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Foliar Application of Moringa Extract and Nanoparticles to Improve Performance Growth, Yield and Quality of Garlic Plants Grown on Saline Soil

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ABSTRACT

Nanotechnology can put advents for increasing yields to support agricultural sector and decreasing environmental risks. Also, natural plant extracts can stimulate the performance of plants grown on salt affected soil. A little is known about the joint effects of external application of moringa extract plus foliar spraying with Nanoparticles on garlic plants grown on saline soil. So, a field research work was executed aiming at assessing the influence of the external applications of moringa extract [with (30 ml L^{-1}) and without foliar spray, as main plots], copper oxide Nanoparticles (CuO NPs) as sub plots at different rates *i.e*, 0.0, 1.0 and 2.0 ng L^{-1} and magnetite iron oxide Nanoparticles (Fe_3O_4 NPs) as sub-sub plots at different rates *i.e*, 0.0, 2.0 and 4.0 ng L^{-1} on the performance of garlic plants grown on saline soil at two periods (100 and 180 days from planting). The findings indicate that the garlic plants grown on saline soil with foliar application of moringa extract had the best performance compared to the corresponding garlic plants grown without external application of moringa extract. On the other hand, the plant improvement increased as the rate of NPs increased. Generally, the best performance was recorded when garlic plants were sprayed in combination with moringa extract (30 ml L^{-1}), CuO NPs (2.0 ng L^{-1}) and magnetite Fe_3O_4 NPs (4.0 ng L^{-1}) compared to other combined treatments. Generally, it can be concluded that studied substances acted to mitigate the influences of salinity stress of soil on garlic plants.

Keywords: Nanotechnology, salt affected soil, CuO NPs, Fe_3O_4 NPs and garlic plants.

INTRODUCTION

Soil salinity is one of the biggest factors limiting plant performance in the agriculture sector especially in arid and semiarid regions such as Egypt, where saline soils represent about 30 % of the total cultivated area of Egypt (FAO 2005). Currently, it is known that the salinity of soil has a harmful influence on plants growth performance and crops yield through raising the production of reactive oxygen species (ROS) responsible for damage of plant cells (Othman, 2021).

A little reports show that moringa leaf extract is involved in salt-stress tolerance (Howladar, 2014; Merwad, 2017 and Hassan *et al.*, 2020). Moringa (*Moringa oleifera*) belongs to Moringnance family and it is rich in vitamins *e.g.*, V.A and V.C and nutrients *e.g.*, iron, calcium and antioxidants *e.g.*, phenolics (Matthew, 2016). Also, it possesses a sufficient quantity of cytokinins (Biswas *et al.*, 2016). Even though knowledge about the high content of moringa of mineral, sugars, amino acids, antioxidant and phytohormones, but scanty reports are available discussing the amelioration of salt stress by moringa extracts. For example, Abdel Latef *et al.*, (2017) reported that foliar application of moringa leaf extract could mitigate the harmful influence of salinity on fenugreek plants.

Nanotechnology monitors a leading agricultural controlling process, especially by its miniature dimension (Shalaby *et al.*, 2016).The ambition of Nanoparticles in agriculture is to reduce the amount of spread chemicals, minimize nutrient losses in fertilization and increased yield through pest and nutrient management. Nanotechnology is a brilliant solution to many common issues in the agricultural field in Egypt including the urgent need to reduce synthetic fertilization, where many research works have confirmed that Nanoparticles have a special attributes that do not exist in their conventional counterparts (Helaly *et al.*, 2014; Dewdar *et al.*, 2018 and Sofy *et al.*, 2021).

Garlic (*Allium sativum* L.) plants are one of the most important vegetable bulbs and spice crops in Egypt. After onion, it is the 2nd most widely used cultivated bulb crop in Egypt (Samy and El-Zohiri, 2021). It is used for local consumption and exportation, where it has a high medical value (El-Shal *et al.*, 2021). Its total cultivated area in Egypt according to FAO, (2019) reached 15503 ha with total production exceeding 318800 tons.

Therefore, this investigation aims to evaluate the effect of moringa extract and nanoparticles on improving the performance growth, yield and quality of garlic plants grown on saline soil.

MATERIALS AND METHODS

A field research work was executed in a private farm located in El-Serw area, Damietta Governorate, Egypt during two successive seasons of 2017/2018 and 2018/2019 aiming at assessing the influence of the external applications of moringa extract [with (at rate of 30 ml L^{-1}) and without foliar spray, as main plots], copper oxide Nanoparticles (CuO NPs) as sub plots at different rates *i.e*, 0.0, 1.0 and 2.0 ng L^{-1} and magnetite iron oxide Nanoparticles (Fe_3O_4 NPs) as sub-sub plots at different rates *i.e*, 0.0, 2.0 and 4.0 ng L^{-1}

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on the performance of garlic plants grown on saline soil at two periods (100 and 180 days from planting).

1. Soil Sampling:

The analyses of initial soil sample (taken at depth of 0-25 cm) were done before execution of the current research work according to Dane and Topp (2020) and Sparks *et al.* (2020), where Table 1 shows the initial soil attributes.

Table 1. Characteristics of the initial soil.

Mechanical analysis	Values	Chemical properties	Values
Sand,%	19.87	Organic matter,%	1.99
Silt ,%	32.61	$CaCO_3$, %	1.75
Clay,%	47.52	EC_w, dS m^{-1}	5.85
Texture is class clay		pH (1:2.5 soil suspension)	7.90

2. Garlic Cloves Used in Cultivation:

Garlic cloves (Cv. Balady) were obtained from the Ministry of Agri. and Soil Rec (MASR), where it is a local cultivar grown in Egypt for its strong aroma which the mature cloves have white covering scale.

3. Substances Studied:

Moringa extract.

Young leaves and branches of moringa were taken from young full-grown trees. Moringa extraction was executed according to Yasmeen, (2011), by grinding leaves and branches with a pinch of water (1.0 L 10.0 kg^{-1} fresh material) using an extraction machine. After sieving through cheesecloth the extract was centrifuged for 15 min at 8000 × rpm.

Chemical composition of natural extract of moringa is shown in Table 2.

Table 2. Chemical composition of natural extract of moringa.

Components		Values
Super oxide dismutase (SOD)	(IU min $^{-1}$	193.2
Peroxidase (POD)	mg $^{-1}$	22.30
Catalase (CAT)	protein)	6.950
Total soluble protein (mg g $^{-1}$)		1.40
Total phenolic contents (mg g $^{-1}$ GAE)		8.00
Ascorbic acid (m mole g $^{-1}$)		0.40
N,%		2.10
P,%		0.25
K,%		1.98
Ca,%		2.15
Mg,%		0.01
Fe, mg kg^{-1}		600

Nanoparticles.

Copper oxide and magnetite Fe_3O_4 Nanoparticles were obtained from National Research Center, Egypt.

Physicochemical properties of copper oxide and magnetite Fe_3O_4 Nanoparticles were characterized via TEM imaging Figs 1 and 2.

The images of the synthesized copper oxide Nanoparticles reveal a spherical shape and an average particle size of 12.9 to 29.0 nm (Fig1), while the images of the synthesized magnetite Fe_3O_4 Nanoparticles reveal a spherical shape and an average particle size of 12.5 to 17.5 nm (Fig 2).

Fig 3 shows the X-ray diffraction (XRD) pattern of copper oxide and magnetite Fe_3O_4 Nanoparticles.

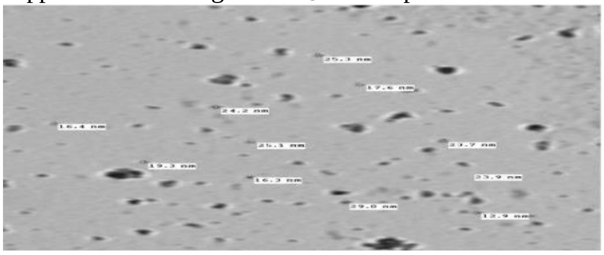


Fig. 1. TEM imaging of the prepared copper oxide Nanoparticles revealed a spherical shape of the particles, with an average size of 12.9-29.0 nm (inset shows electron diffraction pattern).

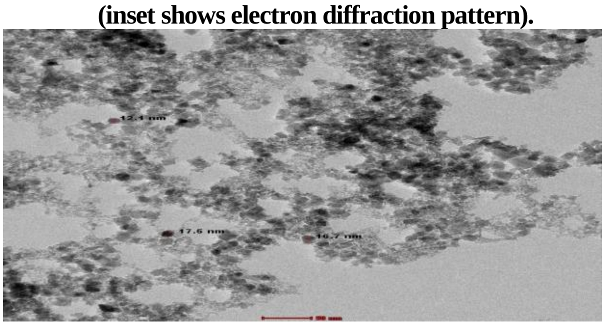
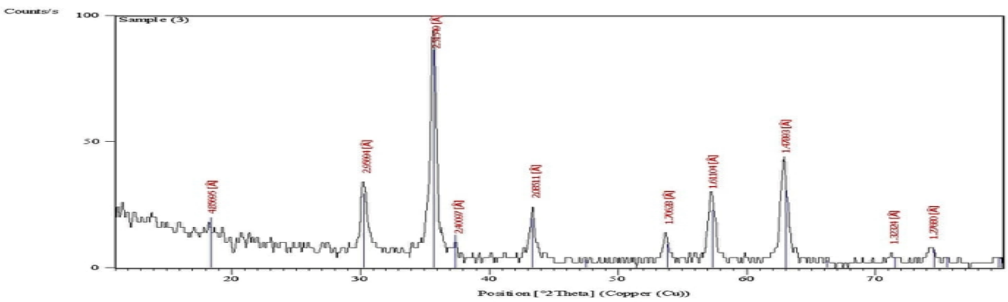
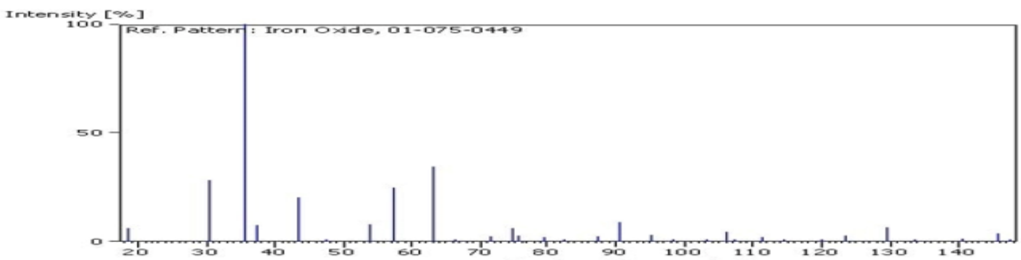


Fig. 2. TEM imaging of the prepared magnetite Fe_2O_3 nanoparticles revealed a spherical shape of the particles, with an average size of 12.1-17.5 nm (inset shows electron diffraction pattern).



Copper oxide Nanoparticles



Magnetite Fe_3O_4 Nanoparticles

Fig. 3. X-ray diffraction (XRD) pattern of Nanoparticles.

4. Experimental Design and Cultivation:

The trial was allocated in a spilt split-plot design with three replicates. Prior to sowing were split into the individual cloves, where the cloves were exposed to running water for 18 hours before planting. Main plots were pre-irrigated one day before sowing and cloves were sown, where the cloves were sorted to select the largest cloves (uniform and healthy cloves). Garlic cloves were manually planted on one side of the ridges at a distance of 10 cm apart on September 1st during both studied seasons. The experimental area was 86.4 m² consisted of eighteen ridges; each was 0.8 m in width and 6.0 m in length. Each sub subplot contained three ridges, where each ridge was divided into 3 replicates.

5. Fertilization:

Fertilization process was done according to MASR. A month before sowing cloves, organic fertilizer was added at rate of 10.0 ton fed^{-1} as well as calcium superphosphate (15.5% P_2O_5) was added before planting at rate of 400 kg fed^{-1}. N and K fertilizers were added during plant life period, where ammonium sulphate (20.5% N) was added at rate of 800 Kg fed^{-1}, while potassium sulphate (48% K_2O) was applied at the rate of 100 kg fed^{-1}. Other traditional agricultural practices for garlic production were done according to MASR. After a period of 45 days from sowing, the external application of moringa extract and nanoparticles as a combined treatments was done with repeating three times with 3 weeks intervals.

6. Irrigation and Harvesting:

Irrigation process was done as garlic plants required using Nile River. Harvesting was done at maturity of bulbs (after 180 days from sowing).

7. Measurements.

At a period of 100 days from planting, five garlic plants from each sub sub-plot were taken for measuring the following parameters;

- Growth criteria expressed in No. of leaves plant^{-1}, fresh and dry weights (g plant^{-1}).
- Chlorophyll content (SPAD, reading value).
- Super Oxidase Dismutase (SOD, U min^{-1} g^{-1} FW) was determined using methods described by Alici and Arabaci, (2016).
- Malondialdehyde (MDA, nmol MDA g^{-1} FW) was analyzed using method of Heath and Packer (1968).

Also, five garlic plants from each sub sub-plot were taken when bulbs of garlic plants reached to the proper maturing stage (after 180 days from sowing) for measuring the physical bulb attributes *i.e.*, bulb diameter (cm), neck diameter (cm), bulbing ratio (BR) and No. of cloves bulb^{-1}, where BR was measured as the following formula according to Mann (1952);

$$BR = \frac{\textbf{Neck diameter (cm)}}{\textbf{Bulb diameter (cm)}}$$

Bulb yield and marketable yield (ton ha^{-1}) were measured. Also quality traits of bulbs *i.e.*, dry matter(%) vitamin C (mg 100g^{-1}), crude protein (%) , carbohydrates (%) were determined according to AOAC, (2000),while pungency (purvate content πmol.ml^{-1}) was estimated according to Anthon and Barrett (2003).

8. Statistical Analysis.

It was executed depending on Gomez and Gomez, (1984), using CoStat (Version 6.303, CoHort, USA, 1998–2004)].

RESULTS AND DISCUSSION

1. Performance of Garlic Plants at Period of 100 Days: Growth criteria and chlorophyll content:

Data of Table 3 show the individual influence of foliar applications of moringa extract, CuO NPs and magnetite Fe_2O_3 NPs at various rates as well as their interactions on growth criteria of garlic plants grown on saline soil expressed in No. of leaves plant^{-1}, fresh and dry weights (g plant^{-1}) and chlorophyll content (SPAD, reading value) at period of 100 days from planting during two seasons (2017/2018 and 2018/2019).

Individual effect*:*

Data of the same Table show that the garlic plants grown on saline soil with foliar application of moringa extract had the highest values of No. of leaves plant^{-1}, fresh and dry weights (g plant^{-1}) and chlorophyll content (SPAD, reading value) compared to the corresponding garlic plants grown without external application of moringa extract. The same trend was found in both studied seasons.

The positive effect of moringa extract treatment under salinity circumstances may be attributed to its contents of enzymatic and non- enzymatic antioxidants in addition to its high content of nutrients (as shown in Table 2), thus, it can be said that external application of moringa extract had an effective role in alleviating the salt stress-induced damages in garlic plants, where moringa extract application conferred the capacity to improve the garlic plant's growth performance, and stress tolerance under salinity circumstances. Our results are in harmony with those of Hegazi *et al.*, (2016) who studied moringa leaf extract application to achieving sustainable horticulture production and declared that performance of garlic plants was enhanced by moringa foliar application. Beside, Mohamed *et al.*, (2019) found that growth of garlic plants was increased with moringa foliar application.

Regarding foliar application of copper oxide NPs, the data of the same Table illustrate that the values of No. of leaves plant^{-1}, fresh and dry weights (g plant^{-1}) and chlorophyll content (SPAD, reading value) increased as rate of copper oxide NPs increased, where the external application of copper oxide NPs at rate of 2.0 ng L^{-1} was superior treatment followed by copper oxide NPs at rate of 1.0 ng L^{-1}, while the plants grown without copper oxide NPs (at rate of 0.0 ng L^{-1}) possessed the less values of all aforementioned traits. The same trend was found in the both studied seasons. The vital effect of copper element on garlic plant performance may be attributed to that it activated some enzymes in garlic plants which are involved in lignin synthesis in addition to its importance in several enzyme systems. Also, it is known that Cu required in plant metabolism of carbohydrates and proteins (Yruela, 2005).

Concerning foliar application of magnetite Fe_3O_4 NPs, the data of the same Table illustrate that the values of No. of leaves plant^{-1}, fresh and dry weights (g plant^{-1}) and chlorophyll content (SPAD, reading value) increased as rate of magnetite Fe_3O_4 NPs increased, where the external application of magnetite Fe_3O_4 NPs at rate of 4.0 ng L^{-1} was superior treatment followed by magnetite Fe_3O_4 NPs at rate of 2.0 ng L^{-1}, while the plants grown without magnetite

Fe_3O_4 NPs (at rate of 0.0 ng L^{-1}) possessed the less values of all aforementioned traits. The same trend was found in both studied seasons. The vital effect of iron element on garlic plant performance attributed to that it plays critical role in metabolic processes *e.g.*, respiration, DNA synthesis and photosynthesis, where it is involved in the chlorophyll synthesis in addition to its importance for the maintenance of chloroplast structure and function (Rout and Sahoo, 2015).

The superiority of Nanoparticles may be due to that Nano-fertilizers was more advantageous comparing with the conventional chemical fertilizers because Nanoparticles can triple the effectiveness of both Cu and Fe elements, thus reducing the requirement of Cu and Fe mineral fertilizers. Also, it can be said that Nanoparticles can increase the resistance of garlic plants to salinity in addition to being less hazardous to the environment (Suresh *et al.*, 2016 and Shankramma *et al.*, 2016).

Interaction effect:

Data elucidate that the highest values of No. of leaves plant^{-1}, fresh and dry weights (g plant^{-1}) and chlorophyll content (SPAD, reading value) for garlic plants grown on salt affected soil during both seasons were recorded when garlic plants were sprayed, in combination, with moringa extract (30 ml L^{-1}), CuO NPs at rate of 2.0 ng L^{-1} and magnetite Fe_3O_4 NPs at rate of 4.0 ng L^{-1} compared to other combined treatments. Generally, it can be noticed that studied substances acted to mitigate the influences of salinity stress of soil on garlic plant through reducing responses of garlic grown to the stress.. These results come in accordance with Hegazi *et al.*, (2016); Suresh *et al.*, (2016) ; Shankramma *et al.*, (2016) and Mohamed *et al.*, (2019).

Table 3. Impact of moringa extract and nanoparticles on growth performance of garlic plants at period of 100 days from planting during seasons of 2017/2018 and 2018/2019.

Treatments			Plant height, cm		No. of leaves plant^{-1}		Fresh weight, g plant^{-1}		Dry weight, g plant^{-1}		Chlorophyll, SPAD	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Moringa extract (main factor)												
Without (control)			68.67b	70.00b	6.37b	7.85b	71.34b	72.85b	17.03b	17.34b	34.27b	35.44b
Moringa extract			76.24a	77.87a	9.07a	10.81a	77.40a	79.35a	18.53a	18.89a	36.95a	38.36a
LSD at 5%			0.11	0.08	2.07	1.12	0.05	0.13	0.02	0.04	0.06	0.38
Copper nanoparticle levels (sub main)												
0.0 ng L^{-1} (control)			70.20c	71.59c	6.72b	8.17b	72.50c	73.98c	17.30c	17.63c	34.73c	35.95c
1.0 ng L^{-1}			72.82b	74.27b	7.89a	9.72a	74.77b	76.58b	17.87b	18.19b	35.80b	37.12b
2.0 ng L^{-1}			74.34a	75.94a	8.56a	10.11a	75.84a	77.75a	18.18a	18.53a	36.31a	37.63a
LSD at 5%			0.57	0.13	0.82	1.02	0.15	0.15	0.14	0.13	0.07	0.28
Iron nanoparticle levels (sub-sub main)												
0.0 ng L^{-1} (control)			71.30c	72.71c	7.22b	8.72a	73.34c	75.16c	17.51c	17.85c	35.10c	36.41b
2.0 ng L^{-1}			72.59b	74.09b	7.78ab	9.44a	74.58b	76.22b	17.83b	18.14b	35.71b	37.13a
4.0 ng L^{-1}			73.48a	75.00a	8.17a	9.83a	75.20a	76.93a	18.01a	18.36a	36.02a	37.16a
LSD at 5%			0.64	0.22	0.75	N.S	0.23	0.23	0.15	0.18	0.11	0.36
Interaction												
Without (control)	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	67.85lmn	69.15n	5.00k	5.67h	69.47n	70.65m	16.48o	16.80m	33.06o	34.25i
		2.0 ng Fe L^{-1}	65.72o	66.84q	5.33jk	6.33gh	69.73n	71.06m	16.59o	16.97lm	33.41n	34.76hi
		4.0 ng Fe L^{-1}	66.53no	67.70p	5.67ijk	7.00fgh	70.02n	70.86m	16.69no	17.02klm	33.67n	34.33i
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	67.33mn	68.61o	6.00hk	7.67eh	70.59m	72.21l	16.84mno	17.17klm	33.95m	35.31gh
		2.0 ng Fe L^{-1}	69.13kl	70.38m	6.67gk	8.6cg7	71.71l	73.43k	17.15klm	17.41ijk	34.58k	35.91fg
		4.0 ng Fe L^{-1}	70.14jk	71.55l	7.00fj	9.00bg	72.46k	74.06j	17.36jkl	17.63hij	34.86j	35.88fg
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	68.19lm	69.42n	6.67gk	8.00dh	71.22l	73.28k	17.01lmn	17.31jkl	34.23l	35.50gh
		2.0 ng Fe L^{-1}	71.12ij	72.61k	7.33ei	9.0bg0	73.10j	74.65i	17.50ijk	17.74ghi	35.19i	36.38ef
		4.0 ng Fe L^{-1}	71.97hi	73.71j	7.67dh	9.33af	73.76i	75.46h	17.68hij	18.00fgh	35.50h	36.62ef
Moringa extract	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	72.82gh	74.45i	8.00cg	9.67af	74.59h	76.38g	17.86ghi	18.16efg	35.79g	37.24de
		2.0 ng Fe L^{-1}	73.77fg	75.32h	8.00cg	10.00ae	75.30g	76.80g	18.01fgh	18.25ef	36.08f	37.55cd
		4.0 ng Fe L^{-1}	74.48ef	76.05g	8.33bg	10.33ae	75.89f	78.09f	18.18efg	18.55de	36.35ef	37.58cd
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	75.44de	76.72f	8.67bf	10.67ad	76.77e	78.78e	18.34def	18.74d	36.62e	37.79cd
		2.0 ng Fe L^{-1}	76.98cd	78.71d	9.33ad	11.00abc	78.16e	80.27d	18.68bcd	18.96cd	37.21c	38.71ab
		4.0 ng Fe L^{-1}	77.92bc	79.66c	9.67abc	11.33abc	78.91b	80.73bc	18.87bc	19.23bc	37.56b	39.09ab
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	76.15d	77.90b	9.00ae	10.67ad	77.40d	79.65d	18.52cde	18.91cd	36.93d	38.40bc
		2.0 ng Fe L^{-1}	78.80ab	80.67b	10.00ab	11.67ab	79.45b	81.12b	19.07ab	19.54ab	37.82b	39.45a
		4.0 ng Fe L^{-1}	79.82a	81.33a	10.67a	12.00a	80.13a	82.37a	19.27a	19.69a	38.17a	39.46a
LSD at 5%			1.57	0.53	N.S	N.S	0.56	0.58	0.39	0.43	0.28	0.87

Antioxidants:

Regarding garlic plant's self-production from Super Oxidase Dismutase (SOD, U min^{-1} g^{-1} FW) and Malondialdehyde (MDA, nmol MDA g^{-1} FW), the data of Table 4 show that salinity stress of soil (control treatment) led to raising SOD and MDA contents in garlic leaves at period of 100 days from planting, where the cultivation without any external applications caused an increase of garlic self-production from SOD and MDA to scavenge the free radicals or ROS and increase garlic tolerance to salinity stress.our results are in harmony with Abdel Latef *et al.* (2017) who reported that salinity stress boosted the contents of proline, MDA, the activity of catalase (CAT) and ascorbate peroxidase (APX).

Data in Table 4 illustrate that garlic plants grown without exogenous application of moringa extract contained SOD and MDA higher than garlic plants grown with exogenous application of moringa extract. Data of the same Table indicate that the garlic plants treated with CuO NPs at both studied rates produced SOD and MDA less than garlic plants grown without application of CuO NPs, where the lowest values of SOD and MDA were recorded with treatment of 2.0 ng L^{-1} CuO NPs. Also, the data of the same Table show that the garlic plants treated with magnetite Fe_3O_4 NPs at both studied rates produced SOD and MDA less than garlic plants grown without application of magnetite Fe_3O_4 NPs, where the lowest values of SOD and MDA were recorded with treatment of 4.0 ng L^{-1} magnetite Fe_3O_4 NPs.

Table 4. Impact of moringa extract and nanoparticles on antioxidants in leaves of garlic plants at period of 80 days from planting during seasons of 2017/2018 and 2018/2019.

Treatments			Super oxidase dismutase ($U\ min^{-1}\ g^{-1}$ FW)		MDA (nmol MDA g^{-1} FW)	
			1st	2nd	1st	2nd
Moringa extract (main factor)						
Without (control)			95.34a	97.20a	4.95a	5.06a
Moringa extract			90.68b	92.65b	4.18b	4.29b
LSD at 5%			0.05	0.02	0.07	0.07
Copper nanoparticle levels (sub main)						
0.0 ng L^{-1} (control)			94.59a	96.49a	4.86a	4.98a
1.0 ng L^{-1}			92.65b	94.45b	4.49b	4.58b
2.0 ng L^{-1}			91.79c	93.84c	4.36c	4.46c
LSD at 5%			0.16	0.16	0.05	0.05
Iron nanoparticle levels (sub-sub main)						
0.0 ng L^{-1} (control)			93.88a	96.10a	4.71a	4.83a
2.0 ng L^{-1}			92.82b	94.52b	4.53b	4.63b
4.0 ng L^{-1}			92.34c	94.16c	4.46c	4.56c
LSD at 5%			0.27	0.28	0.04	0.04
Interaction						
Without (control)	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	97.46a	99.20a	5.18a	5.29a
		2.0 ng Fe L^{-1}	96.89ab	98.48b	5.14ab	5.27ab
		4.0 ng Fe L^{-1}	96.43bc	98.38b	5.07bc	5.19bc
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	95.88cd	98.02bc	5.00cd	5.12cd
		2.0 ng Fe L^{-1}	94.79ef	95.89d	4.89ef	4.99ef
		4.0 ng Fe L^{-1}	94.33fg	96.46d	4.83fg	4.92fg
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	95.26de	97.50c	4.96de	5.09de
		2.0 ng Fe L^{-1}	93.75gh	95.96d	4.78gh	4.89gh
		4.0 ng Fe L^{-1}	93.32hi	94.90e	4.72hi	4.81hi
Moringa extract	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	92.78ij	95.19e	4.65ij	4.78ij
		2.0 ng Fe L^{-1}	92.23jk	93.76fg	4.59jk	4.69jk
		4.0 ng Fe L^{-1}	91.77kl	93.91f	4.54k	4.66k
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	91.17lm	93.12g	4.35l	4.46l
		2.0 ng Fe L^{-1}	90.14no	92.27h	3.97n	4.05n
		4.0 ng Fe L^{-1}	89.60op	90.93i	3.87no	3.95no
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	90.74no	93.58fg	4.13m	4.25m
		2.0 ng Fe L^{-1}	89.09pq	90.77i	3.81op	3.89o
		4.0 ng Fe L^{-1}	88.60q	90.36i	3.76p	3.86o
LSD at 5%			0.67	0.68	0.10	0.10

Generally, it can be noticed that moringa extract and studied nanoparticles have a beneficial role on reducing garlic plant's requirements from SOD and MDA self-production. The role of moringa extract in increasing the resistance of the garlic plants to salinity and declining garlic plant's self-production from SOD and MDA maybe attributed to its contents of enzymatic and non- enzymatic antioxidants (as shown in Table 2), thus reducing garlic plant's requirements from SOD and MDA self-production under salinity circumstances (Hassan *et al.,* 2020). While The role of NPs in increasing the resistance of the garlic plants to salinity and declining garlic plant's self-production from SOD and MDA maybe attributed to their role in boosting nutrient absorption and use efficiency under salinity conditions (Li *et al.,* 2013; Tantawy *et al.,* 2014 and Shankramma *et al.,* 2016).

2. Yield and Bulb Traits at Period of 180 Days (Harvest):

Data of Tables 5,6 and 7 show the individual impact of foliar applications of moringa extract, CuO NPs and magnetite Fe_2O_3 NPs at various rates as well as their interactions on physical bulb attributes *i.e.,* bulb diameter (cm), neck diameter (cm), bulbing ratio (BR), No. of cloves $bulb^{-1}$ and bulb yield and marketable yield (ton ha^{-1}) as well as quality traits of bulbs *i.e.,* dry matter(%) vitamin C (mg $100g^{-1}$), crude protein (%) , carbohydrates (%) at maturity stage of garlic bulbs (180 days from planting) during two seasons (2017/2018 and 2018/2019).

Individual effect*:*

Data of the same Table show that the garlic plants grown on saline soil with foliar application of moringa extract had the highest values of all aforementioned yield characteristics and quality traits at harvest stage compared to the corresponding garlic plants grown without external application of moringa extract. The same trend was found in both studied seasons. The same trend was found in both studied seasons. It can be said that enhancement of garlic growth parameters (Table 3) as a result of external exogenous application of moringa positively reflected on garlic bulbs yield and its physical and quality traits, where the benefits of moringa extract were mentioned above. Similar results were obtained by Hegazi *et al.,* (2016) and Mohamed *et al.,* (2019).

Regarding foliar application of copper oxide NPs, the data of the same Table illustrate that the values of all aforementioned yield characteristics and quality traits at harvest stage increased as rate of copper oxide NPs increased, where the external application of copper oxide NPs at rate of 2.0 ng L^{-1} was superior treatment followed by copper oxide NPs at rate of 1.0 ng L^{-1}, while the plants grown without copper oxide NPs (at rate of 0.0 ng L^{-1}) possessed the less values of all aforementioned yield characteristics and quality traits at harvest stage. The same trend was found in both studied seasons. it can be said that the performance of garlic plants after 180 days from sowing looked just like that at period of 100 days from sowing The vital role of copper oxide NPs on growth performance of garlic plant positively reflected on garlic bulbs yield and its physical and quality traits, where the benefits of copper oxide NPs were discussed above.

Concerning foliar application of magnetite Fe_3O_4 NPs, the data of the same Table illustrate that the values of all aforementioned yield characteristics and quality traits at harvest stage increased as rate of magnetite Fe_3O_4 NPs increased, where the external application of magnetite Fe_3O_4 NPs at rate of 4.0 ng L^{-1} was superior treatment followed by magnetite Fe_3O_4 NPs at rate of 2.0 ng L^{-1}, while the plants grown without magnetite Fe_3O_4 NPs (at rate of 0.0 ng L^{-1}) possessed the less values of all aforementioned yield characteristics and quality traits at harvest stage. The same trend was found in both studied seasons. The vital role of magnetite Fe_3O_4 NPs on growth performance of garlic plant positively reflected on garlic bulbs yield and its physical and quality traits, where the benefits of magnetite Fe_3O_4 NPs were mentioned above.

Table 5. Impact of moringa extract and nanoparticles on physical parameters of garlic bulb during seasons of 2017/2018 and 2018/2019.

Treatments			Average bulb weight, g		Bulb diameter, cm		Neck diameter, cm		Bulbing ratio		No. of cloves bulb^{-1}	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Moringa extract (main factor)												
Without (control)			42.69b	43.56b	4.99b	5.08b	1.17b	1.19b	0.235b	0.235b	19.30b	22.04b
Moringa extract			46.11a	47.04a	5.51a	5.62a	1.35a	1.38a	0.256a	0.246a	25.26a	29.41a
LSD at 5%			0.07	0.08	0.13	0.03	0.03	0.03	0.005	0.001	1.59	1.24
Copper nanoparticle levels (sub main)												
0.0 ng L^{-1} (control)			43.26c	44.27c	5.08b	5.19c	1.21a	1.23b	0.237b	0.237b	20.00c	23.17b
1.0 ng L^{-1}			44.66b	45.60b	5.29a	5.40b	1.28b	1.31a	0.242a	0.242a	22.89b	26.39a
2.0 ng L^{-1}			45.28a	46.03a	5.38a	5.47a	1.30c	1.33a	0.242a	0.243a	23.94a	27.61a
LSD at 5%			0.32	0.33	0.10	0.05	0.02	0.02	0.003	0.001	0.93	1.53
Iron nanoparticle levels (sub-sub main)												
0.0 ng L^{-1} (control)			43.78b	44.68b	5.15b	5.25b	1.22b	1.24b	0.236b	0.237c	21.06b	24.28b
2.0 ng L^{-1}			44.52a	45.45a	5.27a	5.38a	1.27a	1.30a	0.241ab	0.241b	22.56a	26.17a
4.0 ng L^{-1}			44.90a	45.78a	5.32a	5.43a	1.29a	1.32a	0.243a	0.243a	23.22a	26.72a
LSD at 5%			0.43	0.44	0.09	0.05	0.02	0.02	0.004	0.002	1.10	1.03
Interaction												
Without (control)	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	41.12o	41.94m	4.75i	4.89m	1.10i	1.13g	0.231fg	0.232j	17.00k	18.00l
		2.0 ng Fe L^{-1}	41.61no	42.86lm	4.81i	4.91lm	1.12i	1.14g	0.233efg	0.232ij	17.67jk	19.33kl
		4.0 ng Fe L^{-1}	41.94mno	42.99klm	4.86i	4.91hkl	1.14i	1.15g	0.235d-g	0.234h	18.33ijk	20.00jkl
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	42.32lmn	43.28j-m	4.92hi	5.01j-m	1.15hi	1.17fg	0.234d-g	0.233hi	19.00h-k	20.67jk
		2.0 ng Fe L^{-1}	43.07kl	43.63h-k	5.06fg	5.1h-k5	1.20gh	1.22ef	0.237c-g	0.237g	20.00g-j	23.67hi
		4.0 ng Fe L^{-1}	43.46jk	44.50g-j	5.12ef	5.g-j25	1.22fg	1.25de	0.238b-f	0.238f	20.33f-j	24.00ghi
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	42.76klm	43.61i-l	4.99gh	5.0i-l9	1.13i	1.16g	0.226g	0.228k	19.67g-k	22.00ij
		2.0 ng Fe L^{-1}	43.76ijk	44.59f-i	5.18ef	5.27f-i	1.24fg	1.26de	0.240a-f	0.239ef	20.67f-i	25.00fgh
		4.0 ng Fe L^{-1}	44.16hij	44.69e-h	5.24e	5.29e-h	1.26ef	1.27de	0.241a-f	0.240e	21.00f-i	25.67e-h
Moringa extract	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	44.58ghi	45.56d-g	5.32d	5.4d-g3	1.27def	1.30cd	0.239b-f	0.239ef	21.67e-h	26.33efg
		2.0 ng Fe L^{-1}	44.92fgh	45.82def	5.36cd	5.def48	1.30cde	1.33bc	0.242a-f	0.242d	22.33d-g	27.33def
		4.0 ng Fe L^{-1}	45.39efg	46.48cde	5.39cd	5.5cde2	1.32cd	1.35bc	0.245a-d	0.244c	23.00def	28.00cde
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	45.76def	46.53b-e	5.43cd	5.52b-e	1.33c	1.35bc	0.244a-e	0.244c	24.00cde	29.00bcd
		2.0 ng Fe L^{-1}	46.49bcd	47.79abc	5.57ab	5.68abc	1.38ab	1.41a	0.248abc	0.248b	26.67abc	30.33abc
		4.0 ng Fe L^{-1}	46.85abc	47.88ab	5.61a	5.78ab	1.40ab	1.44a	0.249ab	0.249b	27.33ab	30.67ab
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	46.12cde	47.18a-d	5.50bc	5.57a-d	1.35bc	1.36a	0.245a-d	0.244cd	25.00bcd	29.67a-d
		2.0 ng Fe L^{-1}	47.25ab	48.01a	5.65a	5.80a	1.41a	1.45a	0.249ab	0.249b	28.00a	31.33ab
		4.0 ng Fe L^{-1}	47.60a	48.12a	5.71a	5.81a	1.43a	1.46a	0.250a	0.251a	29.33a	32.00a
LSD at 5%			1.06	0.21	0.13	0.05	0.05	0.52	N.S	0.001	2.71	2.52

Table 6. Impact of moringa extract and nanoparticles on yield of garlic plants during seasons of 2017/2018 and 2018/2019.

Treatments			Bulb yield, ton ha^{-1}		Marketable yield, ton ha^{-1}	
			1st	2nd	1st	2nd
Moringa extract (main factor)						
Without (control)			15.71b	16.03b	13.74b	14.05b
Moringa extract			16.97a	17.31a	14.66a	14.98a
LSD at 5%			0.03	0.03	0.01	0.05
Copper nanoparticle levels (sub main)						
0.0 ng L^{-1} (control)			15.92c	16.29c	13.90c	14.19c
1.0 ng L^{-1}			16.43b	16.78b	14.28b	14.62b
2.0 ng L^{-1}			16.66a	16.94a	14.42a	14.73a
LSD at 5%			0.12	0.13	0.03	0.04
Iron nanoparticle levels (sub-sub main)						
0.0 ng L^{-1} (control)			16.11b	16.44b	14.04c	14.34c
2.0 ng L^{-1}			16.38a	16.72a	14.21b	14.54b
4.0 ng L^{-1}			16.52a	16.85a	14.35a	14.67a
LSD at 5%			0.16	0.16	0.05	0.04
Interaction						
Without (control)	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	15.13o	15.43g	13.32l	13.48l
		2.0 ng Fe L^{-1}	15.31no	15.77fg	13.41l	13.72k
		4.0 ng Fe L^{-1}	15.43mno	15.82fg	13.53k	13.80k
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	15.57lmn	15.93f	13.64j	13.97j
		2.0 ng Fe L^{-1}	15.85kl	16.05ef	13.84i	14.13i
		4.0 ng Fe L^{-1}	15.99jk	16.38de	13.96h	14.33h
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	15.74klm	16.05ef	13.73j	14.09i
		2.0 ng Fe L^{-1}	16.10ijk	16.41de	14.08g	14.46g
		4.0 ng Fe L^{-1}	16.25hij	16.44de	14.16g	14.49fg
Moringa extract	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	16.41ghi	16.76cd	14.28f	14.58f
		2.0 ng Fe L^{-1}	16.53fgh	16.86c	14.39e	14.74e
		4.0 ng Fe L^{-1}	16.70efg	17.11bc	14.49de	14.84d
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	16.84def	17.12bc	14.58d	14.93cd
		2.0 ng Fe L^{-1}	17.11bcd	17.59a	14.77c	15.17b
		4.0 ng Fe L^{-1}	17.24abc	17.62a	14.88b	15.18b
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	16.97cde	17.36ab	14.69c	14.98c
		2.0 ng Fe L^{-1}	17.39ab	17.67a	14.78bc	15.03c
		4.0 ng Fe L^{-1}	17.52a	17.71a	15.08a	15.35a
LSD at 5%			0.39	0.40	0.11	0.11

Interaction effect:

Data elucidate that the highest values of values of all aforementioned yield characteristics and quality traits at harvest stage for garlic plants grown on salt affected soil during both seasons were recorded when garlic plants were sprayed, in combination, with moringa extract (30 gL^{-1}), CuO NPs at rate of 2.0 ng L^{-1} and magnetite Fe_3O_4 NPs at rate of 4.0 ng L^{-1} compared to other combined treatments, where all studied substances acted to mitigate the influences of salinity stress of soil on garlic plant through reducing responses of garlic grown to the stress and this positively reflected on garlic bulbs yield and its physical and quality traits. Our results are in agreement with those of Hegazi *et al.,* (2016); Suresh *et al*., (2016); Shankramma *et al.,* (2016) and Mohamed *et al.,* (2019).

Table 7. Impact of moringa extract and nanoparticles on quality parameters of garlic bulb during seasons of 2017/2018 and 2018/2019.

Treatments			D.M, %		Vitamin C, mg/100g		Protein, %		Carbohydrates, %		Pungency (purvate content πmol.ml^{-1})	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Moringa extract (main factor)												
Without (control)			27.79b	28.34b	13.76b	14.06b	11.99b	12.20b	25.07b	25.56b	11.44b	11.69b
Moringa extract			29.25a	29.82a	15.76a	16.09a	13.95a	14.23a	26.72a	27.26a	13.08a	13.33a
LSD at 5%			0.61	0.19	0.20	0.09	0.01	0.03	0.04	0.17	0.11	0.01
Copper nanoparticle levels (sub main)												
0.0 ng L^{-1} (control)			28.00b	28.55c	14.19c	14.50c	12.34c	12.58c	25.34c	25.83c	11.72c	11.98c
1.0 ng L^{-1}			28.66a	29.20b	14.87b	15.18b	13.11b	13.35b	26.02b	26.51b	12.36b	12.61b
2.0 ng L^{-1}			28.90a	29.49a	15.21a	15.55a	13.46a	13.72a	26.33a	26.91a	12.70a	12.94a
LSD at 5%			0.34	0.27	0.10	0.01	0.03	0.03	0.05	0.23	0.12	0.02
Iron nanoparticle levels (sub-sub main)												
0.0 ng L^{-1} (control)			28.24b	28.80b	14.42c	14.72c	12.62c	12.85c	25.58c	26.08b	11.97c	12.18c
2.0 ng L^{-1}			28.57a	29.14a	14.82b	15.13b	13.04b	13.27b	25.96b	26.51a	12.32b	12.58b
4.0 ng L^{-1}			28.76a	29.30a	15.04a	15.38a	13.25a	13.52a	26.16a	26.65a	12.50a	12.77a
LSD at 5%			0.26	0.28	0.15	0.05	0.04	0.04	0.08	0.25	0.12	0.04
Interaction												
Without (control)	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	27.02k	27.64h	13.04m	13.33r	11.21r	11.45r	24.26n	24.81m	10.74n	10.97r
		2.0 ng Fe L^{-1}	27.24jk	27.92gh	13.18lm	13.48q	11.41q	11.68q	24.51m	25.10lm	10.93mn	11.18q
		4.0 ng Fe L^{-1}	27.49ijk	28.01fgh	13.35klm	13.67p	11.58p	11.81p	24.70lm	25.18klm	11.08lm	11.35p
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	27.63h-k	28.13fgh	13.54jkl	13.83o	11.75o	11.98o	24.85l	25.29klm	11.20lm	11.45o
		2.0 ng Fe L^{-1}	28.ghi02	28.58d-g	13.91ij	14.20m	12.16m	12.35m	25.29j	25.76ijk	11.62jk	11.84m
		4.0 ng Fe L^{-1}	28.1fgh7	28.65def	14.10hi	14.45l	12.38l	12.60l	25.47ij	25.95hij	11.83ij	12.10l
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	27.82hij	28.50efg	13.70jk	13.97n	11.95n	12.12n	25.06k	25.63jkl	11.38kl	11.62n
		2.0 ng Fe L^{-1}	28.25fgh	28.69def	14.32h	14.59k	12.59k	12.77k	25.67hi	26.08g-j	12.02hi	12.26k
		4.0 ng Fe L^{-1}	28.47efg	28.93cde	14.70g	15.03j	12.84j	13.08j	25.86gh	26.28f-j	12.17gh	12.46j
Moringa extract	0.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	28.58efg	29.07cde	14.93fg	15.25i	13.06i	13.26i	26.00fg	26.39e-h	12.33fg	12.60i
		2.0 ng Fe L^{-1}	28.74def	29.26cd	15.24ef	15.56h	13.29h	13.48h	26.19f	26.67efg	12.54ef	12.82h
		4.0 ng Fe L^{-1}	28.93cde	29.42bc	15.42de	15.69g	13.49g	13.77g	26.41e	26.80def	12.69de	12.93g
	1.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	29.10b-e	29.51bc	15.55de	15.86f	13.75f	14.06f	26.57de	26.96de	12.87d	13.11f
		2.0 ng Fe L^{-1}	29.45abc	30.04ab	15.94bc	16.28d	14.17d	14.38d	26.87c	27.41bcd	13.23c	13.49d
		4.0 ng Fe L^{-1}	29.60ab	30.27a	16.18a	16.49c	14.42c	14.71c	27.08b	27.70abc	13.43bc	13.69c
	2.0 ng Cu L^{-1}	0.0 ng Fe L^{-1}	29.29a-d	29.96ab	15.74cd	16.09e	13.97e	14.25e	26.75cd	27.37cd	13.27c	13.33e
		2.0 ng Fe L^{-1}	29.73ab	30.34a	16.32a	16.69b	14.60b	14.94b	27.23ab	28.08a	13.58ab	13.89b
		4.0 ng Fe L^{-1}	29.87a	30.51a	16.49a	16.92a	14.81a	15.17a	27.43a	27.99ab	13.77a	14.09a
LSD at 5%			0.63	0.70	0.37	0.12	0.10	0.10	0.20	0.61	0.30	0.10

CONCLUSION

According to the obtained results, spraying garlic' Balady variety' plants grown on salt affected soil with moringa extract (30 ml L^{-1}), CuO NPs (2.0 ng L^{-1}) and magnetite Fe_3O_4 NPs (4.0 ng L^{-1}) as combined treatment is the best treatment that could be recommended to improve bulb quality of garlic plants and obtain the highest yield under salinity conditions.

Generally, it can be concluded that moringa extract and Nanoparticls represent an attractive tool under salinity condition for sustainable crop management programs**,** where these substances acted to mitigate the influences of salinity stress of soil on garlic plants.

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التطبيق الورقي لمستخلص المورينجا والجسيمات النانوية لتحسين أداء النمو وجودة محصول الثوم النامي بتربة ملحية.

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يمكن لتقنية النانو أن تقدم مزايا من شأنها زيادة المحصول لدعم القطاع الزراعي وتقليل المخاطر البيئية. أيضًا، يمكن للمستخلصات النباتية الطبيعية أن تحسن من أداء النباتات النامية بالأراضي المتأثرة بالأملاح. من ناحية اخري لا يُعرف الكثير عن التأثيرات المشتركة للتطبيق الورقي لمستخلص المورينجا مع الرش الورقي بالجسيمات النانوية على النباتات النامية بالأراضي المتأثرة بالأملاح. لذلك، تم إجراء تجربة حقلية بهدف تقييم تأثير الإضافات الورقية لمستخلص المورينجا [في وجودها مرة (بمعدل 30 مل/ لتر) وعدم وجودها مرة اخرها، كمعاملات رئيسية] والرش الورقي لجسيمات النحاس النانوية كمعاملات منشقة أولي بمعدلات مختلفة، وهي 0.0 ، 1.0 و 2.0 نانوجرام / لتر والرش الورقي لجسيمات الحديد النانوية المغناطيسية كمعاملات منشقة ثانية بمعدلات مختلفة، وهي 0.0، 2.0 و 4.0 نانوجرام / لتر على أداء نباتات الثوم النامي بأرض ملحية عند فترتين نمو (بعد مرور 100 و180 يومًا من الزراعة). تشير النتائج إلى أن نباتات الثوم النامية بالتربة المالحة مع الرش الورقي لمستخلص المورينجا امتلكت أفضل أداء مقارنة بنباتات الثوم المقابلة النامية بدون رش ورقي لمستخلص المورينجا. من ناحية أخرى، زاد تحسن أداء النبات كلما زاد تركيز الجسيمات النانوية المضافة. بشكل عام، تم تسجيل أفضل أداء عند رش نباتات الثوم بمستخلص المورينجا (بمعدل 30 مل/ لتر) وجسيمات النحاس النانوية (بمعدل 2.0 نانوجرام/ لتر) وجسيمات الحديد النانوية المغناطيسية النانوية (بمعدل 4.0 نانوجرام/ لتر) كمعاملة مشتركة مقارنة بالمعاملات المشتركة الأخرى. بشكل عام، يمكن استنتاج أن المواد المدروسة عملت على تخفيف تأثيرات إجهاد ملوحة التربة على نباتات الثوم.