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EFFECT OF DIFFERENT CONCENTRATIONS OF NANO BORON, COPPER, INOCULATION OF *ANABAENA SP.* AND MAGNETIZING WATER ON YIELD OF GARLIC (*ALLIUM SATIVUM*L.)

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ABSTRACT

An experiment was conducted at Al-Hadhara district, located in Al- Diwaniyah city, during the growth season 2018-2019 by using the pots have each one a 5 kg of soil for cultivating garlic (*Allium sativum* L.) in order to determine the response of garlic to different concentrations of nano-boron and copper, inoculation of Anabaena sp. and magnetized water on the yield of garlic. Randomized complete block design (RCBD) was adopted for a factorial experiment consisting of three factors (5 × 2 × 3): The first factor consisted of five concentrations of nano-boron (0, 2, 4) $g.L^{-1}$ and copper (1, 2) $g.L^{-1}$. The second factor includes the inoculating soil of Anabaena sp. The third factor consisted of three intensities of magnetized water (0, 500, and 1000) gauss with three replicates for each treatment, including the total experiment 90 experimental units 45 of them were inoculated of algae. The highest total yield of 29.23 $ton.hectar^{-1}$ was obtained with the application of boron 4 g. L^{-1}. Among the boron levels application of 2 g. L^{-1} gave a higher yield of 28.67 $ton.hectar^{-1}$ than copper levels application of 1, 2 g. L^{-1} that of (26.91, 27.83) $ton.hectar^{-1}$ respectively, while control treatment of 22.78 $ton.hectar^{-1}$. Inoculation of algae showed a higher effect of (28.44 $ton.hectar^{-1}$) than without (25.40 $ton.hectar^{-1}$). Magnetized water had significant effect under 1000 gauss intensity of (28.19 $ton.hectar^{-1}$) comparison with 500 gauss intensity (26.09 $ton.hectar^{-1}$) or control treatment (26.09 $ton.hectar^{-1}$). Biological yield affected of these factors significantly. It was high under boron 4 g. L^{-1} of (49 ton.hectar) while control (37.81). Inoculated plants were showed (43.66 ton. hectare) comparison with control (41.91 ton.hectar). Magnetized water has an effect on this trait under 1000 gauss (46.58 ton.hectar), while the control (42.58 ton.hectar).

***Keywords*:** Nano boron, nano copper, Water magnetized, garlic, algae, nitrogen fixing
Running title: Effect of different concentrations of nano boron on yield of garlic

Introduction

Garlic (*Allium sativum* L.), belongs to the Amarylidacera family (Fritsch *et al.*, 2010) like other plants, has an exquisite defense system, composed of as many different components as the human immune system. In order to protect itself from insects and fungi, garlic produces allicin by enzymatic reaction when it is injured. Thus, allicin is mother-nature's insecticide. Since ancient times, garlic has been used worldwide, not only as a food but also as a medicine (Block, 1985). As early as 3000 B.C., in ancient civilizations, including Egyptian, Phoenicians, Greek, Indian, Roman, Babylonian, Viking, and Chinese, garlic was used for the treatment of heart conditions, arthritis, pulmonary complaints, abdominal growths (particularly uterine), respiratory infections, skin disease, symptoms of aging, diarrhea, bulbache, bites, worms, wounds, ulcers, and tumors (Freeman and Kodera, 1995; Rivlin, 2001).

Copper is a redox-active transition element that has roles in photosynthesis, respiration, C and N metabolism, and protection against oxidative stress. Some studies suggest that Cu may play a part in the synthesis or the stability of chlorophyll and other plant pigments. Most of the functions of Cu are based on enzymatically bound Cu which catalyzes redox reaction (Selvaraj, 2002). Boron (B) is a micronutrient that plays a pivotal role in cell wall stability, photosynthesis, and carbon metabolism in the plant (Wang, 2015). Thus, B deficiency inhibits plant growth, hinders leaf expansion, causes leaf chlorosis or shoot tip dieback, deforms leaf, flower, or fruit, decreases yield and fruit quality, limits root elongation (Mishra and Heckathorn, 2016).

Algae are microscopic organisms that are a normal and important part of ponds, streams, rivers, lakes, oceans, and other aquatic habitats. They form the base of the aquatic food web, providing food for invertebrates and fish (Paudel *et al.*, 2012). They get their energy through photosynthesis, much like plants, and in the process produce a significant amount of the oxygen we breathe every day. Cyanobacteria (CB), known as blue-green algae (BGA), are a group of gram-negative photosynthetic bacteria that have colonized the earth surface for nearly 3.5billion years and are considered as the predecessors of modern-day chloroplast (Grzesik *et al.*, 2017).

Magnetic water is obtained by passing water through permanent magnets or through the electromagnets installed in or on a feed pipeline (Ali *et al.*, 2014). The permanent ceramic magnets or electromagnets are installed around the incoming water pipe. According to Ampere's law, when electricity passes through a wire, a magnetized field will be created around it. Up to now, different devices have been produced to magnetize water. In spite of a variety of

structures and shapes for these devices, the performing mechanism is almost the same. When a fluid passes through the magnetized field, its structure and some physical characteristic such as density, salt solution capacity, and deposition ratio of solid particles will be changed (Ali *et al.*, 2014).

Materials and Methods

Location of the study: Al-Hadhara district, located in Al-Diwaniyah city, was chosen as the site for the study during the 2018-2019 growth season using;5 kg potting soil for cultivating garlic (*Allium sativum* L.) in order to determine the response of garlic plant to different concentrations of nano-boron, copper and magnetized water.

Preparation of experimental units:

- Plastic pots (5 kg soil) were used for planting. They were filled with 4kg of sandy loam soil (Table 1) detected according to (Page *et al.*, 1982)
- The cloves garlic were used (horizontal diameter = 1 cm) from common variety for implantation.
- Nano-boron and copper processed from Iranian Sepeher Parmis company was used preparation = direct dissolution in distilled water according to the instructions on the sheet.
- Magnetize water by using two systems one of them gives 500 gause another 1000 related with intensities were used in study.
- Inoculation of soil with Anabaena algae (100g.kg^{-1}) to half pots, mean 45 treatment units.

Experimental design and implementation: Randomized complete block design (RCBD) was adopted for a factorial experiment consisting of three factors (5×2 × 3): The first factor consisted of five concentrations of nano-boron and copper separately; nano boron 2, 4 g.L^{-1} while nano copper 1, 2 g.L^{-1} and zero to control. The second factor includes inoculating soil of Anabaena sp. for half of the pots, with three replicates for each treatment, including the total experiment 90 experimental units, 45 of them were inoculated another without. The third factor consisted of three intensities of Magnetize water (0, 500, and 1000 gauss), Pre-prepared potted soils were planted with three cloves of garlic per pot on 20/9/2018 and after 10 days 100% full germination was obtained for all cultivated cloves. In addition, the service of plants from irrigation and potted follow-up in anticipation of fungal or insect infestation continuously is pending measurements of the indicators under study. The concentrations of substances were adding according to the aforementioned concentrations dissolved in irrigation water were arranged in the order of foliar spray method in the early morning with pre-irrigation of plants to avoid closure of stomata due to dehydration as well as increased absorption efficiency of the sprinkler (Gruda, 2005) taking into account consider all precautions and measures necessary to prevent the interaction of the process of application between one treatment to another, as the treatment took place on 25/12/2018 and in order to the study factors.

Studied total and biological yield measurements were taken when all plants became maturated within the same treatment at all replicates. The mean was calculated by dividing the characteristic of the number of plants within the same treatment. The total yield was measured depending on the weight and number bulbs in the area of the pot then transformed to ton per hectare. While the biological yield was measured depending on all parts of the plant before harvest, including roots, leaves, and bulbs.

Statistical analysis: Results data were analyzed statistically by using the analysis of variance for a factorial experiment consisting of three factors according to RCBD, The process was implemented in the SPSS program and the means of treatments were compared when the differences were significant using the least significant difference (LSD) test at $P \leq 0.05$ (Steel and Torrie, 1980).

Table1: Physical and chemical characteristics of soil experiment before implantation Characteristic Value Measure

Characteristic	Value	Measure unit
E.C.	2.61	µS/cm
pH	7.5	-
Organic matte	7.4	%
Nitrogen	0.37	%
Phosphorus	0.01	%
Potassium	3.9	%
Sand	38.5	%
Silt	44.7	%
Clay	16.8	%
Soil texure	Sandy loam	

Results

Total yield

The results of table (2) show the significant effect of the concentrations of the different nanomaterials used in the study, inoculation of algae, the magnetization of irrigation water and their significant interference on the total yield of garlic plants, as it reached a maximum of (29.23ton.he^{-1}) when using nanoscale boron. 4g L^{-1} compared to the comparison treatment of (22.78 tons. he^{-1}), followed by the treatment of boron at a concentration of 2 g. L^{-1}, when the total plant yield reached (28.67 ton. he^{-1}), and copper at a concentration of 2 g. L^{-1} showed a significant effect. (27.83 ton. he^{-1}) and (26.91 ton. he^{-1}) for copper at a concentration of 1 g. liter^{-1} meaning that the total plant yield increased with all the concentrations of nanomaterials used. The table also shows the significant effect of Anabaenainoculated, as the total yield with moss inoculated was (28.44 tons. he^{-1}) compared with the comparison treatment that amounted to (25.40 tons. he^{-1}). It was also noted from the table the significant effect of the magnetization intensity of irrigation water, as it reached the maximum average of the studied characteristic (28.19 tons. he^{-1}) at the magnetization intensity of 1000 gauss, followed by the magnetization intensity of 500 gauss which amounted to (26.92 tons. he^{-1}) compared with the comparison treatment that amounted to (26.09 tons. ha^{-1}). The double interaction between the concentrations of nanomaterials and inoculation with algae showed that the maximum yield of the plant was (30.61 tons. he^{-1}) when interfering with boron at a concentration of 4 g. Liter^{-1} and inoculated with moss compared with the comparison treatment (20.09 tons. he^{-1}).

The double interaction between the concentrations of nanomaterials and the magnetization of the irrigation water showed that the maximum yield was (29.97 tons. he^{-1}) when the two combinations interfered (boron at a concentration of 4 g.L^{-1}), followed by the interaction (boron at a concentration

of 2 g. Liter^{-1} and highly magnetized water. (1000 gauss), as it reached (29.48 tons. he^{-1}) compared to its counterparts within this interaction, including the comparison treatment, which amounted to (21.19 tons. he^{-1}).

As for the two-way interaction between magnetization intensity of irrigation water and inoculated with moss, it was noticed that the highest yield was when the interaction between inoculated with moss and magnetization intensity of irrigation water was 1000 gauss, reaching (29.67 tons. he^{-1}), followed by an interaction of intensity 500 gauss for inoculated plants, which amounted to 28.70 tons. he^{-1}) compared to the comparison treatment of (24.25 tons. he^{-1}). The triple interaction of study factors showed the combination (boron concentration 4 g. Liter^{-1} and the magnetization intensity of 1000 gauss water with inoculation with algae) gave the highest average for the studied trait of (31.48 tons. he^{-1}) compared to the comparison treatment that amounted to (17.22 tons. he^{-1}), as it was observed. From the same interaction, there was no significant difference in the mean total yield between the boron concentrations 2 and 4 g. l^{-1} for plants inoculated with moss when using strongly magnetized water of 500 gauss.

Biological yield

Table (3) shows the significant effect of the used nanomaterials, inoculation with anabaena, and magnetization of irrigation water on the biological yield of the garlic plant, where it showed superiority in the treatment of nanoscale boron at a concentration of 4g.l^{1-} compared to its counterparts, including the comparison treatment, which amounted to (49.00 tons. he^{-1}), while the comparison treatment amounted to (37.81 tons. he^{-1}), followed by the treatment of boron at a concentration of 2 g. Liter^{-1} when it reached 46.20 tons. he^{-1}). Copper concentrations showed a significant effect on the mean of the studied characteristic, when the copper concentration was 2 gm. Liter^{-1} was (44.88 tons. he^{-1}), as for copper, at a concentration of 1 g. Liter^{-1} it was (43.54 tons. he^{-1}) compared to the comparison. The table itself shows. The significant effect of inoculated with moss reached (43.66 tons. he^{-1}) for inoculated plants compared to non-inoculated plants, which amounted to (41.91 tons. he^{-1}). The table also showed the significant effect of the intensity of magnetization of the irrigation water, as the intensity exceeded 1000 gauss over its counterparts, including the comparison treatment, reaching (46.58 tons. he^{-1}), while the comparison treatment reached (42.29 tons.he^{-1}). Also, the intensity of 500 gauss showed a significant effect of (43.99 tons. he^{-1}).

The bilateral interaction between inoculation with algae and the concentration of nanomaterials showed that the combination (inoculation with a boron concentration of 4 gm. L^{-1}) gave the highest average for the studied trait of (51.80 tons. he^{-1}) compared to the comparison treatment, which amounted to (33.45 tons. he^{-1}). The same interaction shows that there is a significant difference between the concentration of boron 4 and 2 g. liter^{-1} for the moss inoculated plants, while there is no significant difference between the copper concentrations (1 and 2 g.l^{-1}) with inoculated and non-inoculated plants. The double interaction between the concentrations of the used nanomaterials and the magnetization of the irrigation water indicates the superiority of the combination of two factors (boron at a concentration of 4 g. L^{-1} and the magnetization intensity of 1000 gauss water) as the biological yield reached (53.66 tons. he^{-1}) compared to the comparison treatment that amounted to (35.18 tons. ha^{-1}) followed by the combination between (boron 2 g. Liters^{-1} and the magnetization intensity of 1000 gauss water), reaching (48.93 tons. he^{-1}).

The interaction also indicates that there is a significant difference between the concentration of copper and boron at the same concentration at the intensity of 500 gauss. The bilateral significant interaction between inoculated with moss and magnetization of irrigation water showed that the maximum average biological yield at the combination (inoculated with moss with magnetization intensity of 1000 gauss) reached (49.04 tons. he^{-1}), followed by the combination (intensity 500 gauss of magnetized water with inoculated with moss). It amounted to (46.02 tons. he^{-1}) compared to the comparison treatment, which amounted to (39.66 tons. he^{-1}).The triple interaction of study factors showed the combination (boron at a concentration of 4 gm. L^{-1} and the magnetization of water with an intensity of 1000 gauss and inoculated with algae) gave the highest yield of (58.35 tons. he^{-1}) compared to the comparison treatment of (28.77 tons. he $^{-1}$). Also, the same interaction showed the absence of Significant difference between the two combinations (boron 2 gm.L^{-1} and copper 2 gm.L^{-1}) under the magnetization intensity of 1000 and 500 gauss and inoculation with algae, as well as the absence of a significant difference between the concentrations of copper 1 gm. Liters^{-1} and 4 gm. Liter^{-1} at the same water strengths and the same inoculated conditions.

Table 2: The effect of different concentrations of nano (copper and boron), inoculation with Anabaenalgae and magnetization of water on average total yield (ton.hec^{-1}) of garlic.

magnetized water	magnetized water	concentrations of nano materials(g.L^{-1})					interaction = magnetized water× Inoculation algae
		Control	Copper		Boron		
		0	1	2	2	4	
Without inocul.	0	17.22	24.88	25.74	26.34	27.06	24.25
	500	18.37	25.39	26.48	27.47	28.05	25.15
	1000	24.69	25.94	26.96	27.99	28.46	26.81
Inoculated	0	25.16	27.52	28.21	29.09	29.67	27.93
	500	25.24	28.04	29.39	30.17	30.68	28.70
	1000	26.00	29.69	30.20	30.96	31.48	29.67
average concentrations of nano materials		22.78	26.91	27.83	28.67	29.23	
L.S.D (p≤ 0.05)	concentrations of nano materials =0.23						interaction(2 factors) =0.25
	(3 factors)interaction=0.57						
interaction (magnetized water×nana materials)							

magnetized wate (gaus)	concentrations of nano materials ($g.L^{-1}$)					Average to magnetized wate
	Control	Copper		Boron		
	0	1	2	2	4	
0	21.19	26.20	26.98	27.72	28.37	26.09
500	21.77	26.72	27.94	28.82	29.37	26.92
1000	25.35	27.82	28.34	29.48	29.97	28.19
L.S.D(p≤ 0.05)	**Interaction (nana materials × magnetized wate) =0.33**					**magnetized wate=0.18**
interaction (nana materials× Inoculation algae)						
Inoculation Algae	**concentrations of nano materials**					**Average to Inoculation Algae**
	Control	**Copper**		**Boron**		
	0	1	2	2	4	
Without inocul.	20.09	25.40	26.39	27.26	27.86	25.40
Inoculated	25.47	28.42	29.27	30. 07	30.61	28.44
L.S.D(p≤ 0.05)	**(2 factors) interaction nano materials× Inoculationalgae =0.40**					**Inoculation algae =0.14**

Table (3): The effect of different concentrations of nano (copper and boron), inoculation with Anabaenalgae, and magnetization of water on average biological yield (ton.hec^{-1}) of garlic.

magnetized water	magnetized water	concentrations of nano materials ($g.L^{-1}$)					interaction = magnetized water × Inoculation algae
		Control	Copper		Boron		
		0	1	2	2	4	
Without inocul.	0	28.77	40.81	41.39	43.24	44.11	39.66
	500	35.15	41.80	43.61	43.76	45.51	41.97
	1000	36.44	42.39	44.92	47.83	48.98	44.11
Inoculated	0	41.59	44.72	45.20	45.38	47.66	44.91
	500	42.30	45.45	46.02	46.96	49.37	46.02
	1000	42.61	46.06	48.14	50.03	58.35	49.04
average concentrations of nano materials		37.81	43.54	44.88	46.20	49.00	
L.S.D(p≤ 0.05)	**concentrations of nano materials = 1.18**						**interaction(2 factors) =1.30**
	(3 factors) (interaction=2.90						
interaction (magnetized water×nana materials)							
magnetized water (gaus)	**concentrations of nano materials ($g.L^{-1}$)**						**Average to magnetized water**
	Control	**Copper**		**Boron**			
	0	1	2	2	4		
0	35.18	42.77	43.38	44.22	45.89		42.29
500	38.72	43.63	45.29	44.89	47.44		43.99
1000	39.53	44.23	46.53	48.93	53.66		46.58
L.S.D (p≤ 0.05)	**Interaction (nana materials × magnetized wate) =2.05**						**magnetized water=0.91**
interaction (nana materials× Inoculation algae)							
Inoculation Algae	**concentrations of nano materials**						**Average to Inoculation Algae**
	Control	**Copper**		**Boron**			
	0	**1**	**2**	**2**	**4**		
Without inocul.	**33.45**	**41.67**	**43.31**	**44.94**	**46.20**		**41.91**
Inoculated	**42.17**	**45.41**	**46.45**	**47.46**	**51.80**		**43.66**
L.S.D (p≤ 0.05)	**(2factors)interaction × nana materials =1.67**						**Inoculation algae =0.75**

Discussion

The nano-boron and copper have a remarkable role in accelerating biological reactions due to the large surface area of their particles, which in turn leads to the production of growth materials that are reflected in the vegetative indicators of the plant and reflected on yield either total or biological (Agrawal and Rathore, 2014; Chanchan *et al.*, 2013). With regard to the significant effect of study factors on the studied characteristics or indicators of the outcome, such as total yield included (size, diameter, weight, and number of bulb cloves, weight, and diameter of the cloves) and biological yield included (weight of root and leaves added to bulbs) as shown in tables (2-3), the height of these indicators was a clear positive reflection of the high vegetative growth of the plant due to the use of materials nanoparticles with suitable concentrations by the method of foliar spray and this matches the study of (Abdul-Hafeez *et al.*, 2015; Nasreen *et al.*, 2009).

The increase in most of the growth indicators was due to inoculation with Anabaena sp. And the role of these algae

in the biological fixation of nitrogen, as nitrogen is one of the necessary elements to build the amino acid Tryptophan, which forms the basis for building the growth hormone Indol acetic acid (IAA) responsible for the elongation of plant cells (Mahmoud *et al.*, 2019). Inoculation with Anabaena stimulates the production of auxins, which encourages cell division and cell elongation (Prasad and Prasad, 2003). Also, the increase in the characteristics of vegetative growth may be attributed to the role of nitrogen that promotes growth and cell divisions (Massignam *et al.*, 2009), and then the increase in cell breadth, and this is what was found by (Rai, 2006; Swamalakshmi *et al.*, 2013) about the relationship of nitrogen in the increase of vegetative growth, as it may be due to the effect of nitrogen on impeding leaf aging and yellowing due to ability to build proteins and RNA as well as slow their breakdown (Rashad *et al.*, 2019). On the other hand, the increase in the activity of photosynthesis and other processes led to an optimal vegetative growth that required the absorption of nutrients and access to the state of nutritional balance as a result of increased growth and increased leaf area, which contributed to improving the physiological plant processes and giving better growth (Hussain and Hasnain, 2011).

The use of magnetized water led to an increase in the content of the leaves of chlorophyll, directly with the severity of magnetization, because the use of magnetized irrigation water leads to a lot of modification to the characteristics of the water such as density, surface tension and viscosity and raising the ability of water to dissolve minerals, vitamins, and salts (Morejon *et al.*, 2007). This is consistent with the study by (Suhail and Mahdi, 2013; Abdel Nabi *et al.*, 2019). The superiority of water magnetization coefficients in their effect on vegetative growth compared to irrigation with regular water may be due to the fact that magnetization of irrigation water increases the levels of enzymes and the maintenance of hormonal balance, which leads to an increase in growth, expansion and cell division and extension. It may facilitate the absorption process by the root cells, which affects the transfer of nutrients, as well as increases the readiness of nutrients in the soil, leading to an increase in the growth of the plant (Takachenko, 1997). As well as, the use of magnetized water in irrigation improves plant growth. Noticeably due to the facilitation of the absorption of major elements from the soil and its reflection on the growth of the vegetative plant Ali *et al.*, 2014).

Conclusion

One of the most important findings of the present study is the superior significant effect by treatment with 4 g. L^{-1} of nano -boron by foliar spray as well as treatment with inoculation of Anabaena sp. Algae and use magnetized water irrigation on most growth indicators of the garlic plant.

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