Improving Yield and Quality of Garlic by some Bio-treatments

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ABSTRACT

Field experiments were conducted during the two successive seasons of 2019/2020 and 2020/2021 at Mallawi Research Station, El-Minia Governorate, Egypt, aiming to minimize rates of mineral nitrogen fertilizer application at garlic production Egaseed 1 cultivar (Eg1). Mineral nitrogen fertilizer was used with three levels (50, 75 and 100% of the recommended dose of N). Four kinds of bio-fertilization (Control, Minia-azotien 3.0 L. fed^{-1}, Spirolina plantlets 4.0 $g.L^{-1}$, and 3.0 L./fed. of Minia-azotein + 4.0 $g.L^{-1}$ of Spirolina plantlets) for studying its effects on yield and quality of garlic.The experiment was laid out through a split-plot randomized complete block design (RCBD) with three replications, where the three rates of mineral nitrogen supply occupied the main plots. The bio-fertilization treatments were distributed at random in the sub-plots. The mineral nitrogen rates differ significantly in their effects on garlic growth parameters and yield. The best rate for obtaining these characters' highest values was 100% of the recommended dose.

Regarding the biofertilizer effects, the Spirolina plantlets treatment showed the best results to improve either growth parameter or yield and quality of garlic compared with Minia-azotien at uninoculated plants. The interaction effects between mineral and biofertilizer treatment results showed that the best treatment was 100% mineral nitrogen + 4.0 g.L-1 of Spirolina plantlets to obtain better growth and garlic's highest yield and quality. In comparison, the lowest treatment was 50% mineral and un-inoculated plants.

Keywords: Garlic,biofertilizers, Spirolina plantlets, Minia-azotien, yield, bulb quality.

INTRODUCTION

Garlic (*Allium sativum*, L.) is one of the oldest cultivated vegetables, and it is a bulb crop known for thousands of years and has positive effects on the human organism (**Lošák and Kielian, 2006**). Based on importance and cultivation scale, garlic ranks second in the family (Alliaceae) after onions (**Gomez *et al*., 2000**). The economic importance of garlic has increased worldwide due to its great use mainly in most foodstuffs as a spice and in most medicinal preparations (**Rosen and Tong 2001**).

From **Arab Organization for Agricultural Development (AOAD), 2022**, garlic is grown globally on approximately 1.6 million hectares, with an average productivity of 18.7 $tons.ha^{-1}$ produces about 31 million tons annually. China is the most important country, producing more than 42% of the world's production and exporting more than 70% of the world's total garlic exports, which amounted to about $2.5 billion. The total area cultivated with garlic in Egypt was about 37.0 thousand feddan, producing about 319 thousand tons, with an average of 8.8 $tons.fed^{-1}$. Egypt exports approximately 23.8 thousand tons annually.

These figures illustrated that the economic importance of the garlic crop has increased significantly over the world; so increase garlic production and improving bulb quality is a significant aim for both growers and consumers.

The garlic yield, like any other crop, depends on the appropriate environmental conditions for growth and the efficiency of agricultural practices such as temperature (**Rahim and Fordham 2001**), moisture (**Bhuyia*et al*., 2003**) and soil nutrients (**Kilgori *et al*., 2007**).

It is also known that obtaining high yields requires adding large amounts of nutrients, especially nitrogen. However, the use of chemical fertilizers indiscriminately and in an unbalanced manner may lead to many problems such as loss of soil fertility, deficiency of multiple nutrients, and loss of microbial activities that are reflected in a decrease in crop yield and quality (**Singh *et al*., 2017; Tian *et al*., 2016; and Goulding *et al*., 2008**), in addition to the high and ever-increasing costswhile, application of chemical fertilizers with organic manures and bio-fertilizers can maintain soil fertility and soil productivity (**Zaghloul *et al*.,2016**). Therefore, the integrated use of organic and inorganic sources of nutrients is the best way to increase yields in garlic and obtain better benefits and income.

Bio-fertilizers are microorganisms that help plants grow by increasing and promoting the nutrient supply for the overall productivity of the soil (**Saber, 1993; El-Agory et al., 1996; Hanafy *et al*., 2000**). It has become, in the last few decades, a positive alternative to mineral fertilizers; therefore, estimates of the global market for bio-fertilizers varied considerably between $ 668 million in 2010 to $ 1.25 billion in 2016 and was expected to grow up to $ 5.0 billion until 2028 (***GlobeNewswire*, 2022**).

Spirulina plantensis is a photosynthetic blue-green micro-alga and has been largely studied due to its commercial importance as a source of proteins, vitamins, and essential amino and fatty acids (**Leduy and Thorein, 1977; Ciferri and Tibani, 1985; Vonshak and Richmond, 1985; and Vonshak, 1986**). Moreover, it is also known as a rich source of potassium and contains a considerable amount of Ca, Cu, Fe, Mg, Mn, P, and Zn (**Marrez *et al*., 2014**). Many previous studies that used the spirulina extract as a bio-fertilizer with several crops showed positive effects on the vegetative growth, yield, and quality of garlic plants (**Aly and Esawy, 2008; Abou El-Khair *et al*., 2010; Mohsen, 2012; Shalaby and El-Ramady, 2014**). **Fawzy *et al*., 2012;** on Chinese garlic plants.As well as, **Babilie *et al*. 2015; Shafeek, *et al*., 2015; Hidangmayum and Sharma 2017; and Yassen *et al*., (2018**) on onion.

Minia-azotin is a bio-fertilizer product containing *Azotobacter chroococcum*, most commonly inhabiting various soils worldwide (**Mahato *et al*., 2009**). Azotobacter also produces thiamin, riboflavin, indole acetic acid, and gibberellins in addition to nitrogen fixation. Incorporating bio-fertilizers Azotobacter chroococcum plays a major role in improving soil (**Mrkovacki and Milic, 2001**). The research confirmed that incorporating *Azotobacter chroococcum* strains into the soil affected the increase in sugar beet production and soil biogenicity (**Mrkovacki *et al*., 2016**). Promote growth, yield and quality of cabbage. It increased height, leaves, head size, spread and yield per hectare (**Kumar *et al*., 2017**). The reviewed studies on many crops confirmed that its effect positively affected many vegetative growth characteristics and criteria for flowering and quality parameters (**Abdou *et al*., 2004; Hassanein and El-Sayed 2009;** on gladiolus).

Therefore, this work aimed to study the minimized rates of mineral nitrogen fertilizer application by using the different abilities of bio-fertilization treatments to improve the yield and quality of garlic.

MATERIALS AND METHODS

This experiment was conducted during the 2019-2020 and 2020-2021 seasons at Mallawi Research Station (altitude of 27.720 N, longitude of 30.830 E and elevation of 54.38 m above sea level), El-Minia Governorate, Egypt, to study the Improving yield and quality of garlic by some bio treatments.

Soil sampling analysis:

Table (1): Some physical and chemical properties of the soil at 0-30 cm depth during 2019/ 2020 and 2020/2021 seasons.

Properties	Sand %	Silt %	Clay %	pH	ECe	$CaCo_3$ %	O. M %
1st season	8.47	36.82	54.71	7.80	1.52	1.93	1.60
2nd season	10.11	40.57	49.32	7.75	1.59	1.81	1.72
Available nutrient							
	N %		**P** *ppm*		**K** mm		
1st season	0.18		19		340		
2nd season	0.18		22		390		

E.C = Electric conductivity (ds/m, 1:5 soil water extract). O.M= Organic matter.

The experimental treatments:-

Soil samples (0 - 30 cm in depth) were collected randomly from plots, which were pooled, and each three samples was homogenized to make up one sample. Sampling dates were 20 days before planting. The experimental plot's soil was clay loam in texture. The soil characteristics under the experimental plot were analyzed at the Service Laboratory for Soil, Water and Plant Analysis, Faculty of Agriculture, EL-MiniaUniversity). The physical and chemical soil properties of the experimental field plots are presented in Table 1.

Nitrogen fertilizationthe N fertilizer was added in the form of ammonium nitrate 33.5% N) at three levels of mineral nitrogen supply: 100% (N1), 75% (N2) and 50% (N3) based on the recommended dose (120 kg nitrogen fed^{-1}) The given doses were divided into two equal parts, the first was after one month from planting, the second was after one month from the first.

Four kinds of bio-fertilization:-

1] Control.

2] Minia-azotienFresh and active bio-fertilizers, Minia azotein (containing N-fixing bacteria *azotobacter chroococcum*) was obtained from the Laboratory of Bio-fertilizers, unit, Fac. of Agric., MiniaUniv. with level 3.0 $L.fed^{-1}$ after one month of sowing.

This quantity of Minia-azotien for feddan was counted and divided for each experimental unit. Then, supplemented with water for 5 liters, the contents of the jar were poured on the rows below the plants and then irrigated directly. The same steps were repeated for each studied experimental plot.

3] Spirolina plantlets with level 4.0 $g.L^{-1}$. Plants were sprayed with the Spirolina plantlets three times during the growing seasons. The first spray was after 50 days from planting; the second was after 2 weeks from the first one and the third was after two weeks from the second one.

Spirulina platensis was purchased from National Research Centre (NRC), Cairo, Egypt. Chemical composition of *Spirulina platensis* is shown in Table (2).

Table (2): Chemical composition of *Spirulina platensis*.

Composition	Values
Protein% :	55.28%
Lipid %:	6.72%
Ash content%:	8.18%
Carbohydrates (%):	14.40%
- Minerals (g/100 g)	
Potassium (K) :	1.65
Phosphorus (P):	0.83
Iron (Fe) :	0.051
Magnesium:	0.250
- Vitamins (mg/100 g)	
Vitamin B1:	3.36
Vitamin B2 Riboflavin:	4.47
Vitamin B12:	0.24
Niacin:	13.15
Folic acid:	50.5
Pantothenic acid:	0.47

4] 3.0 kg of minia-azotein + 4.0 $g.L^{-1}$ of spirulina (done by the same handling way).

Twenty days before the sowing, the experimental land was plowed twice in two directions with a heavy moldboard. After 10 days, a medium chisel scraped the soil, and the laser broadcasted, and then the soil was planned on 50 cm between rows (Norse-south direction). The plot area was about 10.5 m^2, with six rows three and a half meters long.

A randomized complete block design (RCBD) using split-plot arrangement with with three replications was used in both seasons, where the three nitrogen supply rates occupied the main plots. The bio-fertilization treatments were distributed at random inthe sub-plots.

The large bulbs free of disease were selected, and the larger cloves were selected for cultivation. A day after the plots were irrigated, sowing occurred on the 8th and 15th October in the 1st and 2nd seasons using one clove (10 cm clove-spacing) on one side of the ridge. A month later, the nitrogen fertilization was done from each subplot according to its studied nitrogen rate and added to the plots under studied nitrogen rates of 100%, 75% and/or 50%, respectively. As well as, all other agricultural applications were accomplished as recommended for garlic cultivation.

Data recorded

1- After 130 days from the planting date:

A sample of ten plants was uprooted from each experimental unit to record the

1- Plant height (cm),

2- Neck diameter (cm)

3- Bulb diameter (cm)

4-Bulbing ratio was estimated according to Mann (1952).

$$\text{Bulbing ratio} = \frac{\text{Neck diameter (mm)}}{\text{Bulb diameter (mm)}} \times 100$$

2- Yield characters:

At harvest time (after 180 days from planting):

Harvesting was done when about 70% of the plant leaves turned yellow on the 15th and 18th of April in the 1st and 2nd seasons, respectively. Plants of the three intermediate rows from each subplot were weighed to estimate the fresh total yield ($ton.fed^{-1}$). After that, ten plants were randomly taken from each sub plot and transferred to the laboratory to record and estimate the following parameters.

1- Bulb diameter (cm).
2- Fresh total yield (ton/fed^{-1}).
3- Bulb head weight (g).
4- Average weight of single cured clove (g): was calculated as the average weight of cloves of the previous 10 bulbs.
5- Weight loss percentage %: Cured samples were weighted to determine the percentage of weight loss % during the curing period of May 2020 and May 2021 in the first and second seasons, respectively.

The obtained data were compared using analysis of variance (ANOVA) procedures according to **Gomez and Gomez, 1984,** and mean differences were performed using **Duncan multiple range test, 1955**.

RESULTS AND DISCUSSIONS

Vegetative growth characters:

1- Growth characteristics at 130 DAP:-

Plant height (cm):-

Data in Table (3) show that the plant height of garlic significantly affected different mineral nitrogen fertilizer rates. In contrast, the highest value of this trait was obtained with the highest level of mineral nitrogen (100%), while the lowest values (69.25 and 68.80) were obtained with the lowest rate (50%) of mineral nitrogen in both seasons. These results reported the role of mineral nitrogen in improving some plant growth characteristics, such as plant height; these results agree with those obtained by (**El-Zohiri and Abdou, 2009 and Ahmed *et al*., 2010)**.

The stimulative effect of nitrogen on different plant growth parameters may owe much to the fact that nitrogen is an essential element for building up protoplasm, amino acids and proteins, which promote cell division. Also, nitrogen contributes to several biochemical processes related to plant growth (**Marschner, 1995**).

Regarding the effect of biofertilizers, data in the same Table (3) showed that biofertilizers significantly affected the plant height in the two seasons. The highest values of plant height were obtained with 4.0 g/L Sp. (78.55 and 77.31 cm) and 4.0 g/L Sp + 3.0 L/**fed.** M.A (76.59 and 73.9 cm) in the first and second seasons, respectively. At the same time, the lowest values were obtained with the control in both seasons.

The increments in plant growth due to biofertilizer application may be a result of the vital role of microorganisms that exist in the utilized biofertilizer in producing some hormone substances, i.e., gibberellins, auxins and cytokinins (**Bouton *et al***., **1985**; **Cacciari *et al***., **1989;andNoel *et al***., **1996**). These phytohormones may additionally stimulate cell elongation and improve plant growth (**Paleg, 1985**). The effect of Sp. platensis, considering that microalgae are rich in polypeptides, amino acids, hormones, organic acids, vitamins, and enzymes that could act as growth promoters, was reported by (**Manrich *et al***., **2014**; **and Tarraf *et al***., **2015)**.

The interactions between mineral nitrogen rates and biofertilizers data show significant effects for the interactions treatments in both seasons on plant height, .The highest significant increase was obtained with the combined N100% + 4.0 g/L Sp treatments. (85.83 cm) in the first and second seasons (82.83 cm).compared to the N50% treatment, it gave the lowest values for plant height in both seasons.

Table (3): Effect of mineral nitrogen rats, spring with Spirolina and injection with mini Azotien levels on plant height after 130 days from planting in 2019/2020 and 2020/2021 seasons.

Plant height (cm)			
Mineral nitrogen (Kg/fed.)	**Bio-Treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	78.94 bc	75.72 a
	3.0 L/fed. M.A	78.83 bc	74.27 b
	4.0 g/L S.p.	85.83 a	82.83 b
	4.0 g/L S.p + 3.0 L/fed. M.A	82.05 b	76.94 b
Mean		81.41 a	77.44 a
75% (90 N)	**Control**	70.22 ef	67.32 bc
	3.0 L/fed. M.A	72.66 d-f	69.1 bc
	4.0 g/L S.p.	76.89 c	75.67 bc
	4.0 g/L S.p + 3.0 L/fed. M.A.	76.11 cd	73.54 cd
Mean		73.97 b	71.41 b
50% (60 N)	**Control**	63.61 g	62.83 de
	3.0 L/fed. M.A	68.83 f	67.7 de
	4.0 g/L S.p.	72.94 de	73.44 e
	4.0 g/L S.p + 3.0 L/fed. M.A.	71.61 ef	71.22 f
Mean		69.25 c	68.80 c
Means of bio-treatments	**Control**	70.92 c	68.62 c
	3.0 L/fed. M.A	73.44 b	70.36 c
	4.0 g/L S.p.	78.55 a	77.31 a
	4.0 g/L S.p + 3.0 L/fed. M.A.	76.59 a	73.9 b

S.p: Spirulina platensis and M.A: Minia-azotien

Neck diameter (cm):-

Data in Table (4) show that there are significant differences between the mineral nitrogen fertilizers rates in neck diameter only in the second season, while (100% N 120 kg/fed. N) gave the highest values (1.93 cm and 1.91 cm) in the first and second seasons, respectively.

Concerning biofertilizers' effect, data in the same Table (4) indicate that insignificant effect of biofertilizers type on neck diameter in both seasons. Higher neck diameter (cm) was obtained by applied treatment (4.0 g/L Sp + 3.0 L/fed MA) and (4.0 g/L Sp.) in both seasons. These results are in accordance with those obtained by **Abd El Aziz *et al*.**, (**2011**).

The interactions between nitrogen rates and bio-fertilizer effects on neck diameter after 130 days from planting were highly significant in the second season Table 4. The combined treatments of N50 % + control, and N50% + 3.0 L/fed. MA in the first season show the lowest significant decrease in neck diameter (1.45 and 1.61cm), respectively, with insignificant differences. While in the second season, data show that the combined treatments of N rate 50% + control, and N50 +4.0 g/L Sp + 3.0 L/fed. M.A gave the lowest values (1.36 and 1.47cm), respectively.

Bulb diameter (cm):-

Data in Table (5) indecate that Bulb diameterwas significantly affected by the different rates of mineral nitrogen fertilizers only in the first season. The plants that received the recommended nitrogen rate (100% N rate) produced higher bulb diameters than those fertilized with a rate of 50% in both seasons. This might because of the stimulating effect of N on plant growth. These results are agree with those obtained by **Ahmed *et al*., 2012**.

Also, data shown in Table (5) show significant effects of the bio-fertilizer treatments on bulb diameter. The highest increases in this respect were recorded with the mix treatment of 4.0 g/L S.p (4.82 and 4.16 cm) and 4.0 g/L S.p + 3.0 L/fed M.A (4.73 and 3.77cm) in the two studied seasons. These results are in accordance with those obtained by (**Elarroussi *et al*., 2016**). Furthermore, this algae extract contains polysaccharides, which induce the physiological activities of the grown plants and, hence, positively reflect on their growth characteristics

The interaction between mineral nitrogen rates and bio-fertilizer treatments on bulb diameter after 130 days was significant in the two seasons Table 5. The obtained results show that N100% + 4.0 g/L S.p and N100% + 4.0 g/L S.p + 3.0 L/fed M.A in the first season (5.20 and 4.96 cm), in the second season (4.50 and 4.05 cm) recorded the highest increase in bulb diameter, respectively. Also, N75 +4.0 g/L Sp. recorded the highest value in both seasons (4.84 and 4.12 cm). Similar findings were noticed by (**Briceño-Domínguez *et al*. 2014**; **Döring *et al*. 2015**; **Battacharyya *et al*. 2015**; **andTandon and Dubey 2015)**.

Table (4): Effect of mineral nitrogen rats, spring with Spirolina and injection with mini Azotien levels on neck diameter (cm) after 130 days from planting at 2019/2020 and 2020/2021 seasons.

Neck diameter (cm)			
Mineral nitrogen (Kg/fed.)	**Bio-Treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	2.08 a	2.1 a
	3.0 L/fed. M.A	1.89 ab	1.86 ab
	4.0 g/L S.p.	1.85 ab	1.76 bc
	4.0 g/L S.p + 3.0 L/fed. M.A	1.92 ab	1.91 ab
Mean		1.94 a	1.91 a
75% (90 N)	**Control**	1.76 ab	1.68 b-d
	3.0 L/fed. M.A	1.75 ab	1.46 cd
	4.0 g/L S.p.	1.86 ab	1.78 a-c
	4.0 g/L S.p + 3.0 L/fed. M.A.	1.88 ab	1.75 bc
Mean		1.81 a	1.67 ab
50% (60 N)	**Control**	1.45 a-c	1.36 d
	3.0 L/fed. M.A	1.61 a-c	1.49 cd
	4.0 g/L S.p.	1.83 bc	1.79 a-c
	4.0 g/L S.p + 3.0 L/fed. M.A.	1.86 c	1.47 cd
Mean		1.69 a	1.53 b
Means of bio-treatments	**Control**	1.77 ab	1.71 ab
	3.0 L/fed. M.A	1.75 ab	1.61 ab
	4.0 g/L S.p.	1.85 ab	1.78 ab
	4.0 g/L S.p + 3.0 L/fed. M.A.	1.89 ab	1.71 ab

Sp: *Spirulina platensis* and M.A: Minia-azotien

Table (5): Effect of mineral nitrogen rats, spring with Spirolina and injection with mini Azotien levels on bulb diameter after 130 days from planting at 2019/2020 and 2020/2021 seasons.

Bulb diameter (cm)			
Mineral nitrogen (Kg/fed.)	**Bio-Treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	4.59 a	4.04 a
	3.0 L/fed. M.A	4.31 ab	3.96 ab
	4.0 g/L S.p.	5.20 ab	4.5 a-c
	4.0 g/L S.p + 3.0 L/fed. M.A	4.96 ab	4.05 a-c
Mean		4.77 a	4.14 a
75% (90 N)	**Control**	4.24 a-c	3.44 a-c
	3.0 L/fed. M.A	4.53 a-c	3.47 a-c
	4.0 g/L S.p.	4.84 a-d	4.12 a-c
	4.0 g/L S.p + 3.0 L/fed. M.A.	4.84 a-d	3.75 bc
Mean		4.61 a	3.70 a
50% (60 N)	**Control**	3.7 b-d	3.11 bc
	3.0 L/fed. M.A	3.86 b-d	3.25 bc
	4.0 g/L S.p.	4.41 cd	3.86 bc
	4.0 g/L S.p + 3.0 L/fed. M.A.	4.40 d	3.5 c
Mean		4.09 b	3.43 a
Means of bio-treatments	**Control**	4.18 b	3.53 b
	3.0 L/fed. M.A	4.23 b	3.56 b
	4.0 g/L S.p.	4.82 a	4.16 a
	4.0 g/L S.p + 3.0 L/fed. M.A.	4.73 a	3.77 ab

S.p: *Spirulina platensis* and M.A: Minia-Azotien

Bulbing ratio:-

Data presented in Table (6) indicate that the bulbing ratio insignificantly responded to the Nitrogenlevels in both seasons. However, 75% (N2) gave the highest bulbing ratio (0.40 and 0.45) in the 1st and 2nd seasons, respectively, which agrees with those obtained by**Ahmed *et al*., (2012)**.

Regarding the effect of biofertilizers, data in the same table indicate that spirolina treatment gave appreciable increases in bulbing ratio in the first and second seasons; also Spirolina gave a highly significant effect of bulbing ratio in both seasons recorded the value of the height (0.39 and 0.43) in the first and second season respectively. But Mini azotien did not significantly affect the bulbing ratio in both seasons. On the other hand, interaction between Spirolina and Mini Azotien significantly responded to a bulbing ratio in the second year only. Results agree with those obtained by **Elarroussi *et al*., (2016)**.

Data showed that the Interactions of mineral nitrogen rates and bio-fertilizers significantly affected the bulbing ratio in the first and second seasons. While N100% + 4.0 g/L Sp., the highest values (0.36 and 0.39) were recorded in the first and second seasons, respectively, compared to (N100% + Control), which attained the lowest values. Results agreed with those obtained by **Battacharyya *et al*. (2015)**.

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Table (6): Effect of mineral nitrogen rats, spring with Spirolina and injection with mini Azotien levels on Bulbing ratio after 130 days from planting at 2019/2020 and 2020/2021 seasons.

	Bulbing ratio		
Mineral nitrogen (Kg/fed.)	**Bio-Treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	0.45 a	0.53 a
	3.0 L/fed. M.A	0.44 a	0.47 cd
	4.0 g/L S.p.	0.36 e	0.39 g
	4.0 g/L S.p + 3.0 L/fed. M.A	0.39 d	0.47 cd
Mean		0.41 a	0.47 a
75% (90 N)	**Control**	0.42 bc	0.49 b
	3.0 L/fed. M.A	0.39 d	0.42 f
	4.0 g/L S.p.	0.39 d	0.44 ef
	4.0 g/L S.p + 3.0 L/fed. M.A.	0.39 d	0.47 cd
Mean		0.40 a	0.45 a
50% (60 N)	**Control**	0.40 cd	0.45 de
	3.0 L/fed. M.A	0.41 c	0.47 cd
	4.0 g/L S.p.	0.42 bc	0.47 bc
	4.0 g/L S.p + 3.0 L/fed. M.A.	0.43 ab	0.43 f
Mean		0.42 a	0.46 a
Means of bio-treatments	**Control**	0.42 a	0.49 a
	3.0 L/fed. M.A	0.41 b	0.45 b
	4.0 g/L S.p.	0.39 d	0.43 c
	4.0 g/L S.p + 3.0 L/fed. M.A.	0.40 c	0.46 b

S.p: *Spirulina platensis* and M.A: Minia-azotien

2- Individual plant characteristics

Bulb diameter:-

The presented data in Table (7) shows that mineral nitrogen rates significantly affect Bulb diameter (cm) in the first and second seasons. The highest increase in bulb diameter was recorded with Nitrogen rats 100% (6.66 and 5.83 cm) in the first and second seasons, respectively. These results are agreed with those obtained by **Rahman *et al*.**, **(2004)**.

Regarding the effect of biofertilizers, data in the same tables showed that biofertilizers significantly affected bulb diameter (cm) in both seasons. The highest value for bulb diameter was obtained with

4.0 g/L Sp. (6.67 and 5.73 cm) and 4.0 g/L S.p + 3.0 L M.A (6.52 and 5.42 cm) in the first and second seasons respectively. Agrees with the results of **Shalaby and El-Ramady (2014)** on garlic and **Abd El-Aleem *et al*. (2017)** on fennel.

Concerning the effect of the combinations among mineral N, and bio fertilizers, the results in Tables 7 indicate significant differences between the interaction of mineral nitrogen rates and bio fertilizers on the bulb diameters in both seasons. The obtained results show that N100% + 4.0 g/L Sp. and N100%+ 4.0 g/L Sp + 3.0 L/fed. M.A in the first season (7.06 and 6.9 cm), and in the second season (6.31 and 6.02 cm) respectively. Also, in the two seasons, the treatments of N75% + 4.0 g/L Sp. and N75%+ 4.0 g/L Sp + 3.0 L/fed**.** M.A improved the bulb diameter and gave the highest significant increase with insignificant differences among them. These results agreed with those obtained by (**Döring *et al*. 2015**; **Battacharyya *et al*. 2015**; and **Tandon and Dubey**, **2015)**.

Table (7): Effect of mineral nitrogen rats, spring with Spirolina and injection with Mini Azotien levels on bulb diameter (cm) at harvest of 2019/2020 and 2020/2021 seasons.

Bulb diameter (cm)			
Mineral nitrogen (Kg/fed.)	**Bio-treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	6.17 a	5.49 a
	3.0 L/fed. M.A	6.52 a	5.51 ab
	4.0 g/L S.p.	7.06 ab	6.31 ab
	4.0 g/L S.p + 3.0 L/fed. M.A	6.90 ab	6.02 bc
Mean		6.66 a	5.83 a
75% (90 N)	**Control**	5.80 a-c	4.88 bc
	3.0 L/fed. M.A	5.98 b-d	4.94 bc
	4.0 g/L S.p.	6.67 b-d	5.84 c
	4.0 g/L S.p + 3.0 L/fed. M.A.	6.65 c-e	5.43 c
Mean		6.28 a	5.27 b
50% (60 N)	**Control**	5.13 c-e	4.14 c
	3.0 L/fed. M.A	5.55 de	4.06 cd
	4.0 g/L S.p.	6.28 ef	5.05 de
	4.0 g/L S.p + 3.0 L/fed. M.A.	6.00 f	4.8 e
Mean		5.74 b	4.51 c
Means of bio-treatments	**Control**	5.70 b	4.84 b
	3.0 L/fed. M.A	6.01 b	4.84 b
	4.0 g/L S.p.	6.67 a	5.73 a
	4.0 g/L S.p + 3.0 L/fed. M.A.	6.52 a	5.42 a

***S.p*: *Spirulina platensis* and M.A: Minia-Azotien**

Bulb head weight (g) and clove weight (g):

Results in Tables (8 and 9) indicate that bulb head weight was significantly affected by different rates of mineral nitrogen fertilizers in both seasons. The treatment of N 100% was more effective for increasing bulb head weight (75.99 and 73.64 g) than the treatment of N 50%, which gave the lowest values (69.94 and 67.13 g) in the 1st and 2nd seasons, respectively. These results agree with those that **Rahman et al. (2004)**.

As expected, mineral nitrogen fertilizer rates significantly affect clove weight (g). Also, N 100% recorded the highest clove weight (4.27 and 3.96 g) in both seasons.

On the other hand, the results in Table 8 show significant differences in average cloves weight (g)/bulb in both seasons. Nitrogen levels at 100% in the first season and second season show the heaviest clove weight (g) (4.27g and 3.96 g) compared to the nitrogen levels at 50% treatment (3.67 and 3.48 g), respectively. These results agree with those reported by (**Shrestha *et al*., 2011; Zaki *et al*., 2014; Marzauk *et al*., 2014; and Hassan, 2015).**

Regarding the effect of bio fertilizers, it's clear from the obtained data in Tables (8and 9) that biofertilizer treatments had significant effects on bulb head weight g/plant in both seasons. With the addition of 4.0 g/L of S.p, the heaviest bulb head was recorded in the 1st season (80.02 g/plant) and the 2nd season (77.33 g/plant). The lowest values were obtained with the control treatment(64.62 and 63.68g/plant) in the first and second seasons, respectively. On the other hand, the data revealed that average clove weight (g) was significantly affected by bio-fertilizers 4.0 g/L Sp. recorded the highest clove weight (4.15 and 3.97 g)/bulb compared to the control treatment (3.76 and 3.42 g) in both seasons. These results agreed with the results obtained by **Shalaby and El-Ramady (2014)** on garlic **Abd El-Aleem *et al*. (2017)** on fennel, and **Almaroai and Eissa (2020)** on onion.

Table (8): Effect of mineral nitrogen rats, spring with Spirolina and injection with mini Azotien levels on bulb head weight (g) at harvest of 2019/2020 and 2020/2021 seasons.

Bulb head weight (g)			
Mineral nitrogen (Kg/fed.)	**Bio-Treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	70.12 ef	69.49 d
	3.0 L/fed. M.A	72.38 de	70.62 d
	4.0 g/L S.p.	83.72 a	82.1 a
	4.0 g/L S.p + 3.0 L/fed. M.A	77.74 bc	72.34 cd
Mean		75.99 a	73.64 a
75% (90 N)	**Control**	65.46 g	63.9 f
	3.0 L/fed. M.A	68.65 f	69.67 d
	4.0 g/L S.p.	79.38 b	76.3 b
	4.0 g/L S.p + 3.0 L/fed. M.A.	77.93 bc	75.87 b
Mean		72.86 b	71.43 a
50% (60 N)	**Control**	58.28 h	57.67 g
	3.0 L/fed. M.A	69.55 ef	66.73 e
	4.0 g/L S.p.	76.95 bc	73.6 bc
	4.0 g/L S.p + 3.0 L/fed. M.A.	75.00 cd	70.5 d
Mean		69.95 c	67.13 b
Means of bio-treatments	**Control**	64.62 d	63.68 d
	3.0 L/fed. M.A	70.19 c	69.01 c
	4.0 g/L S.p.	80.02 a	77.33 a
	4.0 g/L S.p + 3.0 L/fed. M.A.	76.89 b	72.9 b

Sp: *Spirulina platensis* and M.A: Minia-azotien

The interactions between Mineral Nitrogen rates and bio-fertilizers' effects onbulb head weight significantly affect both growing seasons (Table, 7). The best values were achieved with the combined treatment of N

100% +4.0 g/L Sp. In the first season (83.72 g) and second season (82.1 g).

Also, N75%+ 4.0 g/L Sp. And N75%+ 4.0 g/L Sp + 3.0 L/fed**.** M.A recorded the best bulb head weight in both seasons. However, in Table (7), the effects of the interaction between Mineral Nitrogen rates and bio-fertilizers on clove weight (g) showed significant differences in both seasons. The combined treatments of mineral nitrogen rates 100% + (4.0 g/L S.p.) gave the highest values in both seasons (4.15 and 4.27g.). The lowest value was obtained with the N50% without biofertilizer application in both seasons. Results agreed with those obtained by (**Briceño-Domínguez *et al*. 2014**; **Döring *et al*. 2015; Battacharyya *et al*. 2015; and Tandon and Dubey, 2015).**

Table (9): Effect of Mineral Nitrogen rats, spring with Spirolina and injection with Mini Azotien levels on clove weight at harvest of 2019/2020 and 2020/2021 seasons.

Clove weight (g)			
Mineral nitrogen (Kg/fed.)	**Bio-Treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	4.14 a	3.61 a
	3.0 L/fed. M.A	4.18 ab	3.92 ab
	4.0 g/L S.p.	4.45 a-c	4.27 ab
	4.0 g/L S.p + 3.0 L/fed. M.A	4.31 a-c	4.05 a-c
Mean		4.27 a	3.96 a
75% (90 N)	**Control**	3.72 a-c	3.39 a-c
	3.0 L/fed. M.A	3.91 a-d	3.58 a-c
	4.0 g/L S.p.	4.11 b-e	4.05 a-c
	4.0 g/L S.p + 3.0 L/fed. M.A.	3.98 b-e	3.7 a-c
Mean		3.93 b	3.68 ab
50% (60 N)	**Control**	3.42 c-e	3.27 bc
	3.0 L/fed. M.A	3.60 c-e	3.52 bc
	4.0 g/L S.p.	3.88 de	3.6 bc
	4.0 g/L S.p + 3.0 L/fed. M.A.	3.79 e	3.53 c
Mean		3.67 c	3.48 b
Means of bio-treatments	**Control**	3.76 b	3.42 b
	3.0 L/fed. M.A	3.90 ab	3.67 ab
	4.0 g/L S.p.	4.15 a	3.97 a
	4.0 g/L S.p + 3.0 L/fed. M.A.	4.03 ab	3.76 ab

Sp: *Spirulina platensis* and M.A: Minia-azotien

3- Yields and Bulb quality:-

Fresh total yield (ton.fed^{-1}).

Fresh total yield (ton/fed) is important because increasing fresh total yield (ton/fed.) means increasing the grower's income. Data presented in Table (10) show that fresh total yield was significantly affected by the studied mineral nitrogen rates only in the second season. N100% gave the highest fresh total yield (ton/fed). These results are in accordance with that obtained by **Ahmed *et al*.**, **(2012)**, who found that garlic yield enhanced with increasing the level of nitrogen fertilization up to 200 kg N/fed in clay loam soil, which means that garlic yield correlated positively with N fertilization.

Data in Table (10) show that biofertilizers significantly increased fresh yield (ton/fed) only in the 1st season. The highest value (7.877 ton/fed) was recorded with the treatment (4.0 g/L S.p). This result is agreed with those obtained by**Almaroai and Eissa (2020)**. This increase may be due to algae's beneficial chemical compounds, which are used as nutrient supplements and bio-stimulants (**Saha *et al*. 2018**).

The interaction between the tested mineral nitrogen rates and the bio-fertilizers on fresh yield (ton/fed) was significant in both seasons (Table, 10). The interactions effect between treatments of N100%+4.0 g and between N100%+ 4.0 g/L S.p + 3.0 L/fed**.** M.A were more effective for increasing fresh total yield (ton.fed-1) in the 1st (8.532, 8.096 ton/fed) and (7.55 and 6.997 ton/fed) in the 2nd season respectively. Also, the same table shows that the highest decrease in fresh total yield (ton/fed) was recorded with the mineral nitrogen rate (N50 %) in both seasons. This result agrees with those obtained by **Battacharyya *et al*.**, **(2015)**, and **Tandon and Dubey, (2015)**.

Table (10): Effect of mineral nitrogen rats, spring with Spirolina and injection with mini Azotien levels on fresh total yield (ton.fed^{-1}) at harvest of 2019/2020 and 2020/ 2021 seasons.

Fresh total yield (ton.fed^{-1})			
Mineral nitrogen (Kg/fed.)	**Bio-Treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	7.39 a	6.597 a
	3.0 L/fed. M.A	7.74 ab	6.567 ab
	4.0 g/L S.p.	8.53 ab	7.55 a-c
	4.0 g/L S.p + 3.0 L/fed. M.A	8.10 ab	6.997 a-c
Mean		7.94 a	6.93 a
75% (90 N)	**Control**	7.14 ab	5.983 a-c
	3.0 L/fed. M.A	7.33 ab	6.511 a-c
	4.0 g/L S.p.	7.76 ab	6.559 a-c
	4.0 g/L S.p + 3.0 L/fed. M.A.	7.37 ab	6.427 a-c
Mean		7.40 ab	6.37 ab
50% (60 N)	**Control**	5.84 a-c	5.433 bc
	3.0 L/fed. M.A	6.67 bc	5.455 bc
	4.0 g/L S.p.	7.34 bc	6.322 c
	4.0 g/L S.p + 3.0 L/fed. M.A.	6.81 c	5.892 c
Mean		6.67 b	5.78 b
Means of bio-treatments	**Control**	6.79 b	6.00 b
	3.0 L/fed. M.A	7.25 ab	6.178 ab
	4.0 g/L S.p.	7.88 a	6.81 a
	4.0 g/L S.p + 3.0 L/fed. M.A.	7.43 ab	6.439 ab

Sp: *Spirulina platensis* and M.A: Minia-azotien

Weight loss (%) after curing:-

Data reported in Table (11) showed that the percentage of weight loss % after curing was significantly affected by the Mineral Nitrogen rates only in the 1st season.
The lowest values for weight loss % were recorded with N 50% and N 75% (21.90 % and 22.88 %), respectively, compared to the N 100% (24.13 %). Similar results were obtained by **Hassan (2015)**, **Mohamed (2015)** and **Kumar *et al*. (2018)** on garlic.

Concerning the effect of biofertilizer on the percentage of weight losses after curing, there was a significant effect in the first seasons only in the same Table (11). 4.0 g/L S.p. gave the lowest weight loss percentage (%). While the highest values of weight loss percentage (%) were recorded with the Control in the first season. On the other hand, the effect of biofertilizer on a percentage of weight losses after curing was insignificant in the second season.

After curing, the interaction between mineral nitrogen rates and biofertilizers significantly affects both seasons (Table, 11). The best value for decreasing weight percentage was gained with the combined treatment of N50% + 4.0 g/L S.p. (20.59 %) followed by the combined treatment of N50% + 3.0 L/fed. M.A (20.71 %) in the 1st season, but the best value for decreasing weight percentage was recorded with N50% (20.83%) in the 2nd season.

Table (11): Effect of mineral nitrogen rats, spring with Spirolina and injection with mini Azotien levels on weight loss (%) after curing of 2019/2020 and 2020/2021 seasons.

Weight loss (%) after curing			
Mineral nitrogen (Kg/fed.)	**Bio-Treatments**	**1st season**	**2nd season**
100% (120 N)	**Control**	24.39 b	23.25 ab
	3.0 L/fed. M.A	24.23 b	24.24 a
	4.0 g/L S.p.	25.21 a	24.36 a
	4.0 g/L S.p + 3.0 L/fed. M.A	22.70 d	21.28 b
Mean		24.13 a	23.28 a
75% (90 N)	**Control**	24.98 a	22.97 ab
	3.0 L/fed. M.A	21.99 f	24.81 a
	4.0 g/L S.p.	22.15 ef	22.68 ab
	4.0 g/L S.p + 3.0 L/fed. M.A.	22.41 de	22.86 ab
Mean		22.80 b	23.33 a
50% (60 N)	**Control**	23.11 c	20.83 b
	3.0 L/fed. M.A	20.71 g	22.55 ab
	4.0 g/L S.p.	20.59 g	22.38 ab
	4.0 g/L S.p + 3.0 L/fed. M.A.	23.21 c	23.91 a
Mean		21.91 b	22.42 a
Means of bio-treatments	**Control**	24.16 a	22.35 a
	3.0 L/fed. M.A	22.31 c	23.87 ab
	4.0 g/L S.p.	22.65 b	23.14 ab
	4.0 g/L S.p + 3.0 L/fed. M.A.	22.77 b	22.68 b

Sp: *Spirulina platensis* and M.A: Minia-azotien

Conclusions

Our experiment results showed that biofertilizers are important in improving the quantity and quality of garlic production. Also, data showed that the best treatment was when treating garlic plants with 100% mineral nitrogen in addition to treated plants with biofertilizers such as *Spirulina platensis* 4.0 $g.L^{-1}$.

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تحسين محصول وجودة الثوم باستخدام بعض المعاملات الحيوية

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أجريت تجربه حقلية خلال موسمى 2020/2019 و2021/2020 بمحطة البحوث الزراعية بملوي بمحافظة المنيا مصر. بهدف تقليل معدلات إضافة الأسمدة النيتروجينية المعدنية عند إنتاج الثوم..تم استخدام السماد النتروجيني المعدني بثلاث معدلات (50- 75- 100% من الجرعة الموصى بها من النيتروجين).أربعة أنواع من التسميد الحيوي (كنترول- المنيا أزوتين 3/ لتر فدان- طحلب الاسبيرولينا 4 جم./لتر، و 3 لتر/ فدان المنيا أزوتين + 4 جم/لتر طحلب سبيرولينا) لدراسة تأثيراته على صفات النمو الخضرى و صفات المحصول وجودة الثوم صنف إيجاسيد1 .أوضحتالنتائجالمتحصل عليهاأنمعدلات النيتروجين المعدني تختلف بشكل كبير في تأثيرها على معايير نمو الثوم والمحصول. وكان أفضل معدل للحصول على أعلى قيم للنمو والمحصول للثوم هو 100% من الجرعة الموصى بها .فيما يتعلق بتأثيرات الأسمدة الحيوية، أظهرت معاملة طحلب الاسبيرولينا أفضل النتائج لتحسين معامل النمو و إنتاجية الثوم مقارنة بمعاملة المينيا أزوتين في النباتات غير الملقحة.أظهرت نتائج التفاعل بين المعاملة المعدنية والسماد الحيوي أن أفضل معاملة كانت 100% نيتروجين معدني + 4 جم/.لتر من طحلب الاسبيرولينا للحصول على نمو أفضل وأعلى إنتاجية وجودة للثوم.