The role of nano-NPK fertilizer in reducing the effect of soil salinity on the growth and yield of wheat (*Triticum aestivum* L.)

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Abstract

Three sites were selected from Nineveh Governorate within the (Tal Abtah) area and due to the agricultural importance of these sites as they are planted with grain crops and are supplement ally irrigated, excited samples were taken at a depth of (0-30) cm from the study sites. The samples were prepared for cultivation and analysis. The experiment was implemented according to a completely random design. The results showed that the dry weight (straw) recorded the lowest value for the dry weight S_2 (1.23 g Pot^{-1}) while the highest value was recorded in the comparison treatment S_1 (1.71 g Pot^{-1}). It surpassed significantly between the treatments, as it is noted in the effect of foliar fertilization, the lowest value for the dry weight F_3 was recorded (1.32 g Pot^{-1}) and the highest effect was recorded for foliar fertilization $F_1$1.56 g Pot^{-1}. As for the number of spikes, the highest value was recorded in the comparison treatment where S1 reached 3.70 spikes Pot^{-1} while the lowest value was recorded S_2 (3.04 spikes Pot^{-1}). As for The effect of foliar fertilization recorded the highest value among the treatments, which was F_3 (3.38 spikelets pot^{-1}), while the lowest value was recorded in the number of spikes, F_2 (3.22 spikelets pot^{-1}). The results showed that the number of grains per spike was the lowest value in the second level, where S_2 reached (9.38 spikelets pot-1), while the effect of ground fertilization was higher in the third level, where it reached $G_3$21.33 spikelets pot^{-1}, and the lowest value was recorded in the comparison treatment, where it recorded G_1 (12.71 spikelets pot^{-1}), and the percentage was 19.48 spikelets pot^{-1}, and the lowest value recorded for the number of grains was 16.45 in the third level, and the percentage of increase was %18.41 F_2.

Keywords: salinity , wheat, nano fertilizer, number of grains

Introduction

Wheat is one of the most important cereal crops and belongs to the Poaceae family, which is cultivated over large areas in the world, occupying approximately 215 hectares. It is considered a primary source for bread production in many countries of the world, and is also an important source of proteins, calories, fats, vitamins and minerals. Wheat is also used in the production of some medicines, while wheat waste is used as animal feed. Because of the importance of wheat and its nutritional role, it is called the king of grains (8). The cultivation of this crop has witnessed a decline in Iraq, as its cultivation decreased from 6,238,000 tons during the year 2020 to 4,234,000 tons during the year 2021. As for Nineveh Governorate, the area cultivated with wheat amounted to about 2,700,000 dunums, with an average production of 5,348 kg/dunum (6).

The decline in wheat production is attributed to several reasons, including those related to environmental conditions such as the scarcity of water, which increases the dryness of the land, and those related to improper soil management such as poor fertilizer management and poor management of irrigation operations, which leads to increased soil salinity and thus a decrease in the areas of arable land and a decrease in soil fertility (5), at a time when the world is facing major challenges due to the increased consumption of wheat and the increased need for it, as the world's population is expected to reach (9) billion people by 2050 (28).

Most fertilizers added to the soil deteriorate and are lost due to adsorption, sedimentation and leaching, so nutrient loss must be reduced during fertilization to increase crop productivity by following new methods or applications and through nanotechnology, nanomaterials and nanofertilizers with effective properties to accelerate crop growth and control the release of nutrients that regulate plant growth and release nutrients on demand (18 and 17). Nanofertilizers are characterized by their high stability under different conditions with high use efficiency (3). Nanotechnology is promising in improving agricultural operations by maintaining and sustaining inputs in agricultural production and good management. Research carried out in the last two decades has focused on the subject of mineral nanoparticles NPs such as mineral chelates, slow-release micronutrients and zinc oxide (16). The importance of effective nanofertilizers has been indicated by studies and proven by results in terms of increasing the efficiency of nutrient use, higher yield and better quality. And a safe environment (19 and 23), it also increases the efficiency of the nutrients used and reduces the toxicity of soil organisms and the potential negative effects of using mineral fertilizers (2), plants absorb nano-fertilizers after dissolving them in water or soil solution and release nutrients in the form of dissolved ions like the ions they take from traditional fertilizers but with a high dissolution rate and a wider range in water or soil solution due to the small size of their particles and their high surface area (26).

Materials and Methods

Collecting soil samples and preparing them for study:

Three sites were chosen from Nineveh Governorate within the (Tel Abta) area due to the importance of these sites from an agricultural standpoint as they are grown with grain crops and irrigated supplementally depending on the difference (rainfall range, vegetation cover, variation in salt distribution). Excited samples were taken at a depth of (0 - 30) cm. On 10/5/2023 from the study sites, Table (3), samples were taken to prepare them for cultivation for analyzes and laboratory studies according to the methods mentioned in (23).

Table (1) The spatial and geographical location, nature of agricultural exploitation, degree of salinization, and type of irrigation used for the study sites

Location	Soil type	geographical location	agricultural exploitation	type of irrigation
Western Tell Abta (S_1)	Non-salty	35°523.5N 42°3246.3E	Field crops	Without irrigation
Southern Tell Abta(S_2)	Salty	35°5131.9N 42°3157.8E	Field crops	Well water irrigation
Southern Tell Abta(S_3)	Salty	35°5132.5N 42°3158.8E	Field crops	Well water irrigation

Chemical and physical analyses

The soil extract (1:1) was used to estimate dissolved ions. The electrical conductivity (EC) and the degree of soil reaction (pH) were measured using the WTW Multi 4001 device (Rowell, 1996). Calcium and magnesium were calibrated with (0.01N) of ferricin (EDTA di -Na) (Rowell, 1996), I use a Shewood model 410 flame photometer to measure both sodium and potassium in the soil extract after adjusting the device with standard solutions and based on (27), carbonates and bicarbonates by calibration with (0.01N). of sulfuric acid and using the phenonphthalene index to estimate carbonates and the methyl orange index in the case of bicarbonate. Chlorides were estimated by titration with (0.01N) of silver nitrate (AgNO3 (27). Sulfates were calculated from the difference between the sum of dissolved positive ion equivalents and dissolved negative ion equivalents organic matter was estimated by the wet oxidation method using potassium dichromate ($K_2Cr_2O_7$) (21), total carbonates (lime) were estimated by titration method with hydrochloric acid at a concentration of (1M) phenolnaphthalene index (9), it was Gypsum was estimated by the acetone precipitation method according to the method used by (14). The hydrometer method was used to estimate soil separations of clay, silt, and sand, according to what was mentioned by (10). The bulk density was estimated by the paraffin wax method (12).

Implementation of the experiment

Plastic pots with a diameter of (25 cm) and a depth of (35 cm) were filled with (7) kg of air-dry soil and sifted through a sieve with a diameter of (4 mm). (10 seeds) of wheat variety (durum desf) were planted in each pot at a depth of (1 cm) from the soil surface, taking into account the selection of healthy seeds of similar sizes. After (10) days of planting, the plants thinned to only three plants per pot. As for the irrigation process, the experimental plants will be placed below 75% of the field capacity of the soil, using water (the Tigris River) throughout the experiment period, and the irrigation process will be conducted using the gravimetric method by weighing each pot and then adding water to the pot for the purpose of obtaining the wet weight.

Experiment design: The experiment will be implemented according to a completely randomized design with three replications as a factorial experiment with three factors:

The first factor: Three levels of soil salinity are:A non-saline comparison soil of less than (0.6 dS m^{-1}) at the western Tell Abta (S_1), a soil with an electrical conductivity of (4.1 dS m^{-1}) at the southern Tell Abta (S_2), a soil with an electrical conductivity of (7.8 dS m^{-1}) The southern Tell Abta (S_3).

The second factor: ground fertilization: The neutral NPK nanofertilizer (20:20:20) will be used, which is produced by Al-Khadra Nano Fertilizer Company, at three levels as a ground additive mixed with the soil before planting. The comparative added levels are (0) kg ha^{-1}, (10) kg ha^{-1}, (18). kg ha-1, noting that the manufacturer's fertilizer recommendation is (8 - 15) kg ha^{-1}.

The third factor: foliar fertilization: Neutral NPK nanofertilizer (20:20:20) will be used at three levels, noting that the fertilizer recommendation for the manufacturer's foliar application is (2) gm L^{-1} (3). The foliage of the plants will be sprayed using nano-fertilizer in two stages of the plant's life. The first spray is in the branching stage, the second spray is in the stem elongation stage, spraying evenly and in all directions until complete wetness, with the addition of a spreading material to the fertilizer solution in the form of drops of liquid washing powder to increase the efficiency. Absorption process, spraying the control plants with distilled water only with the diffuser, the concentration added to the comparison treatment is (0) gm L^{-1}, (2) gm L-1, (3) gm $^{L-1}$.

Statistical analysis: The results are analyzed statistically according to the design used, using the computer, and using the Duncan test.

Results and discussion

Soil salinity and ionic composition:

The results shown in Table (2) show that the ionic composition and electrical conductivity at the western Tel Abta site (S_1) is that the site is not saline, which gives a clear indication that the soil in this site was subject to washing due to the rain falling during that year and the lack of use of salty irrigation water. . As for the southern site of Tell Abta (S_2), the table shows that the electrical conductivity value is at the critical level (4.1 dS m^{-1}), unlike the site of Tell Abta al-Dimi, which indicates the active role of the rise of water through capillary action, since this site is agriculturally exploited and was irrigated with salt water from wells. At the southern Tel Abta site (S_3), the electrical conductivity value was high (7.8 dS m^{-1}) due to the use of salty well water and the failure to use sufficient leaching requirements. The results showed high values in its content of sodium, calcium, magnesium, chlorine, and sulfate, while the potassium ions and bicarbonate were The behavior is opposite with a lower content than other ions of the site (S_3). As for the southern Tel Abta site (S_2), which was at the beginning of the salinization process, Table (2) shows that the behavior of the ion distribution was an increase in the concentration of sodium and chloride more than the concentration of other ions.

The accumulation of dissolved salts is a common characteristic in the soil of the region because the rate of evaporation from it is greater than the rate of rainfall. Therefore, the mechanism of movement and distribution of salts is an important matter in exploiting dry soils and improving their management. The accumulation of salts as a function of electrical conductivity in the cores of the studied soils makes them classified among the soils affected by salts. Because the value of electrical conductivity in the two sites of southern Tel Abta (S_2 and S_3) is greater than (4 ds m^{-1}), and the increase in the concentration of salts in the surface layers indicates that the movement of salts occurs upward by capillary action, and that the temperatures in the region are high, there is intense evaporation, and there is no Effective drainage that allows the accumulated salts to be transferred out of the soil Bedon.

The concentration of dissolved ions in the non-saline and saline study sites. As shown in Tables (2), the dissolved sodium in the soils not affected by salts ranged between (1.1-25.5) $mmol_c$ L^{-1}, while the values of dissolved potassium ranged between (0.07-0.20) $mmol_c$ L^{-1}. The values of dissolved calcium ranged between (3.0 - 30.1) $mmol_c$ L^{-1}, while the values of dissolved magnesium ranged between (2.1 - 25.1) $mmol_c$ L^{-1}. The sequence of positive ions according to their dominance in the western Tel Abta site (S_1), which is not affected by salts, is as follows: :

$$Ca^{+2} > Mg^{+2} > Na^{+1} > K^{+1}$$

The sequence of positive ions according to their dominance in the southern Tel Abta site (S_2) affected by salts was as follows:

$$Na^{+1} > Ca^{+2} > Mg^{+2} > K^{+1}$$

The sequence of positive ions according to their dominance in the southern Tel Abta site (S_3) affected by salts was as follows:

$$Na^{+1} > Ca^{+2} > Mg^{+2} > K^{+1}$$

As for the distribution of dissolved ions, their distribution in the study sites was: the values of dissolved chlorides ranged between (2.2 - 58.2) mmol, charge L-1, and the values of dissolved sulfates ranged between (2.9 - 20.1) mmol, charge L-1. Finally, the values of dissolved bicarbonate ranged between (1.1 - 2.1) Millimole charge per liter-1, and this clearly reflects the role of the prevailing salinization processes due to the effect of incorrect and suboptimal irrigation of these soils on the dissolved ionic species content of the soil. The sequence of negative ions according to their dominance in Western Tell Abta (S_1), soils not affected by salts, was as follows:

$$SO_4^{-2} > Cl^{-1} > HCO_3^{-1}$$

While its sequence in the southern Tel Abta site (S_2), which was affected by salts, was as follows:

$$Cl^{-1} > SO_4^{-2} > HCO_3^{-1}$$

While its sequence in the southern Tel Abta site (S_3), which was affected by salts, was as follows:

$$Cl^{-1} > SO_4^{-2} > HCO_3^{-1}$$

Table (2) Physicochemical properties of the liquid phase of the soils of the study sites

Soil type		**S1**	**S2**	**S3**
Properties		Non-salty	Salty	Salty
Depth		0 – 30 cm	0 – 30 cm	0 – 30 cm
pH		7.2	7.0	7.0
EC_e (dS m^{-1})		0.6	4.1	8.0
CEC $cmol_c$ kg^{-1}		29.5	28.5	25.6
OM (g kg^{-1})		10.6	10.20	9.2
$CaCO_3$ (g kg^{-1})		37.1	35.5	34.0
$CaSO_4$ (g kg^{-1})		0.45	2.30	4.65
ρb (Mg m^3)		1.2	1.2	1.2
gm $100gm^{-1}$	Clay	59.7	59.5	57.2
	Silt	20.3	10.5	15.3
	Sand	20.0	30.0	27.5
texture		Clay	Clay	Clay
dissolved ions mmo_Cl L^{-1}	Na^{+1}	1.1	16.1	25.5
	K^+	0.07	0.12	0.20
	Ca^{2+}	3.0	13.2	30.1
	Mg^{2+}	2.1	12.5	25.1
	HCO_3^{-1}	1.1	1.5	2.1
	CO_3-^{2}	Nil	Nil	Nil
	Cl^{-1}	2.2	22.3	58.2
	SO_4^{-2}	2.9	18.1	20.1
%	N	0.0058	0.0053	0.0049
gm k^{-1}	P	1.70	1.45	1.30

Figure (1) shows the theoretical correlation of salts for the study sites, and it was in the presence of the predominant salts in the non-salt Western Tell Abta site (S_1), in the following order: ($MgCl_2$, $CaSO_4.2H_2O$, $Ca(HCO_3)_2$, Na_2SO_4, NaCl, K_2SO_4) at a rate of (33.8). %, 30.6, 17.7, 15.0, 1.0, 1.6)%, As for the western Tel Abta saline site (S_2), the sequence of salts was in the following order: ($MgCl_2$, $CaSO4.2H_2O$, NaCl, Na_2SO_4, $Ca(HCO_3)_2$, K_2SO_4) at a rate of (29.7, 28.5, 23.8, 14.0, 3.5, 0.2).)%, and in the western Tel Abta saline site (S3), the sequence of salts was in the following order: ($CaSO_4.2H_2O$, NaCl, $MgCl_2$, $CaCl_2$,

$Ca(HCO_3)_2$, Kcl) at a rate of (32.0, 29.2, 28.7, 7.3, 3.5, 0.2)%.
Based on the results of theoretical correlation, the salts in the western Tell Abta (S_3) salt site are sulfate composed of sodium chloride mixed with magnesium chloride sabkha. Likewise, the soil solution is saturated with calcium sulfate when the ratio of soil to water is (1:1), which is the product of precipitation. Chemistry at different depths of freshwater and near-surface terrestrial water with calcium and sulfate ions. This is during the rise of this water by capillary action and being subjected to evaporation until it reaches the point of saturation. Then these salts decompose into positive and negative ionic species after dissolving in the soil solution. When the water evaporates from its electrolyte solutions, the ions will move toward precipitation, forming multiple salts depending on the result of dissolution, and that the first The salts that are least soluble in water precipitate, while the most soluble and highly hydrated salts remain that precipitate in the end. Accordingly, the percentages of the dominant salts out of the total total salts were calculated by the theoretical combination of positive and negative ions according to what was reported by (30). The ions combine and salts are formed according to the solubility of these salts. The more soluble the less precipitated, and vice versa. The appearance of a salt Magnesium chloride may be due to cation exchange between sodium in the soil solution with calcium in the exchange complex, and this confirms the fact reached by (13) when discussing the source of magnesium chloride and its appearance in the soil solution at levels High salinity means the displacement of magnesium chloride from the exchange complex by sodium.

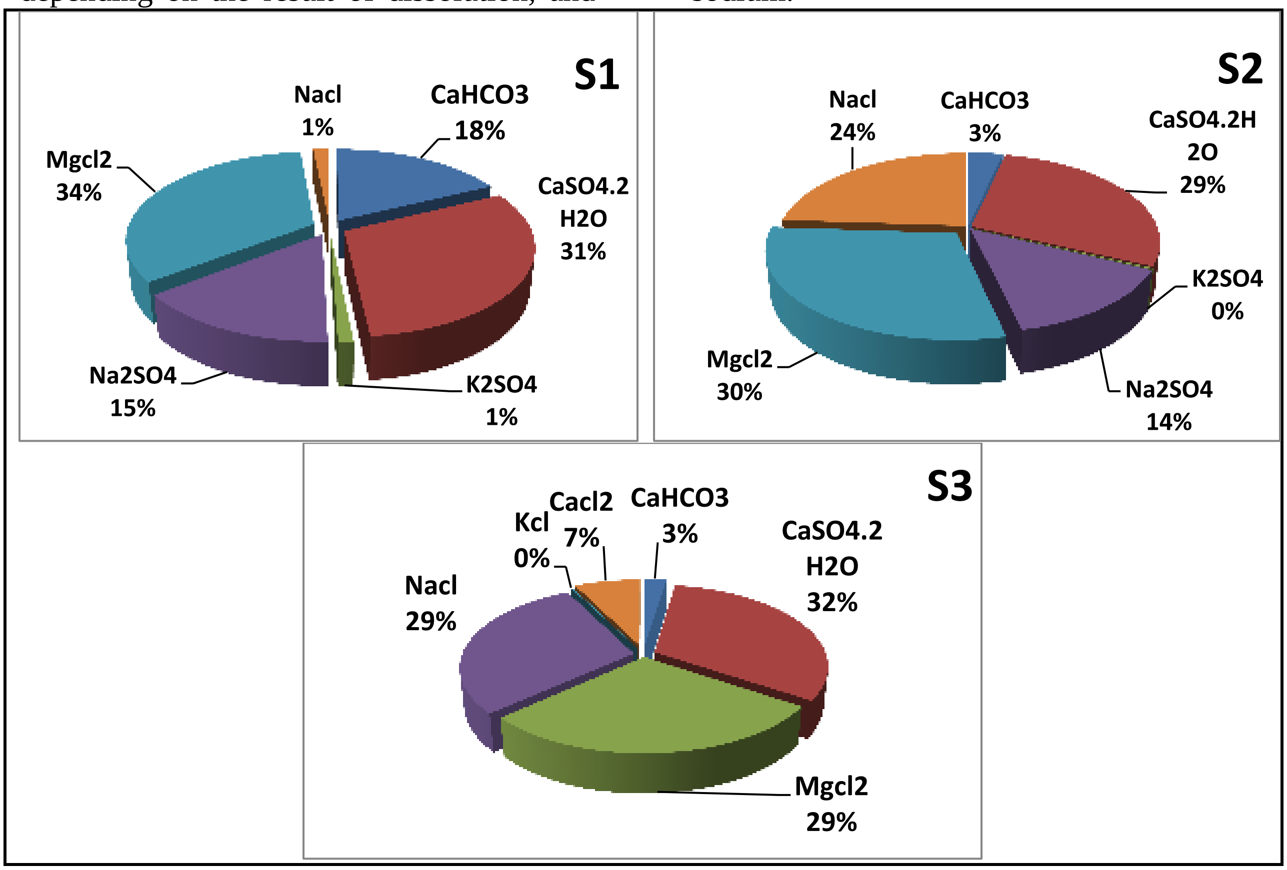

Figure (1) The percentage of salts prevailing in the study sites

Dry weight of the vegetative group (gm pot^{-1})

The results in Table (3) show the effect of salinity and NPK nano-compound fertilization on the dry weight of the vegetative group (straw). It is noted from the table the effect of salinity on the dry weight of the straw, as the lowest value for the dry weight was recorded in S_2 1.23 gm Pot-1,

while the highest value was recorded in the comparison treatment S_1 (1.71 gm Pot^{-1}), so it was significantly superior among the treatments. The effect of soil fertilization on the dry weight of the straw was the lowest value in G_1 1.19 gm Pot-1, while the highest value was recorded among the treatments $G_3$1.61 gm Pot-1, so it was significantly superior. It is noted in the effect of foliar fertilization, as the lowest value for the dry weight F_3 was recorded 1.32 gm Pot^{-1}, and the highest effect was recorded for foliar fertilization $F_1$1.56 gm Pot^{-1}. The table shows the effect of the binary interaction between salinity and soil fertilization, where the lowest value was recorded among the treatments S_2G_2 0.99 g Pot^{-1} and the highest value was recorded S_1G_2 2.01 g Pot^{-1}, while the effect of the binary interaction between salinity and foliar fertilization recorded the lowest value among the treatments S_2F_3 0.94 g Pot^{-1} while the highest value was recorded among the treatments S_1F_1 1.71 g

Pot-1. The binary interaction between soil and foliar fertilization reached the lowest value among the treatments G_2F_3 1.10 g Pot-1 and the highest value for straw dry weight was recorded G_3F_1 2.02 g Pot^{-1}, while the triple interaction between salinity, soil and foliar fertilization and their effect on dry weight recorded the lowest value among the treatments $S_2G_3F_3$ 0.7 g Pot^{-1} while the highest value among the treatments $S_1G_2F_3$ 2.43 g Pot-1. The results showed that there are significant differences between some treatments. Studies conducted in Egypt, evaluating the effect of nano-fertilizers on wheat plants exposed to salinity stress, showed that the use of nano-fertilizers led to a significant improvement in plant growth, dry matter accumulation and grain productivity under saline conditions. The use of nanofertilizers has enhanced nutrient uptake and physiological responses, indicating their potential as a viable solution to mitigate the effects of salinity on agriculture (7).

Table (3) Effect of salinity and nano NPK compound fertilizer on dry weight

Salinity	Ground fertilization	Foliar fertilization			Salinity effect	effect of ground fertilization		salinity x ground fertilization
		F1	F2	F3				
	G1	1.28	1.2	1.29	1.32	G1	1.187	1.26
S_1	G2	1.88	1.72	2.43				2.01
	G3	1.97	1.9	1.81				1.89
	G1	1.53	1.1	0.97	1.32	G2	1.508	1.2
S_2	G2	0.94	0.89	1.16				0.99
	G3	2.59	1.21	0.7				1.5
	G1	1.07	1.2	1.05	1.32	G3	1.615	1.1
S_3	G2	1.5	1.82	1.24				1.25
	G3	1.51	1.6	1.25				1.46
Effect of foliar fertilization		1.58	1.40	1.32	Least significant difference:			
salinity x foliar fertilization	S1	1.71	1.60	1.84	For salinity: 0.429			
	S2	1.68	1.06	0.943	For soil fertilization: 0.429			
	S3	1.36	1.54	1.18	For foliar fertilization: 0.429			
ground x foliar fertilization	G1	1.29	1.16	1.10	For salinity × soil: 0.743			
	G2	1.44	1.47	1.61	For salinity × foliar: 0.743			
	G3	2.02	1.57	1.25	For soil × foliar: 0.743			
					For salinity × soil × foliar: 1.287			

Number of spikes:

It is noted from the results of the table (4) the effect of salinity and nano NPK fertilization on the number of spikes per pot. It is noted from the table that the effect of salinity recorded the highest value in the number of spikes in the comparison treatment, where S_1 reached 3.70 pot spike^{-1}, while the lowest value was recorded in S_2 3.04 pot spike-1. As for the effect of ground fertilization, it recorded the highest value among the treatments in the number of spikes per pot G_2 3.62 pot spike^{-1}, while the lowest value was recorded among the comparison treatments G_1 3.04 pot spike^{-1}. As for the effect of foliar fertilization, the highest value was recorded among the treatments F_3 3.38 pot spike^{-1}, while the lowest value was recorded in the number of spikes F_2 3.22 pot spike^{-1}. As for the interaction between salinity and ground fertilization, the treatment was higher in the number of spikes S_1G_2 4.78 spikelets Pot-1, while the lowest value was recorded among the number of spikes for the binary effect S_2G_2 and S_3G_1 3 spikelets Pot^{-1}. As for the binary interaction effect between salinity and foliar fertilization, the highest value was recorded among the treatments S_1F_3 4 spikelets Pot-1, while the lowest number value was recorded among the treatments S_2F_1, S_2F_2, S_3F_2, and S_3F_3 3 spikelets Pot^{-1}, as the treatments outperformed significantly. As for the triple interaction between salinity, soil fertilization, and foliar fertilization, the highest treatment in the number of spikes $S_1G_2F_3$ was 5.67 spikelets Pot^{-1}, while the lowest value was recorded among the treatments in the triple interaction $S_1G_1F_1$ $S_1G_1F_3$ and $S_1G_3F_1$ and $S_2G_1F_1$ and $S_2G_1F_2$ and S2G2F1 and S2G2F2 and S2G2F3 and S2G3F1 and S2G3F2 and S3G1F1 and S3G1F2 and S3G1F3 and S3G2F2 and S3G2F2 and S3G2F3 and S3G3F2 and S3G3F3 3 spike Pot^{-1} The treatments were significantly superior. The increase in the number of spikes in the fertilized soil as a result of adding nano fertilizer in the ground and foliar methods may be attributed to improving the characteristics of vegetative growth of the plant in general, as nano fertilizer works to improve the utilization of effective rays for the photosynthesis process, which contributes to increasing the availability of materials that support the emergence of seedlings. This is positively reflected in increasing the number of spikes in the cultivated area as a result of increasing the concentrations of ready-made NPK nutrients. The results are consistent with what was reached by (15). Another reason is attributed to the plant's absorption Nutrients uptake by the stomata leads to increased plant growth and thus development (22). According to several studies, the application of nanofertilizers has been effective in mitigating the toxic effects of salt stress in different plants. Foliar application of potassium nanofertilizers in salt-sensitive alfalfa plants was found to improve salt tolerance by enhancing proline and antioxidant enzyme content (11). Studies have shown that reduced oxidative stress led to enhanced antioxidant activity in millet plants treated with nanofertilizers, which led to reduced sodium uptake in the leaves. Data increasingly indicate that the application of nanofertilizers to plants can significantly reduce the harmful effects of salt stress, thus controlling plant adaptation (1).

Table (4) Effect of salinity and nano NPK fertilizer on the number of spikes per pot

Salinity	Ground fertilization	Foliar fertilization			Salinity effect	effect of ground fertilization		salinity x ground fertilization
		F1	F2	F3				
S_1	G1	3	3.33	3	3.703	G1	3.04	3.11
	G2	4.33	4.33	4.33				4.78
	G3	3.0	3.33	3.0				3.22
S_2	G1	3.0	3.0	3.0	3.049	G2	3.62	3.04
	G2	3.0	3.0	3.0				33.0
	G3	3.0	3.0	3.0				3.11
S_3	G1	3.0	3.0	3.0	3.148	G3	3.22	33.0
	G2	3.33	3.0	3.33				3.11
	G3	4.0	3.0	4.0				3.33
Effect of foliar fertilization		3.29	3.22	3.29				
salinity x foliar fertilization	S1	3.44	3.66	3.44	Least significant difference: For salinity: 0.377 For soil fertilization: 0.377 For foliar fertilization: 0.377 For salinity × soil: 0.653 For salinity × foliar: 0.653 For soil × foliar: 0.653 For salinity × soil × foliar: 1.132			
	S2	3.0	3.0	3.0				
	S3	3.44	3.0	3.44				
ground x foliar fertilization	G1	3.0	3.11	3.0				
	G2	3.55	3.44	3.55				
	G3	3.33	3.11	3.33				

Number of grains in spike:

Table results (5) The effect of salinity and fertilization on the number of grains per spike, it is clear from the table values that the effect of salinity on the number of grains in the comparison treatment was greater as $S_1$26.44 spike grain-1 was the highest value, while the lowest value was recorded in the second level as S_2 was 9.38 spike grain^{-1}, while the effect of soil fertilization was higher in the third level as it was G_3 21.33 spike grain^{-1} and the lowest value was recorded in the comparison treatment as it was G_1 12.71 spike grain^{-1} and the increase rate was 67.82%. There were significant differences between the treatments, while the effect of foliar fertilization was the highest value at the second level, which recorded significant differences and the rate was 19.48 spike grain-1 and the lowest value recorded for the number of grains was 16.45 in the third level and the increase rate was 18.41F2%. As for the effect of the binary interaction between salinity and soil fertilization, the highest value was recorded in S_1G_2 in the comparison treatment, where it reached 30.67 grains spike^{-1}, and the lowest value was recorded in S_2G_3, which reached 7.56 grains spike^{-1}. As for the second binary interaction between salinity and foliar fertilization, the highest value was recorded in S_1F_3 from the comparison treatment, where it reached 32.22 grains spike^{-1}, while the lowest value was recorded in the S_2F_3 treatment, where it reached 6.33 grains spike^{-1}. While the interaction between the soil and foliar addition methods, the highest value recorded between the treatments was S_3G_3 26.44 grains spike^{-1}. The lowest value was recorded between the binary interaction with G_1F_1 13.03 grains spike-1, and the increase rate was 102.9%. The triple interaction between salinity and the method of adding soil and foliar fertilizers. There were significant differences between the observations. The highest value between the treatments was $S_1G_2F_3$ 42.67 grains spike^{-1} and the lowest value was 4 grains spike^{-1}. The reason for the increase in the number of grains at a level without the salinity factor is attributed to the availability of nutrients, especially nitrogen, and the lack of tension or osmotic pressure, which facilitates the growth process in the early growth stages of seedling growth and development, which helps in increasing the process of photosynthesis, which in turn contributes to increasing the beginnings of the spikes in which the grains are. This helps in reducing abortion in the flowering process and reducing the state of competition for nutrients. These results are consistent with (4). The reason may also be attributed to the effective role of nano-fertilizers in delivering nutrients to the plant by spraying them on The vegetative group or by adding it to the soil, which increases the efficiency of fertilizer use and reduces the loss of nutrients. This increases the processes of pollination and fertilization, thus increasing the number of grains (19). Nano-fertilizers cause a variety of morphological, physiological and biochemical changes in plants because they increase their resistance to salt stress by increasing the hydraulic conductivity of the plant root and water absorption and showing a different abundance of proteins involved in reducing oxidation and detoxification. Nano-fertilizers also delay the release of nutrients and thus prolong the period of fertilizer effect, which reduces the effect of salts on plant growth. It is clear that there is an opportunity for nanotechnology to have a significant impact on energy, economy and the environment (19).

Table (5) Effect of salinity and nano-NPK fertilizer on the number of grains per spike

Salinity	Ground fertilization	Foliar fertilization			Salinity effect	effect of ground fertilization	salinity x ground fertilization
		F1	F2	F3			
	G1	18.33	16	22.33			18.89
S_1	G2	22.33	27	42.67	26.44	G1 12.71	30.67
	G3	20.0	37.67	31.67			29.78
	G1	10.78	11.33	6.33			9.48
S_2	G2	13.0	11.67	8.67	9.38	G2 19.28	11.11
	G3	9.33	9.33	4.0			7.56
	G1	10.0	13.0	6.33			9.78
S_3	G2	22.44	17.0	8.78	17.28	G3 21.11	16.07
	G3	28.33	32.33	17.33			26.0
Effect of foliar fertilization		17.17	19.48	16.45	Least significant difference: For salinity: 7.88		
salinity x foliar fertilization	S1	20.22	26.89	32.22	For soil fertilization: 7.88		
	S2	11.03	10.77	6.33	For foliar fertilization: 7.88		
	S3	20.25	20.77	10.81	For salinity × soil: 13.64		
ground x foliar fertilization	G1	13.03	13.44	11.66	For salinity × foliar: 13.64		
	G2	19.25	18.55	20.04	For soil × foliar: 13.64		
	G3	19.22	26.44	17.66	For salinity × soil × foliar: 23.63		

Conclusions

According to the results obtained, we recommend researchers to use other different types of nano-fertilizers and different concentrations with wheat crop because it is considered a strategic crop and this type of fertilizer can be used with other crops because this technology is considered one of the modern technologies that has proven its efficiency as an alternative to traditional chemical fertilizers. The results in this study showed that wheat crop with medium tolerance to salinity can give a good percentage of production when grown in medium-saline soils with the use of nano-fertilizer technology that helps the plant to tolerate salt stress and drought stress.

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