Effect of Spraying Zinc and Adding Vermicompost Fertilizer on Wheat Plants Affected by Moisture Stress

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Abstract: This field study was conducted during the fall season 2024-2025 in Diyala Governorate, Al-Muqdadiya District, Al-Wajihiya area, to investigate the effects and phenological adaptations to drought through zinc spraying and vermicompost application on wheat (Triticum aestivum L.) Edna variety. A split-split-plot arrangement within a randomized complete block design (RCBD) with three replications was used, and the least significant difference (LSD) test was applied at the 0.05 probability level. The treatments included three irrigation intervals (every 4, 8, and 12 days), two zinc concentrations (0 and 100 mg Zn L^{-1}), and three vermicompost levels (0, 250, and 500 g per 4 m^2). The results showed that spraying zinc at 100 mg Zn L^{-1} significantly increased proline and chlorophyll contents in leaves, plant height, number of grains per spike, and yield per plant compared with the untreated control. Vermicompost application significantly improved most studied traits. The 250 g per 4 m^2 level recorded higher values for proline concentration and plant height, while the 500 g per 4 m^2 level achieved the highest mean values for chlorophyll content, number of grains per spike, and plant yield. Proline concentration increased with decreasing soil moisture, with the highest values observed under irrigation every 12 days. Irrigation every 8 days produced superior chlorophyll content and plant height, while no significant difference was observed between irrigation every 4 and 8 days for yield per plant. Soil salinity decreased with increasing zinc spraying and vermicompost application, whereas salinity increased with reduced moisture levels, reaching the highest value (5.03 dS m^{-1}) under irrigation every 12 days. The improvement in plant characteristics is attributed to the role of zinc and vermicompost in enhancing water and nutrient uptake and improving plant adaptation to low soil moisture conditions.

1 INTRODUCTION

Moisture stress is the main and determining factor for production in arid and semi-arid regions, as it was found to be responsible for the decline in production by 50%, and the plant can sense water stress through a hormonal system through the inhibition of hormones at the expense of the activation of others. The Zinc is an important microelement in plant growth. This element is involved in many important physiological functions within the plant, such as the formation of the amino acid Tryptophan, which is important in the formation of the growth hormone IAA (Indole Acetic Acid) necessary for cell elongation, It is also necessary for the process of phosphorylation and glucose formation and enters into many enzymatic systems that regulate various metabolic reactions, and contributes to seed maturation, auxin formation and proteins, stability of ribosome segments, protein synthesis and growth and catalyzes the synthesis of cytochrome a, cytochrome b and cytochrome oxidase [1].

Zinc contributes to biological metabolism such as respiration, lipid oxidation, photosynthesis, and RNA and DNA metabolism. Substances to make a higher azimuthal potential [2]. In addition to its contribution to pollen formation, its effect on fertilization, flowering, and chlorophyll synthesis, it has an impact on the carbohydrate ratio in plant leaves due to its important role in activating many enzymes important for photosynthesis and carbohydrate metabolism [3]. Vermicompost is an effective organic fertilizer that is produced by using earthworms to convert organic waste into fertilizer rich in nutrients necessary for the plant, this type of fertilizer has unique properties that make it an ideal choice for sustainable agriculture, as it improves soil fertility, enhances plant growth, and increases its resistance to environmental and biological stresses, and this fertilizer also contributes to reducing the emission of greenhouse gases compared to chemical fertilizers, making it an environmentally friendly option, in addition to that, Vermicompost is an economic option that reduces the need to use chemical fertilizers and pesticides, which improves crop quality and increases economic returns for farmers, in light of the current environmental and economic challenges, Vermicompost stands out as an effective tool to achieve sustainable agriculture and preserve the environment [4].

2 MATERIALS AND METHODS

The field experiment was conducted for the fall season during the 2024-2025 growing season in Diyala Governorate / Muqdadiya District / Al-Wajihiya District / Al-Izziya Village in a soil with a Sandy Clay Loam texture classified as Typic Torrifluvent and Table 1 shows some chemical and physical characteristics of this soil. The aim of this experiment was to study Zinc mineral nutrition and the addition of vermicompost fertilizer to counteract the effect of moisture stress on the phenotypic and physiological traits and yield of wheat plants. The experiment was designed according to Randomized Complete Block Design (R C B D) using Split Plot Design Split design with three replications and the Least Significant Difference (LSD) test was adopted at a probability level of 0.05 and the two moisture tension coefficients were the main coefficients, the levels of vermicompost addition were the secondary coefficients and the zinc spraying levels were the sub-secondary coefficients as follows: Two levels of Zn spraying are (0, 100) mg Zn^{-1}. The plant was added as Zn-EDTA (Zn chelate) (Zn%13). Three levels of vermicompost addition are (0, 250, 500) g. 4 m^2. Three levels of water addition are watering every 4, 8 and 12 days. Thus, the number of experimental units is as follows: 2 concentrations of Zinc spraying, 3 concentrations of Vermicompost, 3 moisture levels, 3 replicates = 54 experimental units. The land was divided into 54 experimental units with an area of (2x2) m^2. The experimental units were placed in three sectors, each sector contains 18 experimental units and the distance between one sector and another 1 m. They were planted with six lines and a distance of 30 cm between one line and another and wheat seeds of the Edna variety were planted on 11/15/2024. The experimental plot was hand weeded, and the experiment was harvested on 2025/6/1. The average height of three plants experimental unit was measured with a graduated ruler at the start of panicle formation from the soil surface to the growing apex. Proline Estimation: proline was extracted and quantified in plant leaves using Aqueous Sulfosalicylic acid according to the method of [5] using a spectrophotometer at a wavelength of 520 nm, and proline content was calculated using the following equation: µ mole proline / g Fr.wt = (Reading * 4 * 5 / wt.in g) 1.47. The total chlorophyll content in the plant was estimated using the Spad apparatus. Soil salinity (EC): Measured using the Conductivity Bridge in a 1:1 (soil: water) ratio according to the method given in [6].

Table 1: Some chemical and physical soil characteristics before planting.

Soil Properties	Unit	Value
pH 1:1	-	7.9
Electrical Conductivity (EC1:1)	ds m^{-1}	2.5
Available nitrogen	mg. kg^{-1} soil	52
Available potassium	mg. kg^{-1} soil	176
Available phosphorus	mg. kg^{-1} soil	19
Available zinc	mg. kg^{-1} soil	0.33
Organic matter	g kg^{-1} soil.	11.0
cation exchange capacity	Centi-mol. kg^{-1} soil	25.34
moisture at field capacity	%	29
moisture at the permanent wilting point	%	13
Available Water	%	16
Clay%	%	34.88
Silt %	%	22.56
%Sand	%	42.56
Soil Texture Class	-	Sandy Clay Loam

3 RESULTS AND DISCUSSION

3.1 Proline Concentration in Plant Leaves (mg g^{-1} fresh weight)

The results in Table 2 show that the level of zinc spraying (100 mg L^{-1}) is superior to the first level of spraying with this element (0 mg L^{-1}) with a significant increase of (10.78 %).Zinc has many different important physiological roles as it is an essential element in manufacturing and metabolic processes, and this element has a role in the vital functions of structural molecules such as nucleic acid and an activator of metabolism and regulation of enzymes , whether under normal conditions or during stress, which ultimately affects the growth and development of plants.The second level of adding vermicompost (250 g) over the level of not adding this fertilizer and (500 gm) with a significant increase of (16.16%, 6.48%). Vermicompost is one of the fertilizers characterized by its high absorption by the plant, as it activates the work of beneficial microorganisms such as bacteria and fungi that fix nitrogen and dissolve phosphate and work to release growth hormones such as auxin and gibberellin [4]. There was a significant increase in leaf proline concentration with decreasing soil moisture content as the third moisture level W3 (irrigation every 12 days) recorded the highest average of (1.78) (mg g^{-1}) over the first and second moisture level which recorded averages of 0.16 and 1.36 (mg g^{-1}) respectively, this result is in agreement with [7]. Which found an increase in proline content in the plant exposed to moisture stress, as proline accumulation increases due to the inability of the plant to build protein biosynthesis, so the amount of amino acids inside the plant increases, including proline acid, which is one of the defense means to reduce the harmful effect of drought, and it is believed It is believed that drought stress leads to the stimulation of proteolytic enzymes and the production of amino acids, including proline, which acts as an isozyme, and the role of this acid in stabilizing and stabilizing cell membranes and increasing the ability of the cell to withdraw water and nutrients dissolved in it from the growth medium and gave a level (100 mg Zn L^{-1}+ 500g of vermicompost addition). The highest average proline concentration in leaves was 1.28 mg g^{-1} fresh weight, while the lowest average was 0.89 mg g^{-1} fresh weight. The significance of the interaction between the two factors indicates the reversal of the effect of the two factors together, as Zinc acts as a co-factor for about 300 enzymes and proteins involved in cell division, nucleic acid metabolism and protein synthesis, and has great importance in affecting reactive oxygen species and protecting plant cells against free radicals [8]. Earthworms increase plant growth regulators such as auxins, cytokinin's and gibberellins [9], which in turn increases cell division and elongation, which is positively reflected on most plant vegetative traits such as plant height, leaf area and chlorophyll content. When comparing the effect of adding vermicompost with the low humidity level, we notice that the interference level (W3 +500 g of vermicompost) is significantly superior to the level of not adding vermicompost at the same humidity level (W3) with a significant increase of (21.51%). As for the effect of the interaction between moisture levels and zinc spraying levels, the zinc spraying treatment and the third moisture level (W3) achieved significant superiority over all other treatments, with an average of (1.83) mg g^{-1}. The appearance of high levels of amino acids observed in plants exposed to stress is caused by either protein degradation or accumulation resulting from the low utilization of these acids in the formation of protoplasm, as increased proline leads to an increase in the cell's osmotic potential and thus leads to increased water withdrawal by plant roots [7]. The triple interaction (V*Zn*W) significantly affected the amount of proline in plant leaves, as the highest average was (42.2) mg g^{-1} at the level of spraying and humidity (W3 + 100 mgZn L^{-1} 500 + g of vermicompost), while the lowest average of this trait was (0.14) mg g^{-1} at no spraying and no fertilizer addition and at the first moisture level (W1), the reason may be due to the role of Zn in managing reactive oxygen species and protecting the plant cell from oxidative stress that arises during stresses, as well as regulating stomatal functions by regulating potassium content in plant cells [10].

3.2 Leaf Total Chlorophyll Content (SPAD)

The results shown in Table 3 indicate that there were significant increases in the concentration of chlorophyll in the leaves with Zn spraying, as the spray level (100 mg Zn L^{-1}) exceeded the level of not adding this element by a significant increase of 23.53%. This may be attributed to the contribution of zinc in biological metabolism such as respiration, lipid oxidation, photosynthesis and RNA metabolism, as well as its contribution to pollen formation, its effect on fertilization, flowering and chlorophyll synthesis, and its effect on the proportion of carbohydrates in plant leaves due to its important role in activating many enzymes important for photosynthesis and carbohydrate metabolism [11], [12]. The third level of addition vermicompost exceeded the first level by an increase of (42.53%) for different moisture levels, respectively. This may be due to the effective role of adding vermicompost fertilizer to the soil, which leads to an increase in seed germination, plant height, number of leaves, leaf area, root length, plant weight, chlorophyll content, protein, carbohydrates and total yield, which is rich in nutrients necessary for the plant in larger quantities compared to conventional fertilizers, and is characterized by its rapid absorption by the plant [13]. The second moisture level (W2) significantly exceeded the first moisture level (W1) and the third moisture level (W3) by a significant increase of (17.48%, 22.03%). The decrease in chlorophyll content with increasing moisture tension is due to the decrease in leaf water potential, thus reducing the process of photosynthesis because of reducing the opening of stomata, and stress also reduces the production of plant pigments, including chlorophyll, which reduces the resulting carbohydrates [14]. The interference by spraying the element and adding fertilizer achieved a significant increase in the concentration of chlorophyll in plant leaves, as the highest average was (52.97) SPAD at the level (100 mg Zn L^{-1}+500 g of vermicompost), while the lowest average was (31.25) SPAD when no element was sprayed and no fertilizer was added with a significant increase of (69%). It is observed from the table that there is a significant effect of the interference of moisture levels and the addition of vermicompost, as the highest average chlorophyll concentration in plant leaves was recorded at (W2+500 g of vermicompost) level (52.41) SPAD and the lowest average reached (29.28) SPAD when not vermicompost was added and at the third moisture level (W3). The interference level (W3+500 g of vermicompost) was significantly superior to the level of not spraying with this fertilizer at the same moisture level (W3) by a significant increase of (39.31%), which indicates the importance of vermicompost in water scarce conditions. Zinc spraying led to a significant increase in leaf chlorophyll content at different moisture levels, and the highest average was recorded at (W2+100 mg Zn L^{-1}) level (49.67) SPAD, and the lowest average was recorded at the level of no zinc addition and the first moisture level (W1) amounted to (32.62). SPAD, a significant increase of (52.62%). It is also noted that increasing the concentration of zinc spraying significantly affected the increase in this trait at the low moisture level, as the level of interaction (W3+100 mg Zn L^{-1}) exceeded the level of no zinc spraying at the same moisture level (W3) by a significant increase of (17.29%). A significant interaction between the moisture and zinc spraying treatments and the addition of vermicompost appeared as the chlorophyll concentration in plants resulting from spraying with a level (100 mg Zn L^{-1}) exceeded the level (100 mg Zn L^{-1} +500 g of vermicompost) at the second moisture level (W2) and recorded an average of (56.93) SPAD, while the lowest average was recorded at no zinc spraying and no vermicompost and at the third moisture level (W3), recording an average of (28) SPAD. 23) SPAD. It is noted that the addition of high concentrations of the two experimental factors led to minimizing the negative impact of low soil moisture on this trait, as the level of (W3+100 mg Zn L^{-1}+500g of vermicompost addition) exceeded the level of (W3 + 100 mg Zn L^{-1} +500 g of vermicompost addition). Significant at the level of not spraying the element and fertilizer and at the same level of humidity (W3) with a significant increase of (64.82%). The low concentration of chlorophyll in the leaves may be useful in plants of dry regions, as plants with high content of this pigment will be reflected in increasing the absorbed radiant energy and then increasing the loss by evapotranspiration, which reduces the efficiency of water use, while plant varieties with low chlorophyll content will increase the efficiency of water use, due to the decrease in absorbed radiant energy.

3.3 Plant Height (cm)

The results shown in Table 4 indicate that zinc spraying significantly outperforms non-spraying in terms of growth, with an increase of 10.83% For different moisture levels, zinc plays an important role in plant growth and development through its role as a cofactor for approximately 300 enzymes and proteins involved in cell division, elongation, nucleic acid metabolism, and protein synthesis. The vermicompost fertilizer treatment was superior in increasing plant height and the highest average (76.93) cm at the second level 250 g of vermicompost addition which did not differ significantly from the third addition level 500 g of vermicompost addition, which achieved an average of 76.28 cm compared to the level of not adding this fertilizer, which achieved an average of 68.22 cm. Studies have shown that vermicompost has a significant role in raising the concentrations of both macro and micro nutrients within the leaves of the wheat plant, as it improved the stability of cell membranes and increased chlorophyll content, plant height and antioxidant activity, which enhances the plant's ability to cope with environmental stresses such as drought [4]. The second moisture level (W2) had the highest average plant height of 81.71 cm, while the lowest average was 68.89 cm at the third moisture level (W3), an increase of 18.60%. The reason for the decreased plant height after exposure to water stress is the decreased division, expansion, and elongation of stem and leaf cells due to the decreased water potential of plant cells, which is related to the decreased readiness of soil moisture.

Table 2: Effect of Zinc element and vermicompost fertilizer and irrigation periods of Triticum on proline concentration in plant leaves (mg g^{-1} fresh weight).

V (vermicompost)	Zn (zinc)	W1 irrigation period (4) days	W2 irrigation period (8)days	W3 irrigation period (12) days	V*Zn (vermicompost× zinc)
V0 (control)	Zn 0 (control)	0.14	1.00	1.53	0.89
	Zn (100 $mg.L^{-1}$)	0.14	1.55	1.64	1.11
V (vermicompost concentration 250	Zn 0 (control)	0.18	1.39	2.09	1.22
	Zn (100 $mg.L^{-1}$)	0.23	1.41	1.63	1.09
V (vermicompost concentration 500)	Zn 0 (control)	0.15	1.18	1.60	0.97
	Zn (100$mg.L^{-1}$)	0.16	1.46	2.24	1.28
LSD 0.05		0.08			0.05
					Mean (vermicompost)
V*W vermicompost levels with irrigation period	V 0 (control)	0.14	1.27	1.58	0.99
	V (250)gm	0.20	1.4	1.86	1.15
	V (500)gm	0.15	1.19	1.92	1.08
LSD 0.05		0.04			0.02
					Mean(zinc)
Zn*W zinc levels with irrigation period	Zn 0 (control)	0.15	1.19	1.74	1.02
	Zn (100$mg.L^{-1}$)	0.17	1.39	1.83	1.13
LSD 0.05		0.05			0.04
Mean (irrigation period)		0.16	1.29	1.78	
LSD 0.05			0.02		

Table 3: Effect of Zinc element and vermicompost fertilizer and irrigation periods of Triticum on concentration of chlorophyll in plant leaves (SPAD).

V(vermicompost)	Zn(zinc)	W1 irrigation period (4) days	W2 irrigation period (8) days	W3 irrigation period (12) days	V*Zn (vermicompost× zinc)
V0(control)	Zn0 (control)	30.26	35.26	28.23	31.25
	Zn (100$mg.L^{-1}$)	32.63	39.83	30.33	34.26
V(vermicompost concentration 250	Zn0(control)	29.1	43.43	39.96	37.58
	Zn (100$mg.L^{-1}$)	47.1	50.46	44.23	47.26
V(vermicompost concentration 500)	Zn 0 (control)	38.26	47.9	35.06	40.40
	Zn (100$mg.L^{-1}$)	55.46	56.93	46.53	52.97
LSD 0.05		12.622			7.287
					Mean (vermicompost)
V*W vermicompost levels with irrigation period	V0 (control)	31.44	37.54	29.28	32.75
	V (250)gm	38.23	46.94	42.09	42.42
	V (500)gm	46.86	52.41	40.79	46.68
LSD 0.05		8.925			5.15
					Mean(zinc)
Zn*W zinc levels with irrigation period	Zn 0 (control)	32.62	41.86	34.41	36.29
	Zn (100$mg.L^{-1}$)	45.06	49.07	40.36	44.83
LSD 0.05		7.287			4.207
Mean (irrigation period)		38.84	45.63	37.39	
LSD 0.05		5.15			

Consequently, the leaf area decreases, as does the amount of light intercepted and the efficiency of converting it into chemical energy, resulting in a lower rate of accumulation of dry matter, which is important for the process of photosynthesis. Lengthening due to increased respiration. The decrease in plant height after exposure to water stress may be due to the inhibition of auxin activity due to the lack of opportunity for it to work on the elongation of plant cells due to the small size of the leaves and the lack of formation, osmotic stress impedes the absorption of nutrients from the soil, particularly nitrogen, which plays a significant role in plant growth and cell division [15] The results in the same table show the effect of adding zinc and vermicompost on increasing the height of the plant, with the highest average (81.55 cm) at the level of interaction (100 mg ZnL^{-1} +500 g vermicompost) and the lowest average (66.88 cm) at the absence of zinc and vermicompost, with a significant increase of 21.93%. There were significant differences in the interaction, with the highest average increase in plant height (85.83 cm) observed in treatment (W2+500gm of vermicompost addition) and the lowest average increase (62.49 cm) observed in treatment (W1 + 0 gm of vermicompost addition). When the plant to drought during the vegetative growth stage, the leaf area and its ability to intercept light decrease, which negatively affects the plant's height, dry matter, and ultimately, grain yield [16], the interaction between moisture levels and zinc spraying was statistically significant. The treatment (W2 + 100 mg Zn L^{-1}) produced the highest plant growth rate of 85.66 cm, while the treatment (W3 + 0 mg Zn L^{-1}) produced the lowest growth rate of 63.88 cm. The highest average height of the plant (89.33 cm) was achieved with the following combination: W2+100 mg ZnL^{-1} +500 g vermicompost. The lowest average height (65.66 cm) was achieved with no zinc spraying, not vermicompost addition, and at the third moisture level (W3), which is a 36.04% increase.

When nutrients are available in sufficient and balanced amounts, the excess dry matter produced by net photosynthesis is stored in various parts of the plant, such as the stems and leaves. Some of this stored material is converted into grains when the filling process begins, which increases grain weight and yield. The dry matter stored in the stem can account for up to 10% of the accumulated material in the grain. However, under unfavorable growth conditions such as high temperatures and water scarcity, stem elongation competes with leaf growth and subsequently affects grain yield because the growth of plant organs is synchronized in a single phase.

Table 4: Effect of zinc element and vermicompost fertilizer and irrigation periods on the plant heigh (cm) of Triticum plants.

V (vermicompost)	Zn (zinc)	W1 irrigation period (4) days	W2 irrigation period (8) days	W3 irrigation period (12) days	V*Zn (vermicompost× zinc)
V0(control)	Zn0(control)	67.33	67.66	65.66	66.88
	Zn (100mg.L^{-1})	57.66	81.33	69.7	69.56
V(vermicompost concentration 250	Zn0(control)	72.33	83.33	60.66	72.10
	Zn (100mg.L^{-1})	77.66	86.33	81.33	81.77
V(vermicompost concentration 500)	Zn0(control)	65.40	82.33	65.33	71.02
	Zn (100mg.L^{-1})	84.66	82.33	70.66	81.55
LSD 0.05		12.871			7.431
					Mean (vermicompost)
V*W vermicompost levels with irrigation period	V0(control)	62.49	74.49	67.68	68.22
	V (250)gm	74.99	84.83	70.99	76.93
	V (500)gm	75.03	85.83	67.99	76.28
LSD 0.05		9.101			5.25
					Mean(zinc)
Zn*Wzinc levels with irrigation period	Zn0(control)	187.53	182.83	164.76	178.37
	Zn (100mg.L^{-1})	198.26	189.50	166.68	184.81
LSD 0.05		7.431			4.22
Mean(irrigation period)		70.84	81.71	68.89	
LSD 0.05		5.25			

3.4 The Yield of One Plant (gm)

It is observed from Table 5 that there is a significant increase in the yield of grains per plant when zinc is added, as the level of spraying (100 mg Zn L^{-1}) exceeds the level of not spraying this element by a significant increase of 10.21% for different moisture levels, in order, as zinc contributes to the metabolic process, such as respiration, oxidation of fats, photosynthesis, and metabolism of nucleic acids (RNA and DNA), as well as contributing to pollen formation and affecting fertilization, flowering, and chlorophyll formation, and influencing the carbohydrate content in plant leaves due to its role. The most important thing is to activate many important enzymes for photosynthesis and carbohydrate metabolism [12]. There was a significant increase in the yield of each plant with an increase in the level of vermicompost addition, with the third level of addition surpassing the first level by 30.4%. Different humidity levels Recent research has shown that using vermicompost increases crop yields and improves the quality of production. A decrease in the average grain yield per plant was observed due to decreased soil moisture, as lower soil moisture content reduces the availability of nutrients, resulting in the appearance of deficiency symptoms. On the plant, the deepening of the plant's roots in search of moisture may lead to the depletion of most of the energy produced in the green mass, which undoubtedly affects the yield of the plant [14]. The interaction between the application of the element and the addition of the fertilizer increased this trait significantly, as the highest mean was (9.96) gm $plant^{-1}$ at a level of (0 mg Zn.L^{-1} + 500 g of vermicompost), which was not significantly different from the level of (100 mg Zn L^{-1} + 500 gm of vermicompost). In contrast, the lowest mean was (6.37) g $plant^{-1}$ when the element was not sprayed and the fertilizer was not added, with a significant increase of 35.56%. The table shows that there is a significant effect on the yield of the grain for each plant due to the interaction between moisture levels and vermicompost addition levels. The treatment (W1 500 + g of vermicompost) produced the highest average for this trait, reaching 10.43 g $plant^{-1}$, while the lowest average was recorded when vermicompost was not added and at the third moisture level, reaching 6.28 g $plant^{-1}$. As the amount of vermicompost added increased, so did the yield of grains per plant at the third moisture level, with the interaction level of (500+W3 g of vermicompost) surpassing the interaction level of (0+W3 g of vermicompost) by a statistically significant margin of 70.52%. This indicates that it is possible to adapt to water scarcity by adding vermicompost to the plant. As for the interaction between moisture levels and zinc spraying levels, the results showed some significant differences. The highest average yield of grain per plant (0.659 g $plant^{-1}$) was achieved with treatment (W2 + 100 mg Zn L^{-1}), and the lowest average yield (0.757 gm $plant^{-1}$) was achieved with no zinc spraying and the third moisture level (W3). The interaction between the three factors under study significantly affected this trait, with the highest mean (10.73 g $plant^{-1}$) at level (W1+0 mg Zn L^{-1} +500 g vermicompost), which was not significantly different from level (W1+100 mg Zn L^{-1} +500 g vermicompost). The lowest mean (4.64 g $plant^{-1}$) was at the level of not adding the element or the fertilizer and at the third level of humidity (W3). The decrease in grain yield may be due to decreased water content in the plant, decreased growth, and decreased accumulation of dry matter, as well as decreased number of grains. The filling stage of grains is one of the stages most affected by drought stress. The increase in temperature, the decrease in relative humidity, and the temperature extremes associated with drought may also play a role in reducing grain yield.

3.5 Soil salinity (dS m^{-1})

As shown in Table 6 there was a decrease in soil salinity when zinc was sprayed at a level of 100 mg Zn L^{-1}, achieving an average of 4.53 ds m^{-1}. However, the level of not spraying zinc resulted in the highest average soil salinity, achieving an average of 4.969 ds/m. The results in the same table show a significant decrease in soil salinity with increased application of vermicompost, with a level of 500 g of vermicompost on the level of 0 g of vermicompost addition), and 50 g of vermicompost addition. At a concentration of 26.00% and 10.40%, respectively, vermicompost is one of the important organic inputs for improving the natural, chemical, and biological properties of soil [17], [18] organic content of soil, improves the structure of its particles, reduces salinity, increases its ability to retain moisture, and raises the cation exchange capacity, which increases the availability of macronutrients and micronutrients for plants [19], [20]. The results shown in the table indicate that the second level of moisture (W2) is more effective in reducing the amount of salts in the soil, achieving an average of 4.02 ds m^{-1}.

Table 5: Effect of Zinc element and vermicompost fertilizer and irrigation periods of Triticum on yield plant (gm plant^{-1}).

V(vermicompost)	Zn(zinc)	W1 irrigation period (4) days	W2 irrigation period (8) days	W3 irrigation period (12) days	V*Zn (vermicompost× zinc)
V0(control)	Zn 0 (control)	8.11	6.36	4.64	6.37
	Zn (100mg.L^{-1})	8.80	9.91	7.92	8.87
V(vermicompost concentration 250	Zn 0 (control)	9.40	9.20	9.14	9.24
	Zn (100mg.L^{-1})	9.75	9.53	9.26	9.51
V(vermicompost concentration 500)	Zn 0 (control)	10.73	9.69	9.47	9.96
	Zn (100mg.L^{-1})	10.14	9.51	9.72	9.79
LSD 0.05		0.756			0.410
					Mean (vermicompost)
V*W vermicompost levels with irrigation period	V0 (control)	8.45	8.13	6.28	7.59
	V (250)gm	9.57	9.36	9.20	9.37
	V (500)gm	10.43	9.60	9.59	9.87
LSD 0.05		0.612			0.520
					Mean (zinc)
zn*W zinc levels with irrigation period	Zn 0 (control)	9.41	8.41	7.75	8.52
	Zn zinc concentration 100mg.L^{-1}	9.56	9.65	8.96	9.39
LSD 0.05		0.410			0.355
Mean(irrigation period)		9.48	9.03	8.35	
LSD 0.05			0.520		

Table 6: Effect of Zinc element and vermicompost fertilizer and irrigation periods on Triticum on Soil salinity (ds m^{-1}).

V(vermicompost	Zn (zinc)	W1 irrigation period (4) days	W2 irrigation period (8) days	W3 irrigation period (12) days	V*Zn (vermicompost× zinc)
V0 (control)	Zn0(control)	6.09	4.88	5.99	5.65
	Zn (100mg.L^{-1})	5.69	4.15	5.21	5.01
V (vermicompost concentration 250	Zn0(control)	5.52	3.91	5.13	4.85
	Zn (100mg.L^{-1})	4.89	3.84	4.80	4.51
V (vermicompost concentration 500)	Zn0(control)	4.63	3.75	4.75	4.37
	Zn (100mg.L^{-1})	4.37	3.59	4.32	4.09
LSD 0.05		0.486			0.281
					Mean (vermicompost
V*W vermicompost levels with irrigation period	V0(control)	5.89	4.51	5.60	5.33
	V (250)gm	5.20	3.87	4.96	4.67
	V (500)gm	4.50	3.67	4.53	4.23
LSD 0.05		0.344			0.198
					Mean(zinc)
zn*W zinc levels with irrigation period	Zn0(control)	5.41	4.18	5.29	4.96
	Zn zinc 100mg.L^{-1}	4.98	3.86	4.77	4.53
LSD 0.05		0.281			0.162
Mean(irrigation period)		5.19	4.02	5.03	
LSD 0.05			0.198		

The highest salt concentration was found at the first level of moisture (W1), with an average salinity of 5.19 ds m^{-1}, which was not significantly different from the third level of moisture (W3), with an average salinity of (5.03) ds m^{-1}. Good nutrition with the interaction of the element and fertilizer led to a decrease in soil salinity. The interaction of the level (100 mg Zn L^{-1} + 500 mg of vermicompost addition) achieved the greatest decrease in soil salinity with an average of (4.09) ds m^{-1}, while the highest soil salinity values (5.65) dS m^{-1} were recorded at the interaction level (0 mg ZnL^{-1} + 0 mg of vermicompost). This confirms the importance of foliar fertilization with the appropriate levels of zinc and good soil fertilization. Vermicompost in reducing soil salinity levels. The level of interaction (W2+500 g of vermicompost) was statistically higher than the other levels of interaction, registering the lowest average salinity of the soil at (3.67) ds m^{-1}. As the lowest average salinity of the soil was recorded at the intersection of the levels (W2+100 mg Zn L^{-1}) at 3.86 ds/m, while the highest salinity of the soil was recorded at the level of not spraying zinc and at the first moisture level (W1+0 mg Zn L^{-1}) at 5.41 ds/m. The lowest average salinity of the soil was (4.77) ds m^{-1} at the treatment (W3+100 mg Zn L^{-1} (5.29) ds m^{-1}. The lowest mean for this property was found at the interaction level (W3+100 mg Zn L^{-1} + 500 gm of vermicompost), at (3.59) ds m^{-1}. In contrast, the highest salt concentration in the soil was found at the first level of moisture (W1), when zinc was not sprayed and no fertilizer was added (%6.09).

4 CONCLUSIONS

The present study demonstrates that the combined application of foliar zinc and vermicompost is an effective strategy for improving wheat performance under different irrigation regimes. Zinc application enhanced physiological activity, resulting in higher chlorophyll content, greater plant height, improved grain yield, and increased proline accumulation under drought conditions. Vermicompost further promoted plant growth and productivity while reducing soil salinity through improvements in soil fertility and nutrient availability.

Among the irrigation treatments, irrigation every 8 days provided the most favorable balance between water availability and plant growth, producing the highest values for most growth and physiological traits. In contrast, prolonged water deficit (12-day irrigation interval) increased proline accumulation, confirming its role as an indicator of drought stress.

The interaction between zinc application and vermicompost consistently mitigated the adverse effects of water stress, indicating that the combined treatment improves drought tolerance by enhancing nutrient uptake, maintaining physiological activity, and reducing soil salinity. These findings suggest that integrating foliar zinc fertilization with vermicompost application represents a practical and sustainable management strategy for maintaining wheat productivity under limited water availability.

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