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Effect of soil amendments and irrigation levels on Growth Characteristics and Yield of Wheat and Barley

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ABSTRACT

In light of the water scarcity for most Iraqi agricultural areas, especially after the decline in the water level of the Tigris and Euphrates rivers to nearly a third. Solutions become necessary to improve water-crop productivity and achieve the sustainable cultivation of strategic crops through using soil amendments, which reduces the soil water loss. Therefore, this research was conducted at, Al-Raeeid Research Station, Baghdad, Iraq, to study the effect of adding compost fertilizer (7500 kg ha^{-1}) and perlite (250 kg ha^{-1}) to wheat and barley crops that were irrigated with two irrigation levels (when exhausting 30% and 50% of the available soil water). The results showed that wheat growth and productivity decreased with increasing water stress of 50%, while opposite results were obtained from the barley crop. The wheat crop showed more sensitivity to the 50% level, but this level did not appear stressful for the barley crop. Also, adding compost and perlite improved wheat growth and yield indicators, which showed a greater response to compost, while barley responded to perlite more than to compost. This study concluded that the combination of compost and irrigation level of 30% presented the highest water-wheat productivity. In comparison, the combination of perlite and irrigation level of 50% presented the highest water-barley productivity.

تأثير محسنات التربة ومستويات الري على خصائص النمو والإنتاجية للحنطة والشعير

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الخلاصة

نتيجة لشحة المياه في معظم المناطق الزراعية العراقية، وخاصة بعد انخفاض منسوب مياه نهري دجلة والفرات إلى ما يقرب من الثلث، أصبح من الضرورة التوصل الى حلول لتحسين إنتاجية المياه والمحاصيل لتحقيق الزراعة المستدامة للمحاصيل الاستراتيجية من خلال استخدام محسنات التربة، التي تقلل من فقدان مياه التربة. لذلك، أجريت هذه الدراسة في محطة أبحاث الرائد، بغداد، العراق، لدراسة تأثير إضافة سماد الكومبوست (7500 كغم هكتار-١) والبيرلايت (250 كغم هكتار-١) على محاصيل الحنطة والشعير المروية بمستويين من الري (عند استنفاد 30٪ و 50٪ من مياه التربة الجاهزة). بينت النتائج أن نمو القمح وإنتاجيته انخفضت مع زيادة الإجهاد المائي بنسبة 50٪، في حين تم الحصول على نتائج عكسية من محصول الشعير. اذ تبين ان لمحصول الحنطة حساسية أكبر لمستوى 50٪، ولكن هذا المستوى لم يظهر إجهادًا لمحصول الشعير. كما حسّنت إضافة السماد العضوي والبيرلايت مؤشرات نمو وإنتاجية الحنطة، حيث أظهرت استجابةً أفضل للسماد العضوي، بينما استجاب الشعير للبيرلايت أكثر منه استجابته للسماد العضوي. وخلصت هذه الدراسة إلى أن الجمع بين السماد العضوي ومستوى الري بنسبة 30% حقق أعلى إنتاجية للمياه والحنطة. وبالمقارنة، حقق الجمع بين البيرلايت ومستوى الري بنسبة 50% أعلى إنتاجية للمياه والشعير.

الكلمات المفتاحية: الإجهاد المائي، محسنات التربة، السماد العضوي، البيرلايت، المحاصيل الاستراتيجية العراقية.

INTRODUCTION

As a result of the low rainfall rates in dry, semi-dry, or semi-humid climatic conditions around the world, and the emergence of the global warming phenomenon, Iraq is one of the countries affected by this phenomenon (Al-Sudani et al., 2024; Shahadha et al., 2023a). That exacerbated this problem is the significant decrease in Iraq's share of the Tigris and Euphrates waters due to the policy of the upstream countries and the shrinkage of the green cover due to overgrazing of pastures and urban expansion at the expense of agricultural lands (Adamo et al., 2020; Shahadha et al., 2023b; Ibraheem, et al., 2024). Wheat and barley are important strategic crops around the world and in Iraq, are mainly grown in lands that depend on flood or sprinkler irrigation systems (Shahadha and Wendroth, 2025), and very few lands in the north of the country depend on rainfed (Ewaid et al., 2021). Despite the increase in production in recent years, the areas allocated for growing the crop are threatened with reduction, as happened to the rice crop due to the scarcity of irrigation water (El. Fahdawi et al., 2019).

Water scarcity also affects the physical and chemical composition of the soil. Adding soil amendments becomes critical to reduce these accumulated and complex problems, caused by water scarcity, on crops and soil productivity. Applying soil amendments to poorly structured soils improves the formation and stability of soil aggregates and consequently, creates suitable conditions for plant growth (Sarker et al., 2022; Shahadha et al., 2023c). Natural or artificial amendments are added to well-built soils to protect their structure from wind and water erosion effects (Poonam and Kumar, 2019). Natural mineral amendments such as perlite have been used worldwide because of their ability to improve several physical properties such as increasing moisture content and water conductivity, improving soil structure, and forming stable aggregates (Faleh et al., 2023). In addition, it improves the soil chemical properties such as increasing the exchange capacity of positive ions and organic matter content and increasing nutrient availability (Semalulu et al., 2015).

Soil amendments of organic fertilizers are often made from plant waste and are currently produced from animal, household, and city waste. Manufactured fertilizer varies according to the type of waste, which determines its properties and components, which affect the quality of the produced fertilizer (Horrocks et al., 2016). Its use has increased over time to improve its physical and chemical properties. It is also considered an important source of nutrients for plants and contributes to increasing soil fertility and thus increasing the water-crop productivity (Pedera et al., 2008). Although this effect lasts for a limited period, it does not negatively affect the environment, soil, and crops compared to chemical and industrial materials (Al-Saadi and Al-Wardy, 2019). The organic matter can chelate micronutrients and reduce the toxicity of heavy metals in the root zone. It also plays important roles in degradation, activity, and persistence in the applied pesticides (Ali and Shaker, 2018).

El dardiry and Abd El-Hady, 2015 showed in their study that using bentonite at five levels of 0, 2, 4, 6, and 8% in a sandy mixture soil, the level of 6% gave the highest straw and grain yield for barley crop, and they obtained a positive linear correlation between grain yield and the level of bentonite addition. The results of the study by Al-Jammas, 2018 also showed that there was an increase in plant height, leaf area, dry weight of shoots, and yellow corn yield by 8.0, 7.0, 19.6 and 16.4%, respectively when adding wheat straw fertilizer at a level of 15 ton/ha to a sandy clay mixture soil compared to the control treatment. Therefore, this study aimed to evaluate the efficiency of applying compost and perlite and their interaction with water stress in the growth and productivity of wheat and barley.

MATERIALS AND METHODS

This study was conducted in a field of Al-Raeeid Research Station, Abu Ghraib city, Baghdad, Iraq, at longitude 44°24 N, latitude 33°22 E, and an altitude of 34 m). Wheat (cultivar of Bhooth22) and barley (cultivar of IPA 99) were planted on October 20, 2023 and harvested in the last week of April, 2024. Treatments were distributed using a randomized complete block design (RCBD) with factorial distribution experiments on an area of about 1000 m^2. The first factor included adding two types of soil amendments: the first was organic fertilizer (7500 kg/ha), which is a product of the aerobic decomposition of wheat; the second was perlite (250 kg/ha) with dissolving 1 g of PVA in 10 liters of distilled water (Table 1). Before planting, both soil amendments were mixed with the soil surface depth of 15cm. The second factor included irrigation levels depending on the irrigation water depletion (30% and 50%) of available soil water (Table 2). The experimental crops field was irrigated using the sprinkler irrigation system. The total applied irrigation water was 535 and 450 mm per season for the depletion levels of 30% and 50%, respectively. Concerning the local fertilization management, Diammonium phosphate (18%N:46%P) was added two weeks before planting with a rate of 150 kg/ha, while the nitrogen fertilizer (Urea 46% N) was added two months after planting the crop with a rate of 150 kg/ha. The field crop measurements were as follows:

Table 1. Main characteristics of used soil amendments (Compost and Perlite).

Amendments	Characteristic	Value
Compost	Bulk density	0.71 (g/cm^3)
	pH (1:5)	6.7
	EC (1:5)	2.5 (dS/m)
Perlite	Bulk density	0.12 (g/cm^3)
	pH (1:2)	7.12
	EC (1:2)	1.5 (dS/m)

Table 2. Physical soil properties before implementing the experimental treatments.

Soil depth	Soil texture	Soil bulk density	Soil moisture at pressures of		Available soil water
(cm)		g/cm^3	33 KPa	1500 KPa	cm^3 / cm^3
0-25	**Silty clay**	1.40	32	15	17
25-50	**Silty clay**	1.42	32	15	17
50-75	**Silty clay loam**	1.45	33	16	17

1- Number of shoots per plant: The number of shoots was calculated from randomly selected plants (ten plants for each treatment) from the central lines with a length of one meter when the plant reached the stage of full maturity and its average was taken.

2- Plant height (cm): The average plant height was calculated for ten plants from the central lines in the experimental unit when the plants reached the stage of 100% flowering and was measured from the base of the plant (soil surface) to the end of the terminal spike with the ear.

3- Weight of 100 grains (g): One hundred grains were counted from the grain yield per square meter for each experimental unit, and then each sample was weighed for each experimental unit.

4- Grain yield (ton/ha): The grain yield was estimated by separating the ears of the harvested square meter for each experimental unit and then isolating the straw from the grains, cleaning them, and weighing them.

The results of this study were statistically analyzed by the GENESTST PROGRAM to determine the differences in the coefficients; we used LSD at 0.05 and included it in the results.

RESULTS AND DISCUSSION

It was observed that the number of tillers of wheat plants decreased from 5.11 tillers per plant to 3.67 tillers per plant for the irrigation depleting of 30% to 50% of the available water, respectively, with a decrease rate of 28.18. As for barley plants, they showed a completely different response, as the number of tillers increased, after its average was 3.89 tillers of plant at a depletion level of 30%, it increased to reach 4.89 tillers per plant, with an increase rate of 20.45% (Table 3).

The results show that treating wheat and barley plants with perlite and compost improved the growth of their plants and stimulated them to produce more shoots. After they were 3.50 and 3.34 shoots per plant for both crops, they rose to 4.33 and 4.00 shoots per plant as a result of treating them with perlite, with an increase rate of 47.71% and 19.76%, while they reached 4.50 and 4.34 shoots per plant as a result of treating them with compost, with an increase rate of 28.57 and 29.94% for the two crops, respectively.

Table 3: Effect of adding compost and perlite on the number of barley and wheat tillers.

Treatments F	Wheat			Barley		
	Available soil water (%) W		Mean F	Available soil water (%) W		Mean F
	30	50		30	50	
Compost	5.33	3.67	4.50	3.67	5.00	4.34
Perlite	6.00	4.33	5.17	5.00	6.00	4.00
Control	3.00	4.00	3.50	3.00	3.67	3.34
Mean W	5.11	3.67		3.89	4.89	
LSD .05	F= 0.21	W= 0.18	F×W=N.S	F= 1.69	W= N.S	F×W= N.S

We note from the results of Table (4) that irrigation at a depletion level of 50% of the available soil water led to a decrease in plant height by 11.76% for the wheat crop, and in contrast, there was an increase in the height of barley plants by 10.88%. The results in Table (4) showed an increase in the height of the wheat crop from 69.33 cm to 75.50 cm, a rise of 8.90%, as well as for the barley crop, which also increased from 68.36 to 75.00 cm, an increase of 9.71% when adding perlite. The increase rates as a result of adding compost reached 8.48% for the barley crop only, and there was an increase in the height of the wheat crop as a result of adding compost. It is noted that the highest height of wheat and barley plants, when applying perlite under the 30% irrigation treatment, reached 82.67 and 80.00 cm, respectively. However, the lowest value of the overlap (65.00 and 68.33 cm) was for the 50% and 30% irrigation level, respectively.

Table 4: Effect of adding compost and Perlite on the barley and wheat plant height (cm).

Treatments F	Wheat			Barley		
	Available soil water (%) W		Mean F	Available soil water (%) W		Mean F
	30	50		30	50	
Compost	68.33	66.67	67.50	70.00	78.33	74.16
Perlite	82.67	68.33	75.50	70.00	80.00	75.00
Control	70.00	60.00	69.33	65.00	71.67	68.36
Mean W	73.67	65.00		68.33	76.67	
LSD .05	F= 2.17	W=2.08	F×W=3.81	F=3.13	W=2.96	F×W=4.81

It is also noted that the wheat crop was more affected by the increase in water deficit, as the weight of 100 seeds was 2.24 and 1.69 g for the 30% and 50%, respectively; which decreased by 24% when applying the irrigation level of 50%. However, for the barley crop, the weight of 100 seeds was 2.92 and 3.54g for the 30% and 50%, respectively; which increased by 17.51% when applying the irrigation level of 50%, Table (5). It is also noted that there was an increase in the weight of wheat grains as a result of adding perlite and compost by 18.67% and 37.35%, respectively, compared to the control treatment. However, the percentages of increase in the weight of 100 seeds for barley crop under perlite and compost were 26.01 and 14.39%, respectively, which shows that wheat plants responded to compost more than adding perlite, unlike barley plants response to both treatments.

Table 5: Average weight (g) of 100 seeds of barley and wheat plant under the effect of adding compost and perlite

Treatments F	Wheat			Barley		
	Available soil water (%) W		Mean F	Available soil water (%) W		Mean F
	30	50		30	50	
Compost	2.75	1.80	2.28	2.75	3.76	3.26
Perlite	2.20	1.73	1.97	3.59	3.56	3.58
Control	1.77	1.54	1.66	2.42	3.29	2.85
Mean W	2.24	1.69		2.92	3.54	
LSD .05	F=0.28	W=0.21	F×W=N.S	F=0.57	W=0.49	F×W=N.S

The results of Table (6) show that the wheat crop was also affected more by the increase in water stress, as the grain yield decreased by 20.12%, while the increase in the previous indicators was reflected in an increase in the barley crop yield by 27.75%. It is noted that the wheat grain yield increased as a result of adding perlite and compost by 47.99 and 60.45%, respectively, compared to the standard treatment. While the percentages of increase in the grain yield of the barley crop as a result of its treatments with perlite and compost reached 27.57 and 12.54%, respectively. This shows that wheat plants responded more to compost than to adding perlite, unlike barley plants response to both treatments (Table 6).

Table 6: Effects of irrigation levels and soil amendments on crops yield (ton/ha).

Treatments F	Wheat			Barley		
	Available soil water (%) W		Mean F	Available soil water (%) W		Mean F
	30	50		30	50	
Compost	2.583	1.717	2.150	2.283	3.423	2.853
Perlite	2.193	1.773	1.983	2.970	3.497	3.234
Control	1.310	1.370	1.340	1.980	3.090	2.535
Mean W	2.028	1.620		2.411	3.337	
LSD .05	F=0.321	W=0.274	F×W=N.S	F=0.564	W=0.501	F×W=N.S

Figure 7 presents the impact of amendments and irrigation treatments on water use efficiency. The combination of compost and irrigation level of 30% yielded the highest value of 0.70 for the wheat water use efficiency. However, the highest value of barley water use efficiency was 1.06 under the combination impact of perlite and irrigation level of 50%. Applying compost and perlite amendments increased the wheat water use efficiency by 38% and 32 %, respectively. Moreover, applying compost and perlite increased the barley water use efficiency by 12% and 21%, respectively. It is noted that the wheat water use efficiency increased as a result of applying the irrigation level of 30%. However, the water use efficiency of barley increased under the impact of irrigation level of 50%; these results are probably due to the fact that the wheat crop is more sensitive to the water stress than the barley crop. In Addition, the wheat crop showed a better response to the applied soil amendments than the barley crop.

Table 7: Effects of adding compost and perlite on the water use efficiency of wheat and barley (kg/m^3).

Treatments F	Wheat			Barley		
	Available soil water (%) W		Mean F	Available soil water (%) W		Mean F
	30	50		30	50	
Compost	0.70	0.52	0.61	0.62	1.03	0.83
Perlite	0.59	0.54	0.56	0.80	1.06	0.93
Control	0.35	0.41	0.38	0.54	0.93	0.73
Mean W	0.55	0.49		0.65	1.01	
LSD .05	F=0.087	W=0.071	F×W=0.123	F=0.174	W=0.174	F×W=0.302

Wheat and barley are among the most critical strategic crops with multiple uses in the world in general (Shahadha and Wendroth, 2022), and in Iraq in particular. The problem of low yield is due to several reasons, including soil pollution as a result of the continued use of chemical fertilizers at the expense of environmentally friendly fertilizers, including organic fertilizers, or water stress, which has recently worsened with the decline in the levels of the Tigris and Euphrates rivers to approximately 1/3 as a result of the policies of the upstream countries.

There was a decrease in wheat crop growth indicators due to increased water stress, as the plant in the irrigation treatment of 30% of the available water was exhausted, obtained its basic water needs necessary for its growth and building all its tissues. While, irrigation when 50% of the available water was exhausted during the vegetative growth stage exposed the plant to water stress, during which the plant is in dire need of water because it is the stage of building tissues and increasing vegetative growth. Therefore, water deficiency negatively affected the plant's metabolic and physiological processes, which reduced plant growth and consequently gave plants with fewer and shorter branches compared to the control treatment. Therefore, it can be said that the vegetative growth stage is a sensitive stage to water stress with regard to growth traits. This effect was completely opposite to what was obtained in the barley crop, "unexpectedly". The reason for this may be that the water requirements differ for each plant type depending on the anatomical and physiological characteristics and structure of the plant in general and the root system in particular, as it has been proven that some crops may need to go through a period of water stress in the vegetative growth stages to stimulate the root system to grow more, which is later reflected in the growth and yield of the grains. This is what we believe happened to the barley crop. Ati et al., 2013 obtained similar results, as there was an increase in plant height and some growth indicators when irrigation was cut in the vegetative growth stages compared to the irrigation cut in the flowering stages. The results of Hussein and Jassim, 2015 supported this result, as it was observed that barley tolerated water stress even at a level of -6 bar of osmotic pressure created using polyethylene glycol (PEG6000). Previous studies on wheat confirmed a decrease in growth traits such as plant height, number of shoots, root length, and dry weight of root and vegetative systems when irrigated after the soil reached 50% of field capacity (Zeng et al., 2023). The grain yield of wheat decreased as a result of changing irrigation from 25% to 50% depletion of available water in the soil (Mohammed and Kadhem, 2017; Masoud and Shahada, 2020) supported these results.

The results showed that the addition of compost significantly improved growth and yield indicators, and the wheat crop was more responsive to the addition of compost compared to the barley crop. This is due to the fact that compost is a store of bioenergy, a source of some major nutrients, and a stimulant for the activity of several enzymes, plant growth, and microorganisms. Compost helps restore life to the soil due to its role in activating microscopic soil organisms, which is reflected in improving soil properties and plant growth and yield. This result supports the findings of Al-Jammas, 2018 study, which found an increase in plant height and yellow corn yield by 8.0 and 16.4%, respectively, when adding wheat straw compost at a level of 15 megagrams ha^{-1} to the soil compared to the control treatment. Al-Kanani, 2021 also obtained a significant increase in plant height, 1000-grain weight, and grain yield in white corn when adding compost at a concentration of 80 ton/ha.

The addition of perlite improved the performance of wheat and barley plants, which was increased the number of branches, plant height, 100-grain weight, and grain yield. The results of the study showed that barley yield was the most responsive to the addition of perlite compared to wheat. This may be attributed to the beneficial effect of perlite in enhancing the plant development and yield. This may be due to the effective role of perlite in enhancing the soil physical and chemical properties e.g. soil porosity, infiltration, and cation exchange capacity (Kim et al., 2016). The obtained results of Jabbar and Kadhem, 2022 support our results, as they obtained a significant effect of applying perlite of 3% by volume to the soil; it improved plant growth traits, plant height, yield, and nitrogen and phosphorus concentration in plants. This result supports the findings of (Telaf et al, 2023); They found that adding different levels of perlite to wheat crops enhanced vegetative growth indicators, especially at the addition level (2%), specifically the number of shoots and plant height (12.03 shoots per plant and 89.93 cm), respectively.

CONCLUSIONS

It can be concluded from this study that increasing water stress has negatively affected the growth indicators and grain yield of wheat, but this level of water stress may have stimulated the barley, which was reflected in increasing the growth indicators and barley yield. This reinforces the prevailing belief that barley in Iraq is more tolerant to environmental stresses, including water stress, compared to wheat crop. We also note that the addition of perlite and compost has significantly improved the growth indicators and grain yield of wheat and barley crops, but the striking result is that wheat responded to the addition of compost more than the addition of perlite, unlike the response of barley crop to these treatments. This is due to the genetic difference between the two crops, which is reflected in their response to growth factors. A combination of compost and irrigation level of 30% yielded the highest water-wheat productivity. In comparison, the combination of perlite and irrigation level of 50% presented the highest water-barley productivity.

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