured during the crop growing season as well. In addition, the crop yield was measured at the end of the growing season for both crops. As well as the water use efficiency was calculated for both crops.

The study results were statistically analyzed using the GenStat program. The LSD at 0.05 was used to determine the differences among all study treatments. The LSD values were included in each result figure.

RESULTS AND DISCUSSIONS

As already known, soil characteristics can be improved by adding soil amendments, in this study, the possibility of improving field irrigation management through improving the soil properties by adding compost (produced from wheat straw) and extended perlite/PVA to the soil. The focus of the results will be on the soil water content, soil bulk density, soil electrical conductivity, crop yield, and water use efficiency to investigate the capability of achieving an appropriate field irrigation management practice to improve crop yield and water use efficiency for wheat and

Table 1: The chemical properties of the soil before applying the experimental treatments

Depth (cm)	ECe dS/m	pH	Ca^{+2} meq/L	Mg^{+2} meq/L	Na^{+}meq/L	K^{+}meq/L	Cl^{-} meq/L	SO_4^{-}meq/L	CO_3^{-} meq/L	HCO_3^{-} meq/L	NO_3^{-}PPm
0-25	11.68	7.4	198	116	1679	36	3088	3100	0	122	22
25-50	11.04	7.0	170	100	2093	26	830	3100	0	170	25
50-75	6.68	7.2	136	79	1665	28.5	1150	1998	0	146	33
75-100	2.6	7.9	200	86	400	31	873	3000	0	280	39

barley in Iraqi soil; as it is now known that wheat and barley production is declining for many reasons in Iraq (Al-Ani *et al.*, 2011; Adhab *et al.*, 2021; Khalaf *et al.*, 2023).

Soil water content was affected by the compost and perlite treatments at all water irrigation levels (Figure 1). Perlite with PVA treatment showed the highest soil water content compared to the other treatments for all irrigation levels. While the control treatments yielded the lowest soil water content. There was a significant difference in soil water content among all amendment treatments under all irrigation levels. Expanded perlite with PVA and compost applications improved the soil capability of holding more water due to their physical properties. The soil water content typically depends on the soil porosity, which is affected by the percentage of compost and perlite content in the soil. These results are comparable to the findings of Markoska *et al.* (2018b) and Riley (2002).

Compost application beneficial affects the soil bulk density by improving the soil structure, which is associated with an increase in soil porosity due to the interactions between organic matter and minerals fractions. Figure 2 shows the impact of amendment treatments on soil bulk density under different irrigation levels for wheat and barley. Compost and perlite amendments influenced the soil bulk density under both crops. The soil bulk density was significantly affected by both amendment treatments compared to the control treatment under all irrigation levels. The impact of compost on soil bulk density was higher than the perlite treatment, especially, under the barley crop. The influence of perlite treatment on soil bulk density was higher than the control treatment but less than the impact of compost treatment. On the other hand, the irrigation levels do not significantly affect the soil bulk density.

Figure 3 presents the effect of irrigation levels and soil amendments on the crop yield of wheat and barley. As shown in Figure 3, the wheat crop did not reach the harvesting stage due to damage that happened to the treatments under the irrigation level of 70% during the growing season. The irrigation level of 30% produced a higher yield than the other irrigation

Table 2: Physical properties of field soil before applying the experimental treatments

Soil depth	Soil Particles g/kg			Soil texture	Soil bulk density	Soil water content at different pressure			Available soil water
(cm)	Clay	Silt	Sand		g/cm³	0 KPa	33 KPa	1500 KPa	
0-25	350	530	120	Sic	1.39	51.39	31.99	14.72	17.27
25-50	370	520	110	Sic	1.42	52.86	31.56	15.1	16.46
50-75	380	520	100	Sicl	1.46	53.22	32.26	15.36	16.89
100-75	370	530	100	Sicl	1.48	53.98	32.12	15.75	16.37

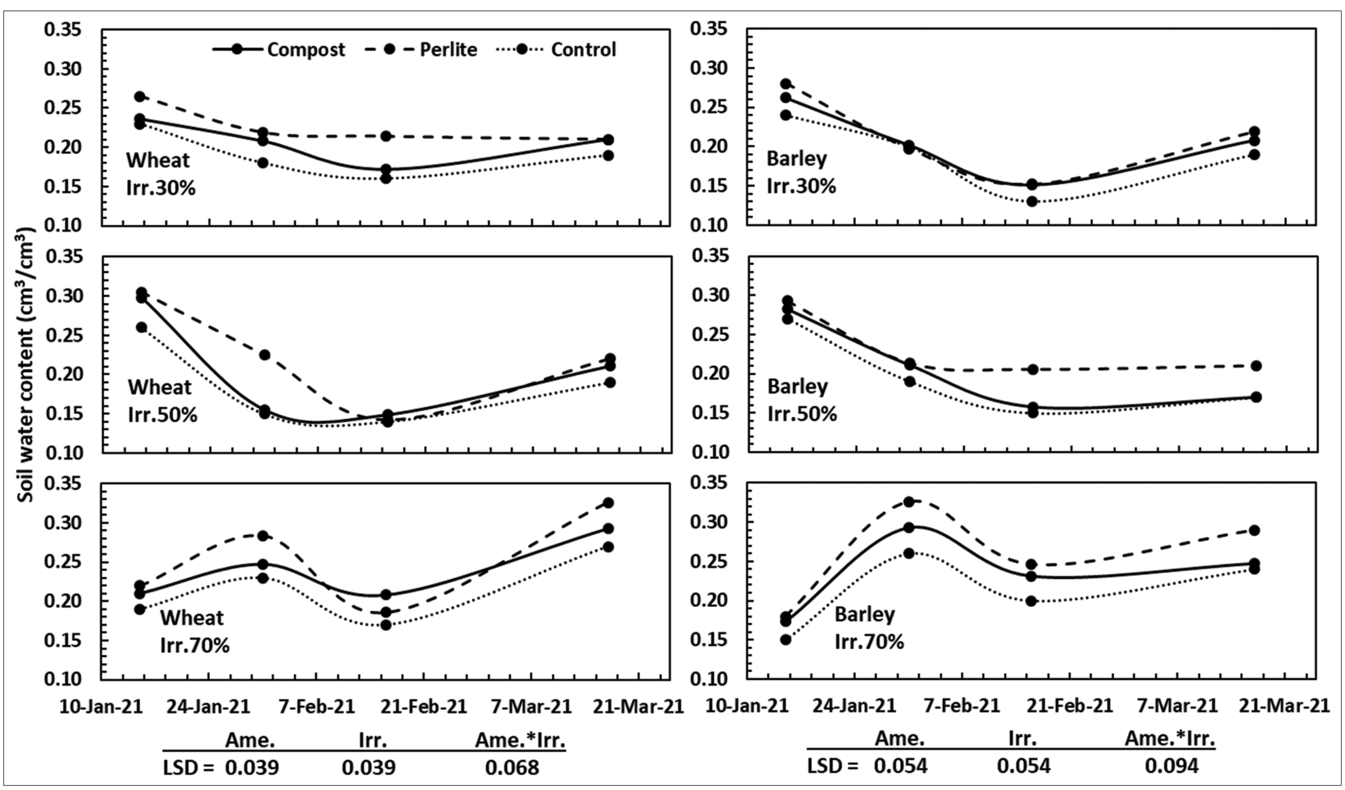

Figure 1: Measured soil water content at a depth of 0-20 cm for the compost and perlite treatments compared to the control treatment under the impact of three levels of irrigation water depletion, which are 30, 50, and 70% of the available water

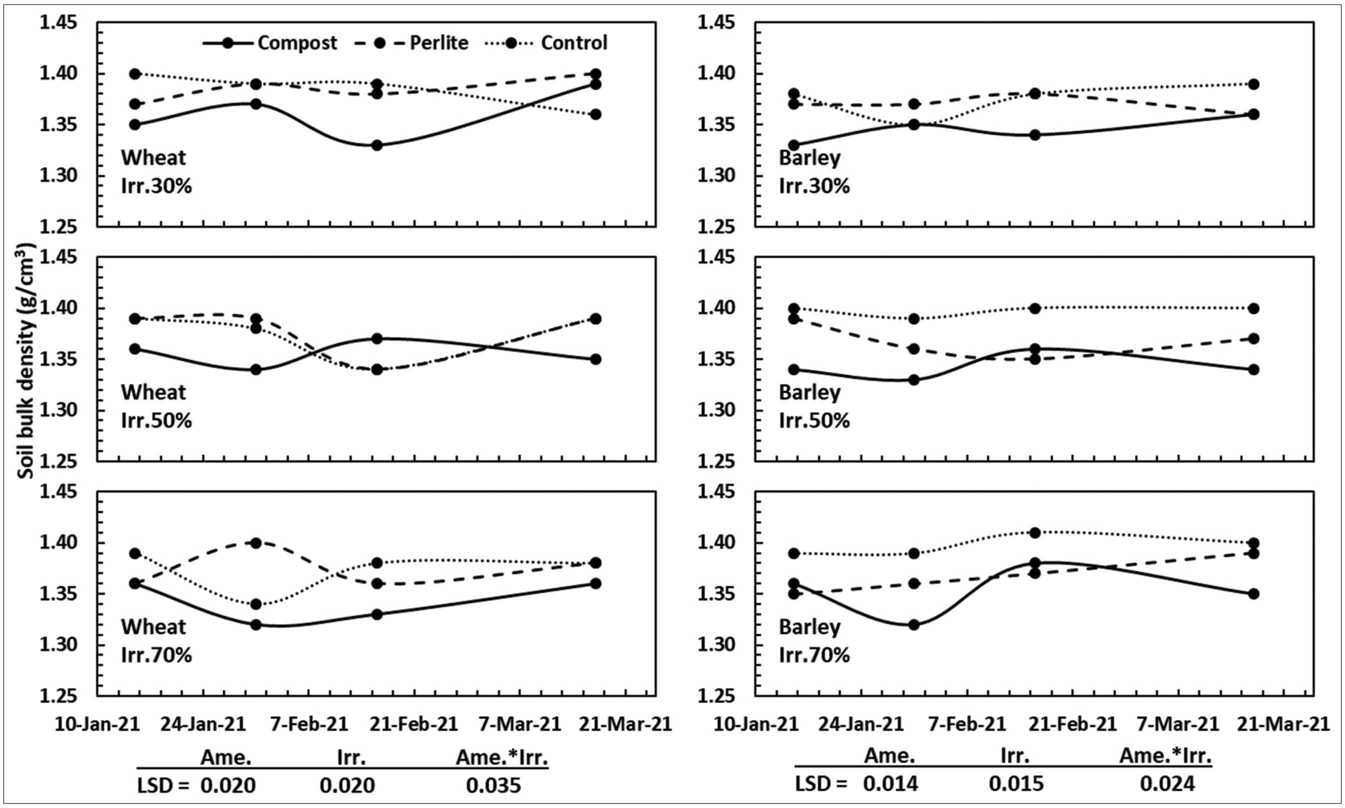

Figure 2: Measured soil bulk density at depth 0-20 cm for the compost and perlite treatments compared to the control treatment under the impact of three levels of irrigation water depletion, which are 30, 50, and 70% of the available water

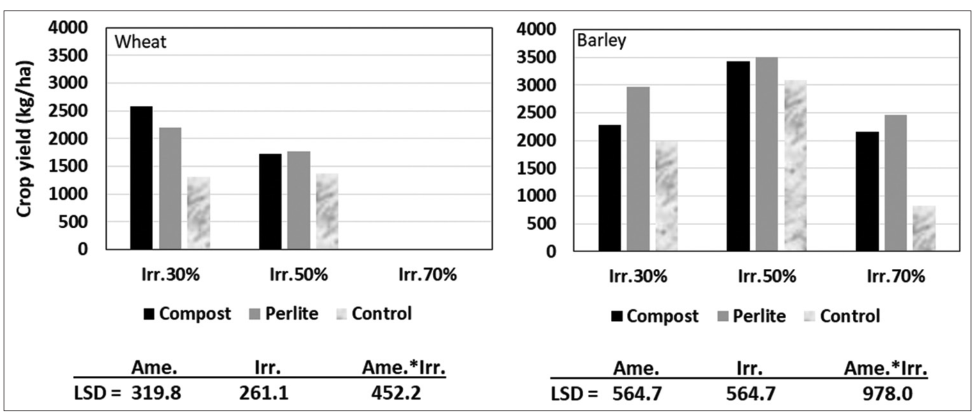

Figure 3: Wheat and barley yield for the compost and perlite treatments compared to the control treatment under the impact of three levels of irrigation water depletion, which are 30, 50, and 70% of the available water

levels for the wheat crop for all soil amendments treatments (compost and perlite). However, the barley crop gave the highest yield under the impact of Irr. 50% for all soil amendment treatments. Compost treatment significantly yielded higher wheat production than the perlite and control treatments under the impact of Irr. 30%. However, under the impact of Irr. 50%, both amendment treatments showed almost similar yields, but their production still significantly differed compared to the control treatment.

The barley crop showed better production than the wheat crop almost for all treatments (Figure 3). The best yield was presented under the influence of Irr. 50% and perlite which reached 3500 kg/ha. In general, the Irr. 50% presented the highest yield than the other irrigation levels. While under the impact of Irr. 70%, the perlite treatments gave the highest yield than the other treatments. The reason behind these results is the capability of compost and perlite to hold water in the soil. The barley crop pointed out very surprising results under the Irr. 70%; Where the result of Irr. 30% and 70% were very close which means that applying compost and perlite with PVA to the soil could improve the water use efficiency due to their capability to improve the soil water holding capacity (Sayara *et al.*, 2020; Pająk *et al.*, 2022). On the other hand, two important reasons could improve plant production. First, compost application improves soil fertility by improving the availability of plant nutrients and thus plant development and production. Second, perlite can capture (adsorb) harmful elements, especially, the heavy metals in the soil which indeed can enhance plant development and productivity (Baize, 2009; Zahedifar *et al.*, 2017); in addition, Perlite is slow-releasing nutrients such as nitrogen and preventing nutrients loss from the soil to the underground water (Markoska & Spalevic, 2020). The production of barley under the impact of perlite was significantly different compared to the control treatment under the irrigation level of 30% and 70%, but it was not significant under the irrigation level of 50%. The barley production under the compost treatment was significantly different compared to the control just under the irrigation level of 70%. That means the expanded perlite produced better results in barley production than the compost treatment.

The soil electrical conductivity (EC) is affected by the soil amendment treatments (Figure 4). On the contrary, the difference in compost treatment was not significant. Under the wheat crop, both amendments presented very close soil EC results for all irrigation levels with no significant differences. However, under the barley crop, there was a significant difference between the soil EC of perlite and compost for irrigation levels of 50% and 70%. Moreover, the expanded perlite yielded very high soil EC compared with other treatments.

The reason behind these results could be due to the effect of expanded perlite with PVA that significantly increases the soil EC compared with the control treatment under all irrigation levels, especially for 70% level, and for both crops. This means that all the PVA was dissolved in the soil then the slat ratio increased and lead to an increase in the EC, in addition to perlite's ability that adsorb the soil elements such as Ca^{2+} and Na^{+} which indeed increases the soil EC. These results are in agreement with the findings of Ghazvini *et al.* (2007) and Khan *et al.* (2021). In addition, the increase in EC happened due to the perlite slowly releasing nutrients such as nitrogen and preventing nutrient loss from the soil and helping improve many pathways inside plants that depend on these nutrients (Adhab *et al.*, 2018; Adhab, 2021), which means adding perlite to the soil could improve crop growth and production.

Figure 5 shows the water use efficiency for wheat and barley under different soil amendment treatments and irrigation levels. The crop water use efficiency values of the wheat crop under the impact of Irr. 0.30% were about 0.7, 0.6, and 0.35 kg/m^3 for the compost, perlite, and control treatments, respectively. The low values of water use efficiency of the wheat crop were

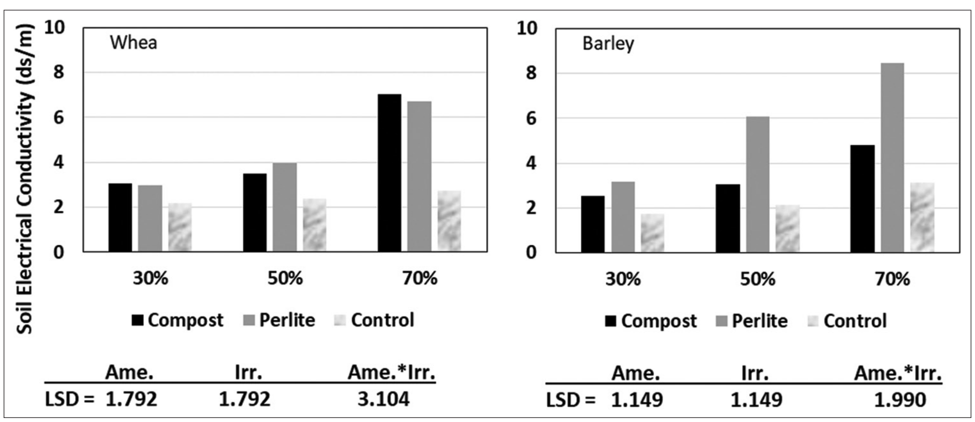

Figure 4: Soil electrical conductivity for wheat and barley crops for the compost and perlite treatments compared to the control treatment under the impact of three levels of irrigation water depletion, which are 30, 50, and 70% of the available water

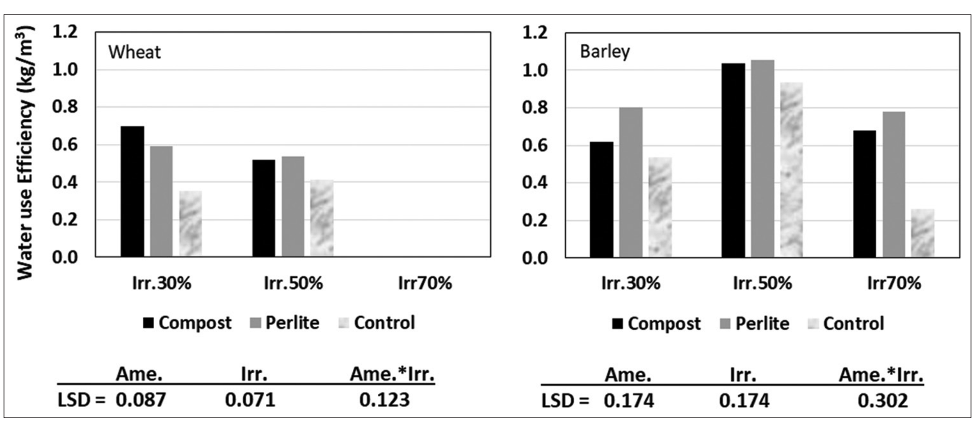

Figure 5: Water use efficiency for wheat and barley crops for the compost and perlite treatments compared to the control treatment under the impact of three levels of irrigation water depletion, which are 30, 50, and 70% of the available water

due to the low yield. The Irr. 50% produced lower values of water use efficiency than the Irr. 30% by about 0.2 for the soil amendments. However, the barley crop yielded better results than the wheat, especially, under the Irr. 50% which reached the value of 1.03 and 1.06 kg/m^3 for the compost and perlite, respectively. The perlite treatment showed significantly higher values of WUE than the compost treatment under the Irr. 30% by about 0.25, with WUE values of 0.8 and 0.62 kg/m^3 for perlite and compost, respectively. The Irr. 70% yielded comparable values to the Irr. 30% for both soil amendment treatments. However, Irr. 70% gave a very low value of WUE for the control compared with the WUE value of the control under the Irr. 30%. This means that the Irr. 70% could be a worth-able management strategy if it is associated with soil amendments.

CONCLUSIONS

Following appropriate irrigation water management becomes a necessity to adapt to the deficiency of irrigation water in Iraq. This study aimed to discover the best field management strategy by examining the effect of soil amendments (compost and perlite/PVA) on wheat and barley yield and water use efficiency under three irrigation levels. The result indicates that the soil properties of water holding capacity and bulk density were improved under the impacts of compost and expanded perlite/PVA. The expanded perlite increased the soil EC. However, it improved the crop yield and water use efficiency under all irrigation levels. Moreover, associating soil amendments of compost and perlite with the irrigation level of 70% could be a worth-able management strategy for improving crop yield and water use efficiency.

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