Effect of Adding Different Mixing Ratios of Perlite and Compost to the Soil and Water Stress on some Physical Soil Properties, Growth Indicators, and Yield of Wheat *Triticum aestivum L.*

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ABSTRACT
This study evaluated the effects of different mixing ratios of perlite and compost, applied individually or in combination, under two irrigation levels on selected soil physical properties and growth and yield-related indicators of wheat (Triticum aestivum L.). A pot experiment was conducted in a greenhouse at the Agricultural Research Station, College of Agriculture and Marshes at University of Thi-Qar, based on three replications and completely randomized design. The soil-amendment factor comprised five levels: an unamended control, 10% perlite, 10% compost, 7.5% perlite + 2.5% compost, and 5% perlite + 5% compost, expressed on a soil-volume basis. Irrigation was maintained at either 100% or 75% of field capacity. Soil bulk density, total porosity, and moisture content were determined, together with plant height, spike length, flag leaf length, number of spikes per plant, plant dry mass, and 100-seed weight. Soil amendments significantly improved most measured soil and plant traits compared with the control. The 5% perlite + 5% compost treatment (T5) produced the highest mean total porosity (55.47%) and moisture content (28.24%), whereas the unamended soil showed the lowest values. Full irrigation (100% field capacity) generally produced greater growth responses than deficit irrigation at 75% field capacity. Significant amendment × irrigation interactions were observed for plant height, flag leaf length, and spike length. Highest values for these attributes were observed in the T5R1 combination (5% perlite + 5% compost with full irrigation), whereas unamended treatment under deficit irrigation showed the lowest responses. Soil amendment also boosted plant dry mass and 100-seed weight. Water stress lowered various growth markers . In general, the results showed that the combination of perlite and compost, especially 5% + 5% under full irrigation, was able to improve the physical status of the root-zone soil and enhance the wheat growth and yield related performance under the conditions of this experiment.

Keywords: bulk density, field capacity, moisture retention, spike development, organic amendment

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INTRODUCTION

Wheat (Triticum aestivum L.) is one of the most important food crops and a major source of food calories and protein in the world supply [1]. Given a shortage of water and ongoing degradation in soil quality, conditions in arid and semi-arid areas like Iraq are increasingly limiting wheat production [14]. Synthetic fertilizers applied over the long period have led to further decline of organic matter, breakdown and increased susceptibility to compaction and erosion of the soil [14]. Moreover, climate variability and dam building on upstream water will significantly affect the surface water flowing into Iraq, calling for immediate use of some water management techniques such as deficit irrigation, which maintains water supply without significantly affecting yield [14]. Due to the degradation of soil, soil conditioning, and the improvement of water-use efficiency have become a topic of wide research interest. Long-term research has been conducted on individual amendments, such as compost, which show potential to reduce bulk density, increase aggregate stability, microbial activity, and availability of plant essential elements (N, P, K, water) [11, 14, 15, 6]. Inorganic mineral conditioners, e.g., expanded perlite, have been individually tested to have low bulk density, high internal pore volume, high macro-porosity, high aeration and high available cation exchange capacity for nutrient non-leaching [10, 22]. The application of compost alone [6, 14] and perlite alone [18, 22] have given mixed results in terms of maintaining root zone moisture and crop biomass under water deficient conditions. Although these recognized benefits, previous studies have had primarily examined the effects of compost or perlite as single soil amendments or on short-term single factor responses [4, 15, 22]. There is still a lack of knowledge on the interactive effect and synergistic effect of different volumetric ratio combinations of using an organic amendment (compost) and using a light mineral conditioner (perlite) under controlled deficit irrigation (CDI) system, especially during controlled deficit irrigation [18]. Individual applications can be used to overcome specific physical or chemical constraints, but combinations of two materials could create a dual benefit - perlite providing the rigid, stable porous matrix for root aeration and water holding capacities [10, 18] and compost providing biological activity and nutrient reserves [6, 11, 14]. Furthermore, the extent to which specific mixing ratios of these amendments can alleviate the physiological and yield penalties imposed by water stress on wheat remains insufficiently quantified under regional climatic conditions [12, 18, 21]. Therefore, this study was conducted to:

1- Evaluate the individual and combined effects of perlite and compost mixing ratios on key soil physical properties (bulk density, total porosity, and moisture retention).
2- Assess the growth, yield components, and biomass responses of wheat (Triticum aestivum L.) under full (100%FC) and deficit (75%FC) irrigation levels.
3- Identify the optimal amendment combination capable of maintaining favorable soil physical conditions and mitigating the negative impacts of water stress on wheat productivity.

MATERIALS AND METHODS

A potting experiment was conducted in the greenhouse of the Field Crops Department, College of Agriculture and Marshes, University of Thi-Qar, to study the effects of adding different levels of perlite and compost individually and mixed with soil based on dry soil weight. Three replicates were used for each treatment to determine the effect on certain soil physical properties and wheat growth indicators. A Completely Randomized Design (CRD) was employed to identify

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the optimal application level that improved soil and plant characteristics. On November 15, 2025, wheat seeds were planted in the pots. On April 10, 2026, soil and plant samples were taken from each pot for laboratory analysis of soil physical properties table (1) and plant growth indicators.

Table 1. The physical properties of the soil studied in the experiment before cultivation

Experimental Treatments and Measured Parameters

These are the various experimental treatments and measured parameters.

The five treatment levels of soil amendment factor were based on soil volume or on dry soil weight:

T1: Control Soil (100% soil volume—no amendments).

T2: Soil with 10% perlite and 0% compost (v/v, total soil volume).

T3: Soil amended with 0% perlite + 10% compost (v/v, total soil volume).

T4: Soil amended with 7.5% perlite + 2.5% compost (v/v, total soil volume).

T5: Soil amended with 5% perlite + 5% compost (v/v, total soil volume).

Dry bulk densities of perlite, compost and mineral soil were between 0.10-0.15, 0.40-0.65 and 1.10-1.40 g cm-3, respectively.

Irrigation was applied based on field capacity (FC) replenishment, comprising two levels:

R1 (Full Irrigation): Irrigation to maintain 100% of field capacity.

R2 (Deficit Irrigation): Irrigation to maintain 75% of field capacity.

1. Soil Physical Characteristics

1.1. Soil Bulk Density (ρ_b)

Soil bulk density was determined using the core sampling method with undisturbed soil samples collected via metallic cores of known volume and mass. The soil cores were oven-dried at 105°C until a constant weight was attained. Dry soil mass was subsequently measured, and soil bulk density was calculated according to Equation (1) as described by [5]:

Where:

ρ_b = Soil bulk density (g cm^{-3})

M_s= Mass of dry soil (g)

V_t= Total volume of the soil core (cm^3)

1.2. Total soil porosity %

The total porosity of the soil was estimated by the method and equation mentioned by Black (5).

$f = (1 - \frac{\rho b}{\rho s}) \times 100$ ..... (2)

Where:

f = Total soil porosity (%)

ρ_b = Soil bulk density (Mg m^{-3})

ρ_s = Soil particle density (Mg m^{-3})

1.3. Soil Gravimetric Water Content (%)

Soil water content was determined gravimetrically using core samplers of known volume and mass. Undisturbed soil cores were weighed immediately upon collection to obtain the wet mass and subsequently oven-dried until a constant mass was reached. The gravimetric moisture content was calculated according to Equation (3) described by [5]:

Where:

$$\theta_w = \left(\frac{M_w}{M_s}\right) \times 100 \quad \text{..... (3)}$$

Where:

θ_w = Soil moisture percentage on a dry weight basis (%)

M_w= Mass of soil water (Mg)

M_s= Mass of dry soil solids (Mg)

2. Wheat Growth and Yield Indicators

2.1.Plant Height (cm**):** Measured from the stem base at the soil surface to the tip of the highest stem/spike using a measuring tape.

2.2.Spike Length (cm **):** Measured from the base of the spike to its apex (excluding awns) using a measuring tape.

2.3. Flag Leaf Length (cm**):** Measured from the leaf base (ligule) to the leaf tip using a measuring tape.

2.4. Number of Spikes per Plant: Determined by counting the total number of fertile spikes per plant.

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2.5. Plant Dry Mass (g): Plant samples were oven-dried at 105°C until a constant mass was achieved, after which the dry weight was recorded using a precision balance.

2.6.100-Seed Weight (g): A sample of 100 seeds was randomly selected per plant and weighed using a sensitive analytical balance.

3. Experimental Design and Statistical Analysis

Data obtained from the pot experiment were subjected to analysis of variance (ANOVA) following a Completely Randomized Design (CRD). Statistical analysis was performed using GenStat software. Using GraphPad Prism (version 8.0.2, GraphPad Software, Boston, MA, USA) was performed for graphical representations. Treatment means were compared using the Revised Least Significant Difference (RLSD) test at a significance level of .

RESULTS AND DISCUSSION

1. Soil Physical Characteristics

1.1. Soil Bulk Density (Mg m^{-3})

Soil bulk density was significantly influenced by the application of soil amendments ($P \leq 0.05$). The lowest mean bulk density was recorded in treatment T_5 ($1.180\ g\ cm^{-3}$), representing a significant reduction compared to the unamended control (T_1 , $1.268\ g\ cm^{-3}$). Irrigation regimes also significantly affected bulk density, with full irrigation (R_1, 100% FC) yielding a lower mean bulk density ($1.211\ g\ cm^{-3}$) than deficit irrigation (R_2, 75% FC , $1.227\ g\ cm^{-3}$). The interaction between soil amendments and irrigation levels ($T \times R$) was not statistically significant.

The observed reduction in bulk density following amendment addition stems from the lower inherent grain bulk densities of perlite ($0.10\text{-}0.15\ g\ cm^{-3}$) and compost ($0.40\text{--}0.65\ g\ cm^{-3}$) relative to the mineral soil ($1.10\text{-}1.40\ g\ cm^{-3}$). Furthermore, organic matter supplied via compost enhances microbial activity and soil structure, which increases the free movement of water, promotes root penetration to access nutrients, and reduces overall bulk density [11, 15, 20].

1.2. Soil porosity

Total soil porosity responded significantly to amendment applications ($P \leq 0.05$). The best mean total porosity (55.47%) was obtained by combined treatment (T5) and was statistically different from all other treatments while the lowest value (53.09%) was obtained for the control (T1). Significant differences were also found for the irrigation levels; the mean total porosity was higher for R1 (54.42%) than for R2 (53.95%). No significant T×R interaction was detected.

The increased porosity under T_5 is directly linked to the physical properties of perlite and compost. Perlite increases soil porosity, permeability, and root aeration, thereby facilitating water and nutrient absorption [10]. Additionally, perlite enhances cation exchange capacity, improving nutrient retention and reducing leaching losses, which promotes root development and overall soil physical condition [10].

1.3 Soil Gravimetric Moisture Content (%)

Soil moisture retention was significantly improved by soil amendments ($P \leq 0.05$). The highest gravimetric water content occurred under treatment T_5 (28.24%), compared to 22.21% in the control (T_1). Full irrigation (R_1) maintained significantly higher mean moisture content (25.25%) than deficit irrigation (R_2 , 24.12%). The T×R interaction was non-significant.

The enhanced moisture retention in amended treatments reflects the ability of perlite to retain water and the capacity of

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compost organic matter to improve soil structure and water-holding capacity, consistent with findings on organic amendments reducing apparent density while increasing moisture retention [11, 15, 20].



Table 2. Effect of soil amendment treatments on selected physical properties of the soil.

Amendments			
Treatments (T)	**Bulk density (g cm $^{-3}$)**	**Total porosity (%)**	**Moisture content (%)**
T *1*	1.268	53.09	22.21
T *2*	1.229	53.61	24.49
T *3*	1.216	54.13	25.16
T *4*	1.202	54.63	26.15
T *5*	1.180	55.47	28.24
RLSD	0.00732	0.2672	0.4486
Irrigation levels			
R1	1.2112	54.42	25.25
R2	1.2270	53.95	24.12
RL SD	0.00463	0.1748	0.2837
Interaction			
T1R1	1.255	52.63	2.21
T1R2	1.225	53.76	24.49
T2R1	1.206	54.50	25.16
T2R2	1.194	54.93	26.15
T3R1	1.175	55.65	28.24
T3R2	1.281	51.66	21.02
T4R1	1.233	53.46	23.14
T4R2	1.225	53.76	24.45
T5R1	1.210	54.33	25.42
T5R2	1.185	55.28	26.55
RL SD	**0.00496 N.S.**	**0.3908 NS**	**0.6344 NS**

2. Growth Indicators

2.1.Plant Height (cm)

Plant height was significantly affected by soil amendments, irrigation regimes, and their interaction ($P \leq 0.01$). Among soil amendments, T_5 recorded the highest mean plant height (68.44 cm), whereas T_1 produced the lowest (49.72 cm).

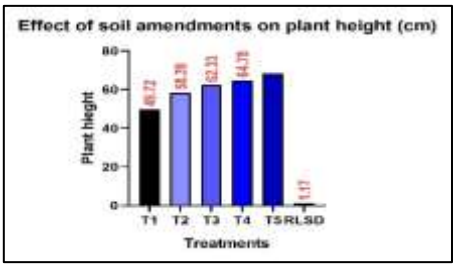


Figure (1) Effect of adding soil amendments on the plant height characteristic (cm)

Comparing the mean values, it was found that full irrigation (R_1) resulted in significantly higher mean value for height (62.58 cm) than the deficit irrigation (R_2 , 58.89 cm). The maximum plant height (69.78 cm) was obtained for interactive treatment T_5 R_1 and minimum plant height (45.11 cm) was obtained for interactive treatment T_1 R_2 (Figure 2).

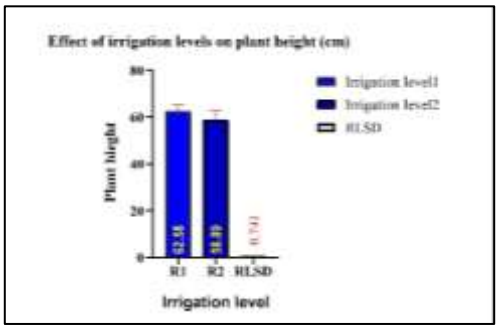


Figure (2) Effect of irrigation levels on the plant height characteristic (cm)

The interaction between compost and

perlite Figure(3) was positive when irrigated both compost and perlite improve the physical properties of the soil, and the former improves the water available for plant growth, while the latter supplies a constant amount of essential nutrients during the vegetative phase supporting cell elongation. Organic fertilizers provide essential nutrients such as N, P and K [6, 7] and perlite promotes the uptake of N and P [9, 22] by the plants. In contrast, a water deficit at 75% field capacity slows down tissue growth and stem elongation, which causes plants to be shorter [21]. Favorable plant growth rates have been seen in other studies conducted in Iraq under water deficit and soil amendment treatments [2, 16].

Figure (3) Effect of the interaction of the studied treatments on the plant height trait (cm)

2.2. Flag Leaf Length (cm)

The length of flag leaf was found to be significantly affected by soil amendments (P≤0.05), irrigation levels (P≤0.05) and their interaction (P≤0.01). The treatment T_5 had the longest flag leaves (18.50 cm) as compared to t_1 (11.33 cm) (Figure 4).

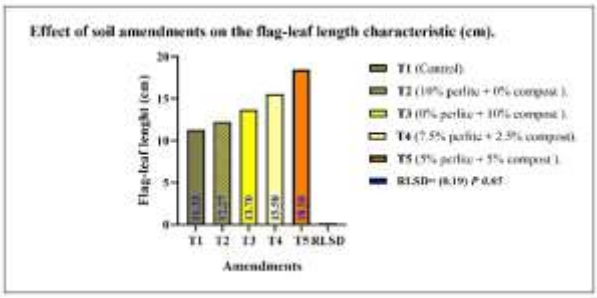


Figure (4) Effect of adding soil amendments on the flag leaf length characteristic (cm).

The flag leaf length obtained from the irrigation treatments were compared in Figure (5). The flag leaf length mean of R_1 was significantly greater (14.78 cm) than the mean (13.78 cm) of R_2 , whereas R_2 was not significantly different from any other treatments.

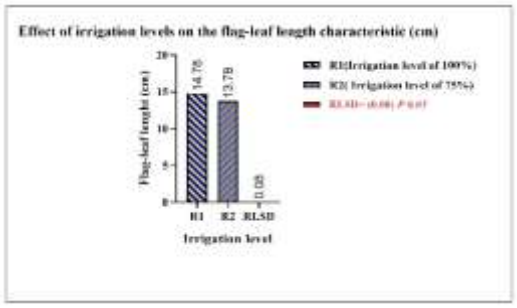


Figure (5) Effect of irrigation levels on the flag leaf length characteristic (cm).

The interaction treatment T_5 R_1 Figure (6) resulted in the highest value (19.11 cm), and the lowest value (11.11 cm) was obtained from the treatment T_1 R_2 .

This better performance is attributed to the synergistic effect of compost and perlite on improving soil physical conditions, increasing available water capacity and providing nutrients through microbial activation activities of the soil [6,18] that in turn increases the photosynthetic area of the flag leaf. Under deficit irrigation (R_2), reduced soil water availability impairs cell expansion, division, and stomatal regulation, limiting leaf expansion [3, 13].



Figure (6) Effect of the interaction of the study treatments on the flag leaf length characteristic (cm).

2.3. Spike Length

According to the results shown in Figure (7), spike length was significantly enhanced by amendment treatments (P≤0.05), full irrigation (P≤0.05), and their dual interaction. Treatment T_5 produced the longest spikes (9.39 cm), whereas T_1 produced the shortest (6.06 cm). Figure (8) R_1 irrigation outperformed R_2 (7.91 cm vs. 7.42 cm).

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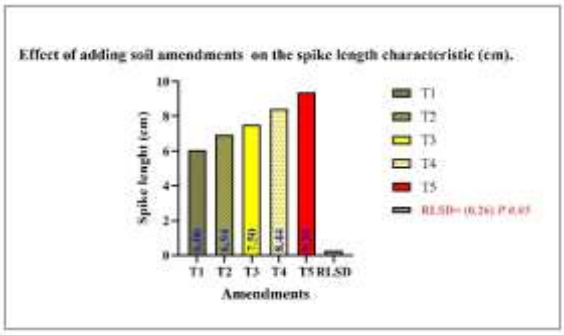


Figure (7) Effect of adding soil amendments on the spike length characteristic (cm).

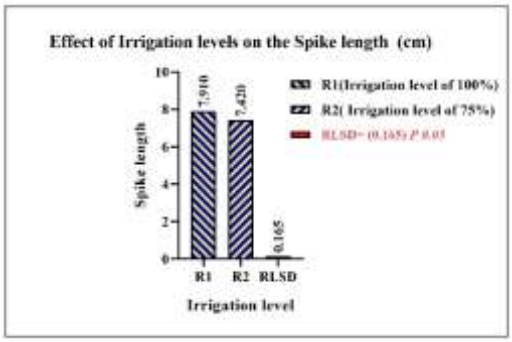


Figure (8) Effect of irrigation levels on the length of the spike (cm)

The interaction T_5 R_1 achieved the maximum spike length (9.56 cm), whereas T_1 R_2 recorded the minimum (5.56 cm) (Figure 9).

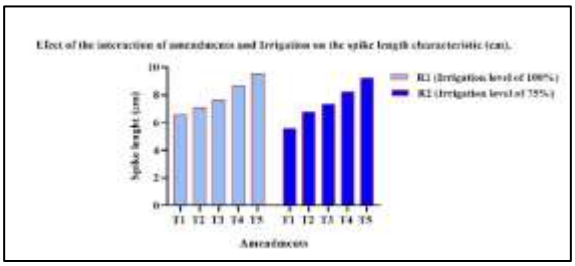


Figure (9) Effect of the interaction of the studied treatments on the spike length characteristic (cm).

2.4. Number of Spikes

Figure (10) shows that applying organic fertilizer and polymer to the soil significantly increases the number of spikes. More specifically, treatment (T5) recorded the highest average number of spikes, reaching 3.55 spikes, while the lowest average number of spikes was recorded by the control treatment (no addition), reaching 2.06 spikes.

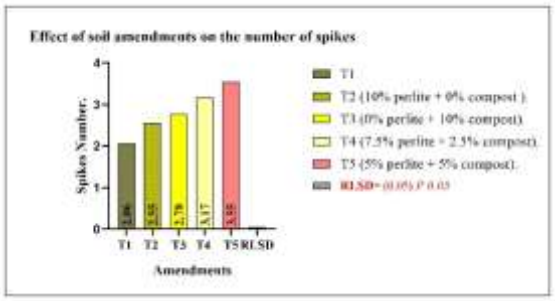


Figure (10) Effect of adding soil amendments on the characteristic of the number of spikes per plant.

Figure (11) shows that there are significant differences in the number of spikes per unit area due to different irrigation levels. The results showed that the 100% field capacity (R1) irrigation treatment resulted in the highest number of spikes, reaching 2.97, while the lowest number of spikes was recorded with the R2 irrigation treatment at a rate of 2.68 spikes of wheat.

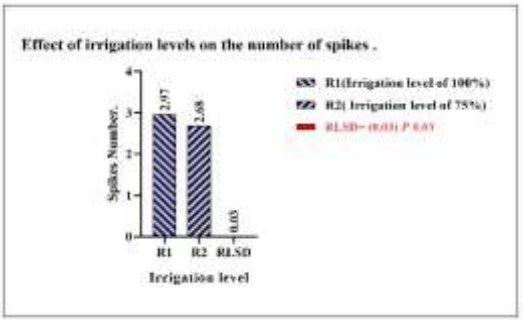


Figure (11) Effect of irrigation levels on the number of spikes per plant.

The increase in fertile spike formation with organic amendments and perlite stems from improved soil physical properties, microbial activity, and enhanced nutrient uptake during early growth stages [6, 10]. Conversely, water scarcity reduces tiller formation, developmental activities, and branch building due to physiological stress and reduced root-zone water absorption

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[21]. Soil amendment did not influence the effect of irrigation levels on the statistics.

2.5. Dry weight (g)

As shown in Figure (12), we observe that there are significant differences in the plant dry weight of the improvers. The results showed that the mixing treatment (T5) recorded the highest average plant dry weight of 22.42 grams, while the control treatment (T1) recorded the lowest average dry weight of 14.56 grams.

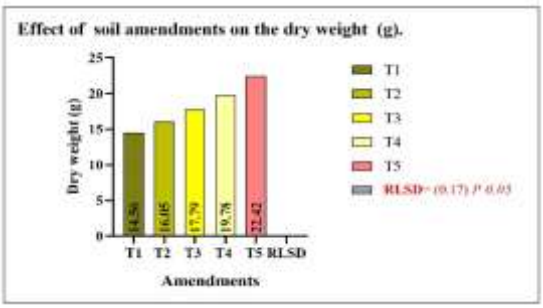


Figure (12) Effect of adding soil amendments on the plant's dry weight characteristic (g).

Figure (13) also indicated significant differences in irrigation levels in the plant dry weight trait. The results showed that the 100% field capacity irrigation treatment R1 recorded the highest average for the trait, reaching 18.60 g per plant, while the lowest average for the trait was recorded by the R2 irrigation treatment, which recorded an average of 17.64 g per plant.

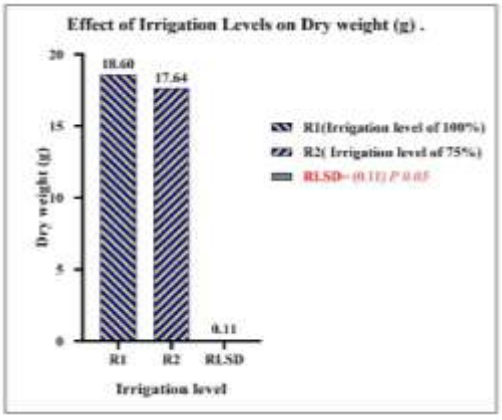


Figure (13) Effect of irrigation levels on the dry weight of the plant (g)

Increased biomass under amended conditions reflects improved soil aeration, enhanced microbial decomposition, and steady nutrient release (N, P, K), which together sustain organic matter synthesis and vegetative growth [6, 7]. Water deficit (R_2) restricts water and mineral absorption, stomatal regulation, and photosynthesis, leading to reduced total shoot and dry weight accumulation [3, 12, 13]. There was no statistically significant interaction of soil amendment and irrigation level.

2.6. Weight of 100 seeds

The weight of 100 seeds in Figure (14) showed a significant effect of adding soil amendments on increasing the weight of 100 seeds. The results showed that treatment T5 was superior in showing the highest average weight of 2.73 g, while the control treatment (T1) recorded the lowest average weight of 1.31 g.

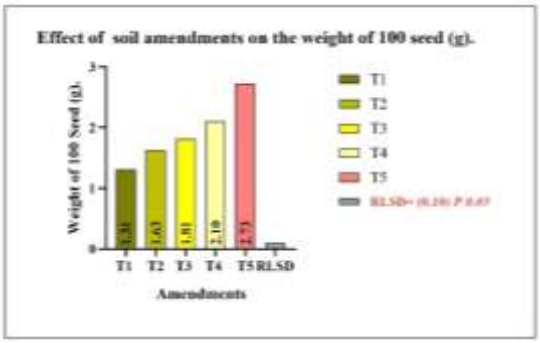


Figure (14) Effect of adding soil improvers on the 100 seed weight (g) characteristic.

The results in Figure (15) also showed a significant effect of irrigation levels on the average weight of 100 seeds. Full irrigation (R_1) achieved a significantly higher 100-seed weight (2.01 g) than deficit irrigation (R_2 , 1.83 g).

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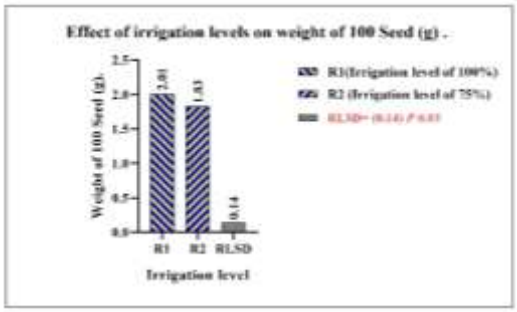


Figure (15) Effect of irrigation levels on the weight trait of 100 seeds (g).

The increase in seed weight under compost and perlite additions is linked to improved soil physical conditions, greater nutrient availability, and enhanced growth indicators that promote carbohydrate synthesis and grain fill [4, 18]. Conversely, water stress during post-anthesis growth stages limits assimilate production and uptake efficiency, resulting in lower grain mass [3, 13]. The combination of soil amendment with irrigation level and neither soil amendment alone nor soil amendment by irrigation level were significant statistically.

CONCLUSIONS

The combined application of perlite and compost improved several physical properties of the soil and growth and yield-related indicators of wheat. The 5% perlite + 5% compost treatment produced the highest total porosity and moisture content and generally enhanced plant height, flag leaf length, spike length, plant dry mass, and 100-seed weight. Full irrigation at 100% field capacity generally outperformed irrigation at 75% field capacity, and significant amendment × irrigation interactions were observed for plant height, flag leaf length, and spike length. Under the conditions of this pot experiment, the 5% perlite + 5% compost combination with full irrigation was the most favorable treatment for maintaining soil physical conditions and wheat growth.

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