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EFFECT OF HUMIC ACID AND BIOCHAR ON YIELD AND QUALITY OF GARLIC UNDER DIFFERENT NITROGEN LEVELS

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ABSTRACT: At the Experimental Farm of El-Gemmeiza, Agric Res. Station, (ARC), Gharbya Governorate (Middle Delta, Egypt), two field experiments were conducted in the winters of 2020/2021 and 2021/2022 to examine the effects of nitrogen fertilization at 50, 75 and 100% of the recommended rate (equal 60, 90 and 120 kg N/fed., respectively) and treated soil with some soil conditioner (humic acid at 10 kg/fad., biochar at 5m^3/fed. and humic at 10 kg/fad. + biochar at 5 m^3/fad.), beside untreated soil (control) on plant growth , mineral uptake , yield and bulb quality of garlic cv. Sids 40 using a flow irrigation system in clay soil. Fertilizing garlic plants with 100% equal 120 kg N/fed. and treating soil with a mixture of humic acid at 10 kg /fed. and biochar at 5 m3/fed. had a significant effect on plant growth (plant height, number of leaves per plant, both neck and bulb diameter, as well as the fresh and dry weight of the bulb and leaves and the total fresh and dry weight), nitrogen, phosphorus, and potassium percentages, and its uptake by the leaves of garlic plants at 135 days from sowing, and gave the highest values of yield and its components (exportable, marketable yield, total yield/fed., and average bulb weight), as well as bulb quality (N, P, and K, total soluble solids, dry matter content, and pungency). Moreover, the interaction between nitrogen at a rate of 75% RR and the mixture of humic acid and biochar gave the best results for increasing the efficiency of nitrogen use, and the relative increases in the total yield were about (4.97 and 5.38%) compared to the interaction between nitrogen at a rate of 100% RR only in both seasons, respectively and a decrease in mineral nitrogen by 25%.

Key words: Garlic, nitrogen, humic acid, biochar, plant growth, yield and bulb quality.

INTRODUCTION

Garlic *(Allium sativum* L), is one of the earliest vegetables to be produced. Its therapeutic benefits have been demonstrated for millennia. Garlic cloves are the part of the plant that can be eaten. Garlic has a variety of enzymes, amino acids, trace minerals, and antibiotics such as allistatin and garlicin. It can be eaten on its own or added to dishes to enhance flavour. Moreover, it goes into making items with smoked meat and several medications. These days, appreciate it for the essential oils it contains (**Malý *et al*., 1998**).

Nitrogen (N) is a necessary ingredient for plant growth, and horticultural and agronomic plants' vegetative growth depends on the availability of nitrogen. One of the main types of nitrogen that is vital to many of the metabolic activities in plants is nitrate. Nitrogen is one of the most crucial elements for plant growth, after water. Deficit in nitrogen causes a reduction in photosynthesis and dry matter production, as well as a drop in the biomass of aerial organs and the leaf surface index. However, long-term overuse of nitrogen will result in illnesses, environmental issues, devastation of soil structure, and a decline in productivity. Regrettably, more nitrogen fertilizer is being used in agricultural production. Approximately 50–70% of the nitrogen that plants take up from the soil is unavailable to them and is not absorbed (**Lei *et al*., 2022**). Nitrogen is a crucial part of the protein molecule

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and has a structural role in nucleic acids and proteins. The kind of soil, the surrounding conditions, and the type of plant all affect how much nitrogen the plant absorbs. Garlic needs nitrogen during its vegetative growth stages; robust growth and leaf development result from adequate nitrogen levels (**Kevlani *et al*., 2023**).

Increasing nitrogen fertilizer increased plant growth, yield and its components and bulb quality **(Farooqui *et al*., 2009; Ahmed *et al*., 2012; Abou El-Magd *et al.*, 2014; Betewulign and Tulu 2014; Hore *et al*., 2014; Hossein *et al*., 2014; Zaki *et al*., 2014; Guesh 2015; Hassan, 2015; Shege, 2015; Nasef and Elwan 2016; Kumar *et al*., 2018; Ibraheim, 2022; Tena and Desta, 2023; Amerian *et al.*, 2024** on garlic).

Humic acid (HA) is a heterogeneous mixture of several molecules, including weak aliphatic and aromatic organic acids. It affects soil properties and plant growth in different ways and is soluble in alkaline water but insoluble in acidic water (**Pettit 2004**). Commercial HA production aims to fertilizer with organic matter. Through a variety of internal plant and soil mechanisms, its components stimulate plant growth and yield, improve soil fertility, and increase the availability of nutrients (**Moraditochaee 2012**). They also lessen the detrimental effects of stressors.

Plant growth, yield and bulb quality were affected by humic acid application (**Abou El-Khair *et al*., 2010; Abdel-Razzak and El-Sharkawy, 2013; Zaki *et al*., 2014; Mahmoud and Youssif, 2015; Shafeek *et al*., 2015; Zeinali and Moradi, 2015; Mohsen *et al*., 2017; Badawy *et al*., 2019; Rizk and Deshesh, 2021; Mohamed *et al*., 2023**).

Biochar is an organic amendment produced by the process called pyrolysis, which is the burning of plant biomass in a limited oxygen environment (**Xiao *et al.* , 2018).** Researches on field crops production system have shown promising results with biochar treatment, but the research on vegetables is scarce. Biochar has been found to reduce fertilizers need, and to maintain or improve crop productivity (**El-Naggar *et al.*, 2019**).

Previous studies showed that the biochar application into soil could stimulate plant growth, yield and bulb quality (**Youseef *et al*., 2017; Zheng *et al*., 2018; Neonbeni and Hoar 2020; Zhang *et al*., 2020; Aneseyee and Wolde, 2021; Kenea *et al*., 2024** all on garlic**,** except **Aneseyee and Wolde, 2021**) on onion.

The aim of this study was to improve the development, yield, and quality of garlic bulbs by applying biochar and humic acid to the soil under different mineral nitrogen levels

MATERIALS AND METHODS

At the Experimental Farm of El-Gemmeiza, Agric Res. Station (ARC), Gharbya Governorate (Middle Delta, Egypt), two field experiments were conducted in the winters of 2020/2021 and 2021/2022 to examine the effect of different nitrogen levels and treated soil with some soil conditioner (humic acid and biochar) on plant growth, mineral uptake, yield, and bulb quality of garlic cv. Sids 40 using a flow irrigation system in clay soil.

This experiment included 12 treatments, which were interacting between three levels of mineral nitrogen (100, 75, and 50 of the recommended rate (RR), which equal 120, 90, and 60 kg N/fed.), and some soil conditioner (humic acid at 10 kg/fed., and biochar at 5 m^3/fed, equal 750 kg, beside untreated (control). These treatments were arranged in a split-plot design with three replications. Different levels of mineral nitrogen were randomly arranged in the main plots, and some soil conditioners were randomly distributed in the sub-plots.

The experimental unit area was 12.0 m^2. It contained five ridges with 4m length and 60 cm in width. One ridge was used for the samples to measure vegetative growth, and the other four ridges were used for yield determination. The Agricultural Research Centre in Giza, Egypt provided the biochar.

Garlic cloves were selected for uniformity in shape and size. Cloves were planted at a distance of 10 cm on both sides of the ridge in the first week of October in both seasons.

One third of mineral nitrogen in the form of ammonium sulphate (20.6% N) was added during soil preparation with all quantity humic acid and biochar and the rest amounts of mineral nitrogen were added at three portions as soil application by one month intervals beginning one month after planting. Biochar and humic acid were obtained by Agricultural Research Centre in Giza, Egypt.

Table 1. The physical and chemical properties of the experimental soil in 2020/2021 and 2021/ 2022 seasons

Season	OM (%)	Clay (%)	Silt (%)	Sand (%)	Texture class	EC mmohs/ cm	pH	Available (ppm)		
								N	P	K
2020/2021 season	1.46	63.60	27.80	8.60	Clay loam	1.39	7.89	8.92	0.041	0.82
2021/2022 season	1.53	64.15	26.72	9.13		1.47	7.94	9.27	0.038	0.79

Samples of the soil were obtained from 25 cm soil surface.

Table 2. Some chemical constitutes of biochar

Chemical contents	2020/2021	2021/2022
Carbon %	29.8	32.7
Nitrogen %	0.77	0.67
Sulphur %	0.09	0.07
Phosphorus %	18.6	16.9
Potassium mg/kg	305	298
Calcium mg/kg	609	719
Magnesium mg/kg	167	189
Sodium mg/kg	861	792
Irion mg/kg	66.8	75.6
Manganese mg/kg	145	166
Zinc mg/kg	11.9	13.7
Copper mg/kg	8.28	9.77
pH (1:2.5 suspension)	10.21	8.98

All plots received the recommended dose of P and K at the rates 60 kg P_2O_5/fad., and 96 kg K_2O/fad., in the form calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48-50% K_2O), respectively. One third of potassium sulphate and all calcium super phosphate were added during soil preparation while the two third of K_2O was added at three portions as soil application by one month intervals beginning one month after planting. The normal agricultural practices were carried out as commonly followed in district.

Data Recorded

Growth Parameters

In order to measure the growth characteristics of garlic plants, which are expressed as plant height, leaf number per plant, neck, and bulb diameter, ten randomly selected plants from each plot were collected 135 days after planting in both study seasons. Measurements were made of the fresh weight of the leaves and bulb/plant, as well as the dry weight of the leaves and bulb/plant and the total dry weight of the plant after the leaves and bulb was oven dried at 70^{o}C until they reached a consistent weight.

Nitrogen, phosphorus and potassium contents

Nitrogen, phosphorus, and potassium contents in leaves at 135 days after sowing in both seasons were determined according to the methods described by According to **AOAC (2018**), N, P, and K uptake by leaves were calculated.

Yield and its components

When the bulbs reached the required maturity stage (200 days after sowing), the bulbs in each plot were collected and sorted into three groups in accordance with the guidelines established by **The Ministry of Economic (1963)** Garlic Exportation: Grade 1 refers to bulbs larger than 5.5 cm in diameter, Grade 2 to those between 4.5 and 5.5 cm in diameter, and Grade 3 to those between 3.5 and 4.4 cm in diameter. Following two weeks of curing, each grade was weighed independently, and the following information was noted: Marketable and total yield (grade 1+grade 2+grade 3) ton/fed, as well as exportable yield (grade 1+grade 2), were computed by dividing the yield of bulbs per plot by the total number of bulbs per plot.

Nitrogen use efficiency (NUE)

It was determined by dividing the bulb yield/ fad., by the nitrogen quantity/fad., and expressed as kg bulb/kg N according to Clark (1982).

Bulb Quality at Harvesting Date

Nitrogen, phosphorus and potassium contents

A sample of 100 gm of bulbs was oven dried at 70^{o}C until it reached a constant weight, and the following parameters were determined at harvesting time by the methods previously mentioned in the N, P, and K contents of the leaves.

Total protein%

It was calculated by multiplying total nitrogen x 6.25.

Total soluble solids (TSS) were measured using Carl Zeis refractometer set, and dry matter (%) in the bulb was determined. Pungency, as pyruvic acid, was measured in bulb tissues at the time of harvest, as reported by **Schwimmer and Westen** (**1961**).

Statistical Analysis

Recorded data were subjected to statistical analysis of variance according to **Snedecor and Cochran (1980**), and means separation was done according to **Duncan (1955).**

RESULTS AND DISCUSSION

Plant Growth

Effect of nitrogen levels

Data tabulated in Tables 3 to 5 indicated that there were significant differences between all nitrogen fertilizer rates of 50, 75, and 100% of the recommended rate (RR) equal 60, 90, and 120 kg N/fed., as for all plant growth characteristics of garlic plants grown in clay soil after 135 days from sowing in both seasons. Plant height, number of leaves, both neck and bulb diameter, as well as fresh weight of leaves/plant, bulb and total, dry weight of leaves, bulb and total dry weight, significantly gradually increased by the addition of nitrogen rates, except neck diameter in both seasons. However, the highest values of plant height (83.25 and 80.75 cm), leaf number per plant (110.0 and 10.5 leaf per plant), bulb diameter (5.28 and 5.22 cm), total fresh weight per plant (102.08 and 101.71 g), and total dry weight/ plant (15.29 and 14.82 g) were recorded with the plants that were fertilized with 100% RR equal to 120 kg N/fed., in the 1st and 2nd seasons, respectively.

There were no significant differences between fertilizing with 100 RR and 75% RR for the number of leaves per plant in the first season and bulb diameter in both seasons.

The depression percentage in total dry weight / plant due to fertilizing with N at 50% RR were 26.29 and 29.55% and due to N at 75% RR 13.28 and 14.91% less than fertilizing with 100% RR in the 1st and 2nd seasons, respectively.

The rise in the plant's mean fresh and dry weight following nitrogen application may be attributed to increased leaf production, length, and physiological maturity following fertilization; these factors may have resulted in a greater amount of assimilate being produced and allocated to the bulbs (**Fikru and Fikreyohannes, 2018**).

Increased nutrient availability, which supports garlic plants' maximum plant growth, and the effect of nitrogen contributing to higher rates of vegetative growth and stem elongation may be the cause of the increase in plant growth (vegetative growth, fresh and dry weight) with a rise in nitrogen up to a certain optimum level (**Amare *et al*., 2020**).

Table 3. Effect of nitrogen levels and some soil conditioners on the vegetative growth of garlic at 135 days after sowing during the 2020/2021 and 2021/2022 seasons

Treatments	Plant height (cm)		Number of leaves / plant		Neck diameter (cm)		Bulb diameter (cm)	
	S1	S2	S1	S2	S1	S2	S1	S2
				Effect of nitrogen levels				
50 % RR	53.75 c	49.50 c	9.00 b	8.00 c	1.49 a	1.43 a	4.52 b	4.39 b
75 % RR	81.00 b	72.75 b	10.00 a	10.00 b	1.52 a	1.49 a	5.22 a	5.15 a
100 %RR	83.25 a	80.75 a	10.00 a	10.50 a	1.56 a	1.53 a	5.28 a	5.22 a
				Effect of soil amendments				
Control	64.00 d	57.00 d	8.66 c	8.66 c	1.44 a	1.40 b	4.74 b	4.57 b
HA	73.33 b	67.66 c	9.66 b	9.66 b	1.53 a	1.48 ab	5.05 a	5.00 a
Biochar	70.66 c	70.00 b	9.66 b	9.66 b	1.52 a	1.50 ab	5.01 a	4.99 a
HA+ biochar	82.66 a	76.00 a	10.66 a	10.00 a	1.59 a	1.56 a	5.23 a	5.13 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 4. Effect of nitrogen levels and some soil conditioners on the fresh weight of garlic at 135 days after sowing during the 2020/2021 and 2021/2022 seasons

Treatments	Fresh weight of leaves (g)		Fresh weight of bulb (g)		Total fresh weight (g)	
	S1	S2	S1	S2	S1	S2
			Effect of nitrogen levels			
50 % RR	61.62 c	56.37 c	31.63 b	30.43 c	93.26 c	86.80 c
75 % RR	65.02 b	61.59 b	34.35 a	33.20 b	99.38 b	94.79 b
100 %RR	67.18 a	66.11 a	34.89 a	35.59 a	102.08 a	101.71 a
			Effect of soil amendments			
Control	62.89 c	57.20 d	30.66 d	31.03 d	93.56 d	88.24 d
HA	64.45 b	62.31 b	34.15 b	33.55 b	98.60 b	95.87 b
Biochar	62.05 d	60.29 c	33.28 c	32.18 c	95.33 c	92.47 c
HA+ biochar	69.05 a	65.62 a	36.41 a	35.53 a	105.47 a	101.16 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 5. Effect of nitrogen levels and some soil conditioners on the dry weight of garlic at 135 days after sowing during the 2020/2021 and 2021/2022 seasons

Treatments	Dry weight of leaves (g)		Dry weight of bulb (g)		Total dry weight (g)	
	S1	S2	S1	S2	S1	S2
			Effect of nitrogen levels			
50 % RR	8.05 c	7.32 c	3.21 c	3.12 c	11.27 c	10.44 c
75 % RR	9.24 b	9.00 b	4.01 b	3.61 b	13.26 b	12.61 b
100 %RR	10.88 a	10.46 a	4.41 a	4.35 a	15.29 a	14.82 a
			Effect of soil amendments			
Control	8.49 d	7.73 d	3.65 d	3.37 d	12.15 d	11.10 d
HA	9.45 b	9.33 b	3.90 b	3.81 b	13.35 b	13.15 b
Biochar	9.10 c	8.63 c	3.78 c	3.60 c	12.89 c	12.24 c
HA+ biochar	10.52 a	10.01 a	4.18 a	3.99 a	14.71 a	14.01 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

These results are similar to those stated by **Zaki *et al*., 2014; Guesh 2015; Hassan**, **2015**; **Shege**, **2015; Tena and Desta, 2023** on garlic. They showed that plant growth parameters such as vegetative growth, fresh weight, and dry weight were significantly enhanced by increasing nitrogen rates.

Effect of soil amendments

Treated garlic plants with some soil amendments such as humic acid or biochar had a significant effect on all plant growth traits (vegetative growth, fresh and dry weight of bulb and leaves) at 135 days after sowing in both seasons as compared to the untreated control treatment (Tables 3 to 5).

Soil amendment with the mixture of humic acid at 10 kg /fed. and biochar at 5 m^3/fed. gave the highest values of plant height (82.66 and 76.0 cm), number of leaves per plant (10.66 and 10.00 leaf/plant) , neck diameter (1.59 and 1.56 cm) and bulb diameter (5.23 and 5.13 cm) as well as total fresh weight (105.47 and 101.16 g) and total dry weight / plant (14.71 and 14.01 g) in the 1st and 2nd seasons, respectively. On the other side, the addition of humic acid to the soil came in second rank for all vegetative growth parameters, while the lowest values of all the above-mentioned traits were obtained with the control treatment (no addition) in both seasons. The relative increases in total dry weight per plant due to the addition of the mixture with humic acid and biochar were 21.07 and 26.22%, followed by treated soil with humic acid (9.88 and 18.47) and biochar (6.09 and 10.27%) over untreated plants in the 1st and 2nd seasons, respectively.

Among the humic compounds, humic acid is one of the most potent biostimulants and has numerous beneficial effects on the growth and development of rice. It effectively increases the rate of photosynthesis, plant growth, the amount of dry matter accumulated, and the amount of organic matter produced and accumulated **(Dan *et al*., 2010**). A solid, carbon-rich byproduct of pyrolysis biomass in an oxygen-limited environment is called biochar (**Xiao *et al*., 2018).** Because biochars are inexpensive and have great qualities like a large surface area, a high reactivity, and a lot of functional groups, they have recently been developed into functional materials for soil improvement and environmental remediation (**El-Naggar *et al*., 2019**).

These results agreed with those obtained by **Abdel-Razzak and El-Sharkawy, 2013; Zaki *et al*., 2014; Mohsen *et al*., 2017** for humic acid, and **Zheng *et al*. 2018** for biochar on garlic, they indicated that treated soil with humic acid or biochar increased plant growth parameters compared to untreated soil.

Effect of the interaction

Data showed that the interaction between nitrogen rates (50, 75, and 100% RR) and treated soil with humic acid (10 kg/fed.) and biochar (5 m^3/fed.) had a significant effect on plant height, number of leaves per plant, both neck and bulb diameter (Table 6), as well as the fresh and dry weight of the bulb and leaves and the total fresh and dry weight of garlic plants (Tables 7 and 8) at 135 days from sowing in both seasons.

Maximum values of plant height (95.0 and 90.0 cm), neck diameter (1.63 and 1.60 cm) and bulb diameter (5.50 and 5.40 cm), total fresh weight (112.86 and 110.12 g), and total dry weight (16.76 and 16.52 g) were recorded with the interaction between N at 100% RR and treated soil with a mixture of humic acid and biochar in both seasons, respectively.

There were no significant differences between the interaction between N at 100% RR and treated soil with a mixture of humic acid and biochar and the interaction between N at 75% RR and the same soil treated with humic acid and biochar for the number of leaves per plant, both neck and bulb diameter, in both seasons. On the other side, there were no significant differences between N at 75% RR and treated soil with a mixture of humic acid and biochar and N at 100 % RR only or with 100% RR and humic acid or 100% RR and biochar in most plant growth parameters in both seasons.

The relative increases in total dry weight per plant due to the interaction between N at 75% RR and the addition of the mixture with humic acid and biochar were 4.99 and 9.14% over fertilizing plants with 00% RR only in the 1st and 2nd seasons, respectively.

These results are in a good line with those reported by **Youseef *et al*. (2017)** on garlic. They found that the interaction between nitrogen fertilizer and treated soil with biochar gave the best results for increasing all plant growth parameters compared to fertilizing with nitrogen only.

Nitrogen, Phosphorus and Potassium Contents in Leaves and its Uptake

Effect of nitrogen rates

Nitrogen, phosphorus and potassium contents in leaves and its uptake at 135 days after sowing significantly increased by increasing nitrogen rates up to the highest rates in both seasons .

Fertilizing garlic plants grown in clay soil with 100% RR equal 120 kg/fed., gave the highest values (4.67 and 4.78%), (0.544 and 0.560%) and K (3.15 and 2.99%) for N, P and K contents in the 1st and 2nd seasons, respectively (Table 9) and (510.15 and 503.33 mg), (59.35 and 58.82 mg) and (344.75 and 314.10 mg) for N,P and K uptake by leaves in the 1st and 2nd seasons, respectively (Table 10), followed by fertilizing plants with 75% RR, while fertilizing with 50% RR gave the lowest values of N, P and K contents and its uptake in both seasons.

The heightened concentration of minerals in the tissues of garlic plants following an increase in nitrogen fertilizer application may be ascribed to the plant's enhanced capacity for absorption. Furthermore, adding nitrogen fertilizer promotes the synthesis of carbohydrates, for which the dry matter content is a trustworthy indicator. This may be the result of roots absorbing more minerals due to an increase in the amount of carbohydrates in the roots (**Mengel and Kirkby, 1978**).

These findings are consistent with those published by **El-Hadidi *et al.* (2016)** on onion and **Mansour *et al.* (2019)** on garlic. They showed that plants were fertilized with the highest concentration of nitrogen fertilizer, the plants recorded the highest values of N, P, and K percentages and their uptake in comparison to plants that were not fertilized or with 100 kg N/fed.

Effect of soil conditioner

Application of humic acid at 10 kg /fed., or biochar at 5 m^3/fed., alone or in the mixture significantly increased the N, P, and K contents in leaves and their uptake by leaves at 135 days after sowing as compared to non addition (control treatment) in both seasons.

Table 6. Effect of interaction between nitrogen levels and some soil conditioners on the vegetative growth of garlic at 135 days after sowing during the 2020/2021 and 2021/2022 seasons

Treatments		Plant height (cm)		Number of leaves / plant		Neck diameter (cm)		Bulb diameter (cm)	
		S1	S2	S1	S2	S1	S2	S1	S2
50 %RR	Control	47.0 j	43.0 j	8.0 d	7.0 e	1.40 a	1.35 b	4.12 e	3.71 f
	HA	55.0 h	50.0 i	9.0 c	8.0 d	1.52a	1.42 ab	4.60d	4.55 e
	Biochar	53.0 i	49.0 i	9.0 c	8.0 d	1.50 a	1.46 ab	4.62 d	4.60 e
	HA+ biochar	60.0 g	56.0 h	10.0 b	9.0 c	1.55 a	1.52 ab	4.75cd	4.70 de
75%RR	Control	70.0 f	60.0 g	9.0 c	9.0 c	1.45 a	1.42 ab	5.00b-d	4.95 cd
	HA	82.0 c	73.0 e	10.0 b	10.0 b	1.50 a	1.48 ab	5.25 ab	5.20 a-c
	Biochar	79.0d	76.0 d	10.0 b	10.0 b	1.53 a	1.51 ab	5.19a-c	5.18 a-c
	HA+ biochar	93.0 b	82.0 c	11.0 a	11.0 a	1.61 a	1.58 a	5.45 a	5.30 ab
100%RR	Control	75.0 e	68.0 f	9.0 c	10.0 b	1.49 a	1.45 ab	5.10a-c	5.05 bc
	HA	83.0c	80.0 c	10.0 b	11.0 a	1.59 a	1.55 a	5.30 ab	5.25 a-c
	Biochar	80.0 d	85.0b	10.0 b	11.0 a	1.55 a	1.54 a	5.22a-c	5.20 a-c
	HA+ biochar	95.0 a	90.0 a	11.0 a	10.0 b	1.63 a	1.60 a	5.50 a	5.40 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 7. Effect of interaction between nitrogen levels and some soil conditioners on the fresh weight of garlic at 135 days after sowing during the 2020/2021 and 2021/2022 seasons

Treatments		Fresh weight of leaves (g)		Fresh weight of bulb (g)		Total fresh weight (g)	
		S1	S2	S1	S2	S1	S2
50 %RR	Control	61.52 g	50.58 g	28.98 g	27.93 g	90.50 h	78.51 g
	HA	62.98 ef	59.28 e	32.24 de	31.92 e	95.22 ef	91.20 e
	Biochar	60.12 h	55.70 f	31.98 ef	29.61 f	92.10 gh	85.31 f
	HA+ biochar	61.89 g	59.92 de	33.33 cd	32.26 de	95.22 ef	92.18 e
75%RR	Control	62.47 fg	58.63 e	31.00 f	31.57 e	93.47 fg	90.20 e
	HA	65.21 c	61.88 cd	35.12 b	33.32 cd	100.33 c	95.20 cd
	Biochar	62.01 fg	60.49 cde	33.39 cd	32.11 e	95.40 ef	92.60 de
	HA+ biochar	70.41 b	65.37 b	37.92 a	35.81 b	108.33 b	101.18 b
100%RR	Control	64.70 cd	62.40 c	32.00 ef	33.60 c	96.70 de	96.00 c
	HA	65.16 c	65.78 b	35.09 b	35.42 b	100.25 c	101.20 b
	Biochar	64.02 de	64.68 b	34.48 bc	34.83 b	98.50 cd	99.51 b
	HA+ biochar	74.86a	71.58 a	38.00 a	38.54 a	112.86 a	110.12 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 8. Effect of interaction between nitrogen levels and some soil conditioners on the dry weight of garlic at 135 days after sowing during the 2020/2021 and 2021/2022 seasons

Treatments		Dry weight of leaves (g)		Dry weight of bulb (g)		Total dry weight (g)	
		S1	S2	S1	S2	S1	S2
50 %RR	Control	7.04 h	6.26 h	3.08 f	2.97 h	10.12 g	9.23 e
	HA	8.42 ef	7.77 fg	3.28 e	3.18 g	11.70 e	10.95 d
	Biochar	7.85 g	7.40 g	3.20 ef	3.14 g	11.05 f	10.54 d
	HA+ biochar	8.91 de	7.85 fg	3.31 e	3.21 g	12.22 e	11.06 d
75%RR	Control	8.16 fg	7.69 g	3.74 d	3.14 g	11.90 e	10.83 d
	HA	9.07 d	9.46 de	4.07 c	3.87 e	13.14 d	13.33 c
	Biochar	8.98 d	8.39 f	3.87 d	3.44 f	12.85 d	11.83 d
	HA+ biochar	10.76 bc	10.46 bc	4.39 b	3.99 d	15.15 b	14.45 bc
100%RR	Control	10.29 c	9.24 e	4.14 c	4.00 d	14.43 c	13.24 c
	HA	10.87 b	10.78 b	4.36 b	4.40 b	15.23 b	15.18 b
	Biochar	10.49 bc	10.12 cd	4.28 b	4.24 c	14.77 bc	14.36 bc
	HA+ biochar	11.90 a	11.73 a	4.86 a	4.79a	16.76 a	16.52 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 9. Effect of nitrogen levels and some soil conditioner on N, P and K contents in leaves of garlic at 135 days after sowing during 2020/2021 and 2021/2022 seasons

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	S1	S2	S1	S2	S1	S2
			Effect of nitrogen levels			
50 % RR	3.32 c	3.41 b	0.439 c	0.451 c	2.67 c	2.63 c
75 % RR	4.39 b	4.69 a	0.475 b	0.487 b	2.99 b	2.89 b
100 %RR	4.67 a	4.78 a	0.544 a	0.560 a	3.15 a	2.99 a
			Effect of soil amendments			
Control	3.70 c	3.81 b	0.467 c	0.480 d	2.74 d	2.71 c
HA	4.20 b	4.41 a	0.484 b	0.495 c	2.92 c	2.83 b
Biochar	4.26 ab	4.45 a	0.485 b	0.503 b	2.98 b	2.85 b
HA+ biochar	4.36 a	4.50 a	0.506 a	0.520 a	3.10 a	2.96 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 10. Effect of nitrogen levels and some soil conditioner on N, P and K uptake by leaves (mg) of garlic at 135 days after sowing during 2020/2021 and 2021/2022 seasons

Treatments	Nitrogen uptake		Phosphorus uptake		Potassium uptake	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**
			Effect of nitrogen levels			
50 % RR	268.20 c	250.74 c	35.47 c	33.05 c	215.80 c	193.18 c
75 % RR	408.65 b	424.80 b	44.02 b	44.04 b	277.45 b	261.60 b
100 %RR	510.15 a	503.33 a	59.35 a	58.82 a	344.75 a	314.10 a
			Effect of soil amendments			
Control	319.08 c	299.70 d	40.33 c	37.61 d	235.33 c	211.57 d
HA	402.49 b	420.16 b	46.30 b	46.73 b	278.20 b	266.13 b
Biochar	394.30 b	390.63 c	44.60 b	44.06 c	273.87 b	247.83 c
HA+ biochar	466.80 a	461.33 a	53.90 a	52.82 a	329.93 a	299.64 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Treated soil with the mixture of humic acid and biochar gave the maximum values (4.36 and 4.50%), (0.506 and 0.520%), and (3.10 and 2.96%) for N, P, and K contents in the 1st and 2nd seasons, respectively, with no significant differences with humic acid or biochar respecting N contents in both seasons (Table 9). As for N, P, and K uptake by leaves, the results showed the same trend with N, P, and K contents in both seasons (Table 10).

These results may be attributed to the effect of humic acid on enhancing of root growth and hence increasing the uptake of nutrients (**Awad and ElGhamry, 2007**). Also, humic acid enhance micronutrient nutrient availability in soil as a chelating agent and increase nutrients uptake to the plants (**Yang *et al.*, 2021**). The great impact of biochar on the cycling of elements and prevention of carbon, nitrogen, and phosphorus waste in the soil, they stated that biochar contained a diverse range of nutrients released at different rates and tremendously affected the soil fertility (**Mukherjee *et al*. 2014**).

Similar results were reported by **Ahmed *et al*. (2010) and Manas *et al*. (2014**) on garlic they found that N, P, K contents of leaves and its uptake were increased by applying humic acid than untreated.

Effect of the interaction

The interaction between nitrogen rates and soil amendments with humic and biochar had a significant effect on N, P, and K contents in leaves as well as N, P, and K uptake by garlic leaves at 135 days after sowing in both seasons (Tables 11 and 12).

The highest values of nitrogen (4.96 and 5.04%), phosphorus (0.571 and 0.581%), and potassium (3.40 and 3.15%) in leaves in the 1st and 2nd seasons, respectively, were obtained with the interaction between N at 100% RR and soil amendments with a mixture of humic acid and biochar, with no significant differences between N at 100% RR and treated soil with humic acid or biochar in both seasons with respect to N content in leaves (Table 11). Also, N, P, and K uptake by leaves significantly increased with the interaction between N at 100% RR and soil amendments with a mixture of humic acid and biochar in both seasons (Table 12). On the other side, the interaction between N at 75% RR and treated soil with a mixture of humic acid and biochar was more effective than the interaction between N at 100 RR only for N, P, and K contents and its uptake by levees in both seasons.

Table 11. Effect of interaction between nitrogen levels and some soil conditioner on N, P and K contents in leaves of garlic at 135 days after sowing during 2020/2021 and 2021/2022 seasons

Treatments		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
		S1	S2	S1	S2	S1	S2
50 %RR	**Control**	3.10 f	3.20 d	0.425 j	0.443 i	2.50 i	2.50 h
	HA	3.35 e	3.45 c	0.437 ij	0.448 i	2.68 h	2.65 g
	Biochar	3.40 e	3.48 c	0.443 hi	0.450 i	2.70 h	2.66 fg
	HA+ biochar	3.43 e	3.53 c	0.451gh	0.464 h	2.80 g	2.72 fg
75%RR	**Control**	3.95 d	4.10 b	0.457 fg	0.467 h	2.85 fg	2.77 ef
	HA	4.45 c	4.85 a	0.469 ef	0.480 g	2.95 e	2.89 cd
	Biochar	4.50 c	4.88 a	0.476 e	0.489 f	3.05 d	2.91 cd
	HA+ biochar	4.69 b	4.93 a	0.498 d	0.515 e	3.12 c	3.02 b
100%RR	**Control**	4.05 d	4.15 b	0.521 c	0.532 d	2.89 ef	2.87 de
	HA	4.80 ab	4.95 a	0.548 b	0.557 c	3.14 bc	2.96 bcd
	Biochar	4.88 a	4.99 a	0.537 b	0.572 b	3.20 b	2.99 bc
	HA+ biochar	4.96 a	5.04 a	0.571 a	0.581 a	3.40 a	3.15 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 12. Effect of interaction between nitrogen levels and some soil conditioner on N, P and K uptake by leaves (mg) of garlic at 135 days after sowing during 2020/2021 and 2021/2022 seasons

Treatments		Nitrogen uptake		Phosphorus uptake		Potassium uptake	
		S1	S2	S1	S2	S1	S2
50 %RR	**Control**	218.23 f	200.30 h	30.10 g	27.73 i	176.00 h	156.50 f
	HA	282.07 e	268.07 g	36.80 f	34.80 gh	225.70 fg	205.90 e
	Biochar	266.90 e	257.50 g	34.80 f	33.30 h	212.00 g	196.80 e
	HA+ biochar	305.60 d	277.10 g	40.20 de	36.40 g	249.50 e	213.53 e
75%RR	**Control**	322.30 d	315.30 f	37.30 ef	35.90 gh	232.60 f	213.00 e
	HA	403.60 c	458.80 d	42.50 d	45.40 e	267.60 d	273.40 c
	Biochar	404.10 c	409.40 e	42.70 d	41.00 f	273.90 d	244.10 d
	HA+ biochar	504.60 b	515.70 bc	53.60 c	53.86 c	335.70 b	315.90 b
100%RR	**Control**	416.70 c	383.50 e	53.60 c	49.20 d	297.40 c	265.20 c
	HA	521.80 b	533.60 b	59.60 b	60.00 b	341.30 b	319.10 b
	Biochar	511.90 b	505.00 c	56.30 c	57.90 b	335.70 b	302.60 b
	HA+ biochar	590.20 a	591.20 a	67.90 a	68.20 a	404.60 a	369.50 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Yield and its Components

Effect of nitrogen levels

Different components of garlic yield and nitrogen use efficiency were significantly affected by nitrogen levels in both seasons (Table 13). Exportable (4.72 and 4.24 ton/fed.), marketable (7.89 and 7.33 ton/fed.), total yield/fed., (8.27 and 8.02 ton/fed.), as well as average bulb weight (62.18 and 60.33 g) in the 1st and 2nd seasons, respectively, were the maximum with increasing N levels up to 100% RR . Fertilizing garlic plants with 75% RR came in the second, while fertilizing with 50% RR gave the minimum values of all yield and its components and the maximum value of NUE (84.79 and 81.56 kg bulb per kg N) in the 1st and 2nd seasons, respectively.

The reduction percentage in total yield /fed. due to fertilizing with N at 50% RR were 38.57and 39.03 % and due to N at 75% RR 9.55 and 8.92 % than fertilizing with 100% RR in the 1st and 2nd seasons, respectively.

Numerous physiological functions depend heavily on nitrogen. It gives plants a deep green hue and encourages the growth and development of the leaves, stem, and other vegetative elements. Additionally, it promotes the growth of roots. Nitrogen stimulates the intake and utilization of other nutrients, such as potassium and phosphorus, and regulates the general growth of plants. It also produces quick early growth, improves bulb quality, boosts the growth of vegetables, and raises crop protein content (**Bloom, 2015**). Furthermore, the observed improvements can be explained by the major contribution of increased nitrogen levels to the creation of key amino acids. These amino acids are necessary for promoting cell division, protein synthesis, chlorophyll synthesis, and cell elongation (**Kadam *et al*., 2020**). According to **Etana *et al*. (2019**), the increase in plant height, the number of leaves per plant, and the length of the leaves may be to blame for these results, as they directly affect the production of dry matter. Increasing bulb weight under high nitrogen rates may also be a result of fertilization-induced increases in growth characteristics such as "plant height, number of leaves produced, leaf diameter, leaf length, and physiological maturity (**Messele, 2016**). These factors may have also enhanced assimilation production and allocation of the bulbs.

The results of **Abou El-Magd *et al*., 2014; Guesh, 2015; Nasef and Elwan, 2016; Kumar *et al*., 2018; Ibraheim, 2022; Tena and Desta, 2023; Amerian *et al*., 2024**, somewhat agree with these findings. They demonstrated that as nitrogen levels rose, yield and its constituent parts increased noticeably.

Effect of soil conditioners

Data in Table 13 showed that there were significant differences between all soil conditioners and control treatment concerning yield and its components and nitrogen use efficiency (NUE) of garlic grown in clay soil in both seasons.

Treated garlic plants with a mixture of humic acid + biochar gave the best results for exportable (4.20 and 3.71 ton/fed.), marketable (6.84 and 6.31 tons/fed.), total yield/fed., (7.51 and 7.20 ton/fed.), average bulb weight (56.46 and 54.16 g) and NUE (85.68 and 82.06 kg bulb / kg N) in the 1st and 2nd seasons, respectively, followed by treated with humic acid and finally treated with biochar, while untreated plants recorded the lowest values of all yield and its components and NUE in both seasons.

The relative increases in total yield due to the addition of the mixture with humic acid and biochar were 16.43 and 16.32%, followed by treated soil with humic acid (9.77 and 10.34) and biochar (4.65 and 8.72%) over untreated plants in the 1st and 2nd seasons, respectively.

Numerous components included in humic acid enhance soil fertility and increase nutrient availability by retaining them on mineral surfaces, which in turn influences plant growth and yield (**Akinci *et al*., 2009**). Furthermore, as numerous scientists have demonstrated, humic materials are mostly utilized to eliminate or lessen the detrimental impacts of chemical fertilizers from the soil and have a significant impact on bulb production (**Ghabbour and Davies, 2001**). Furthermore, assimilation of major and minor nutrients, enzyme activation and/or inhabitation, modifications in membrane permeability, protein synthesis, and ultimately the activation of biomass production are all ways that humic acid promotes plant growth

Table 13. Effect of nitrogen levels and some soil conditioners on yield and its components, as well as nitrogen use efficiency (NUE) of garlic during the 2020/2021 and 2021/2022 seasons

Treatments	Exportable yield (ton/fed.)		Marketable yield (ton/fed.)		Total yield (ton/fed.)		Avege bulb weight (g)		NUE (kg bulb /one unit N)	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
					Effect of nitrogen levels					
50 % RR	2.82 c	2.44 c	4.27 c	3.91 c	5.08 c	4.89 c	38.25c	36.79c	84.79a	81.56a
75 % RR	4.52 b	3.99 b	6.75 b	6.10 b	7.48 b	7.30 b	56.29b	54.95b	83.19a	81.20a
100 %RR	4.72 a	4.24 a	7.89 a	7.33 a	8.27 a	8.02 a	62.18a	60.33a	68.91b	66.87b
					effect of soil amendments					
Control	3.82 c	3.40 c	5.86 c	5.07 d	6.45 c	6.19 c	48.50 c	46.60 c	72.73c	70.28 c
HA	4.09 ab	3.59 b	6.42 b	6.01 b	7.08 b	6.83 b	53.26 b	51.38 b	80.65ab	77.59b
Biochar	3.97 b	3.54 b	6.09 c	5.73 c	6.75 bc	6.73 b	50.75bc	50.62 b	76.80bc	76.25 b
HA+ biochar	4.20 a	3.71 a	6.84 a	6.31 a	7.51 a	7.20 a	56.46 a	54.16 a	85.6 a	82.06 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

(**Ulukan, 2008**). Also, Biochar has been found to reduce fertilizers need, and to maintain or improve crop productivity (**El-Naggar *et al.*, 2019**).

Many investigators obtained data to support the recent results **(Zaki *et al*., 2014; Shafeek *et al*., 2015; Mohsen *et al*., 2017; Badawy *et al*., 2019; Rizk and Deshesh, 2021; Mohamed *et al*., 2023**). They found that treating garlic plants with humic acid significantly increased yield and the components of garlic. As for the biochar effect, some authors, such as **Zheng *et al*. (2018), Neonbeni and Hoar (2020) and Kenea *et al*. (2024)** showed that the highest productivity of garlic was obtained with biochar compared to untreated plants**.**

Effect of the interaction

Yield and its components of garlic as well as NUE were affected by the interaction between nitrogen rates and soil conditioners in both seasons (Table 14).

The interaction between N at 100% RR and treating soil with a mixture of humic acid and biochar gave the highest values of exportable yield (44.93 and 4.40 ton/fed.), marketable (8.15 and 7.96 ton/fed.), total yield/fed. (8.58 and 8.33 ton/fed.), and average bulb weight (64.51 and 62.63 g) in the 1st and 2nd seasons, respectively. On the other side, there were no significant differences between N at 100% RR and treated with a mixture of humic acid and biochar and 75% RR and treated with the mixture of humic acid and biochar in most cases of yield and its components in both seasons. This means that 75% of RR of mineral nitrogen and a mixture of humic acid and biochar increased total yield.

The relative increases in total yield due to the interaction between N 75% RR and treated with the mixture of humic acid and biochar was (4.97 and 5.38 %) over the interaction between N at 100% only in the 1st and 2nd seasons, respectively.

As for NUE, the interaction between N at 75% RR and treating with the mixture of humic acid and biochar gave the best results for increasing NUE (93.89 and 89.26 kg bulbs/kg N) in the 1st and 2nd seasons, respectively, with no significant differences with the interaction between N at 50% RR and treating with the mixture of humic acid and biochar (85.68 and 82.06 kg bulbs/kg N) in both seasons, respectively.

Table 14. Effect of interaction between nitrogen levels and some soil conditioners on yield and its components, as well as nitrogen use efficiency (NUE) of garlic during the 2020/2021 and 2021/2022 seasons

Treatments		Exportable yield (ton/fed.)		Marketable yield (ton/fed.)		Total yield (ton/fed.)		Avege bulb weight (g)		NUE (kg bulb /one unit N)	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
50 %RR	Control	2.53 e	2.28 f	3.86 e	3.66 g	4.60 e	4.57 f	34.59e	34.40 f	76.67c-f	76.25d
	HA	2.96 d	2.47 ef	4.36de	3.96 fg	5.20 d	4.95 ef	37.97d	37.22ef	86.67ab	82.50c
	Biochar	2.77de	2.40 f	4.24de	3.84 fg	5.05de	4.80 ef	39.10d	36.09ef	84.17 a-	80.00cd
	HA+ biochar	3.02 d	2.62 e	4.62 d	4.20 f	5.50 d	5.25 e	41.35d	39.47e	91.67a	87.50ab
75%RR	Control	4.35 c	3.84 d	6.03 c	5.12 e	6.70 c	6.40 d	50.38c	48.12d	74.44d-f	71.11e
	HA	4.58bc	4.05bc	6.97 b	6.40cd	7.75 b	7.45 c	53.01c	56.02 c	86.11a-c	82.78bc
	Biochar	4.51bc	3.99cd	6.25 c	6.12 d	7.05 c	7.35 c	58.27b	55.26 c	78.33b-e	81.67 c
	HA+ biochar	4.65ab	4.11bc	7.76 a	6.78 c	8.45 a	8.03ab	60.53ab	60.40ab	93.89a	89.26a
100%RR	Control	4.58bc	4.08bc	7.69 a	6.44cd	8.05ab	7.62bc	61.28ab	57.29bc	67.08 f	63.50 f
	HA	4.75ab	4.26ab	7.93 a	7.68 a	8.30ab	8.10ab	62.41ab	60.90ab	69.17 ef	67.50 ef
	Biochar	4.65 b	4.23ab	7.79 a	7.24 b	8.15ab	8.05ab	63.53 a	60.53ab	67.92 ef	67.08 ef
	HA+ biochar	4.93 a	4.40 a	8.15 a	7.96 a	8.58 a	8.33 a	64.51a	62.63a	71.50ef	69.42e

S1= 2020/2021 season, S2=2021/2022 season, RR= recommended rate, HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Bulb Quality

Effect of nitrogen rates

Bulb quality at harvesting time was significantly affected by nitrogen application rates in both seasons (Tables 15 and 16). Bulb quality such as nitrogen, phosphorus, potassium percentages, TSS, dry matter%, and pungency in bulb significantly increased with increasing N rates up to 100% RR in both seasons, without significant differences with N at 75 %RR with respect to N at 1st season and K in both seasons. Fertilizing garlic plants grown in clay soil with 100 %RR equals 120 kg N/fed., produced the highest values of N (3.01 and 3.05%), P (0.437 and 0.433%), K (1.65 and 1.60%), TSS (31.97 and 30.97), dry matter content (35.05 and 34.76), and pungency (2.56 and 2.60 as pyruvic acid µmol/gm FW) in the 1st and 2nd seasons, respectively. There were positive correlation among TSS, DM % and pungency in bulbs as shown in Table 16.

The bigger bulb diameter resulting from the high nitrogen treatment was the source of the increased dry matter percentage and TSS of garlic bulbs. Since more nitrogen promotes leaf growth by emulating cell division and development, it is most likely the cause of this rise (**Messele, 2016**).

These results are consistent with those of **Ahmed *et al.* (2012), Hossein *et al*. (2014), Zaki *et al*. (2014), Kumar *et al*. (2018)**, **Ibraheim (2022) and Amerian *et al*. (2024)**. They indicated that N, P, and K, as well as dry matter, total soluble solids, and pungency, significantly increased with increasing nitrogen application.

Effect of soil conditioner

Data in Tables 15 and 16 showed that treated garlic plants with different soil conditioners had a significantly greater effect on bulb quality at harvesting time than untreated plants in both seasons. Treated garlic plants with a mixture of humic acid at 10 kg/fed., and biochar at 5 m^3/ fed. significantly increased N, P, and K contents in bulbs, TSS, dry matter %, and pungency in both seasons, with no significant differences with

Table 15. Effect of nitrogen levels and some soil conditioners on N, P and K contents in bulb after harvesting during 2020/2021 and 2021/2022 seasons

Treatments	N (%)		P (%)		K (%)	
	S1	S2	S1	S2	S1	S2
			Effect of nitrogen levels			
50 % RR	2.23 b	2.22 c	0.350c	0.339c	1.51 b	1.49 b
75 % RR	2.94 a	2.97 b	0.381b	0.376b	1.57ab	1.56ab
100 %RR	3.01 a	3.05 a	0.437a	0.433a	1.65 a	1.60 a
			Effect of soil amendments			
Control	2.68 b	2.71 b	0.376c	0.368 c	1.46 c	1.43 c
HA	2.75 a	2.78 a	0.389b	0.380 b	1.55 bc	1.55 b
Biochar	2.71ab	2.71 b	0.391b	0.387ab	1.62 ab	1.58 b
HA+ biochar	2.76 a	2.79 a	0.402a	0.396a	1.68 a	1.65 a

S1= 2020/2021 season, S2=2021/2022 season, RR= recommended rate, HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 16. Effect of nitrogen levels and some soil conditioners on bulb quality of garlic after harvesting during 2020/2021 and 2021/2022 seasons

Treatments	Total soluble solids (TSS)		Dry matter (DM%)		Pungency as pyruvic acid (μmol/gm FW)	
	S1	S2	S1	S2	S1	S2
			Effect of nitrogen levels			
50 % RR	29.11c	27.87c	29.57c	29.43c	1.64 c	1.60 c
75 % RR	30.88b	29.83b	32.23b	31.04b	1.87 b	1.98 b
100 %RR	31.97a	30.97a	35.05a	34.76a	2.56 a	2.60 a
			effect of soil amendments			
Control	28.89 c	27.85 d	29.85 d	29.50 d	1.64 d	1.75 d
HA	30.37 b	29.29 c	31.54c	31.13 c	1.94 c	1.93 c
Biochar	30.98 b	30.03 b	33.13 b	32.52b	2.08 b	2.14 b
HA+ biochar	**32.38 a**	**31.06 a**	**34.62 a**	**33.81 a**	**2.42 a**	**2.43 a**

S1= 2020/2021 season, S2=2021/2022 season, RR= recommended rate, HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

biochar in the 1st season or humic acid in both seasons concerning N and K in the 1st season and P in the 2nd season. The maximum values of all bulb quality, *i.e.*, N (2.76 and 2.79%), P (0.402 and 0.396%), and K (1.68 and 1.65%), TSS (32.28 and 31.06), dry matter (34.62% and 33.81%), and pungency (2.42 and 2.43 µmol/gm FW as pyruvic acid) in the first and second seasons, respectively, were scored with the plants that were treated with a mixture of humic acid at 10 kg /fed. and biochar at 5 m^3/fed. at the same time, treated plants with biochar came in second, followed by treated plants with humic acid in both seasons. On the other hand, the minimum values of all bulb qualities were recorded with the control plants.

These results may be due to the stimulatory effect of HA and biochar on growth parameters, where humic acid was added through enlargement bulb stage, which may lead to an increase in the contents of dry matter and TSS percentages of garlic cloves (**Mohsen *et al*., 2017**). On garlic, similar findings were reported by **Abou El-Khair *et al*. (2010), Ahmed *et al*. (2010) and Manas *et al*. (2014**), who discovered that adding humic acid boosted the N, P, K, and pungency contents of the bulbs and leaves. Additionally **Rizk and Deshesh (2021)** found comparable results on garlic.

Effect of the interaction

The interaction between N fertilizer rates and treated with some soil conditioners had significant effect on all bulb quality parameters in both seasons (Tables 17 and 18). The interaction between nitrogen at 100% RR and treated with a mixture of humic acid at 10 kg/ fed., and biochar at 5 m^3/fed., was the best interaction treatment and recorded the highest values of N (3.10 and 3.14%), P (0.449 and 0.446%), K (1.76 and 1.72%), TSS (33.55 and 32.50), dry matter content (37.46 and 37.40%), and pungency (3.12 and 2.98 µmol/gm FW as pyruvic acid) in the 1st and 2nd seasons, respectively.

On the other side, there were no significant differences between the interaction between nitrogen at 100% RR and treated with a mixture of humic acid at 10 kg/fed., and biochar at 5 m^3/fed., and the interaction between N at 75% RR and treated with a mixture of humic acid at 10 kg/fed., and biochar at 5 m^3/fed with respect to N and K in both seasons. However, the interaction between N at 75% RR and the soil conditioners was more effective than the application of N at 100% RR only on all bulb quality parameters.

Table 17. Effect of interaction between nitrogen levels and some soil conditioners on N, P and K contents in bulb after harvesting during 2020/2021 and 2021/2022 seasons

Treatments		N (%)		P (%)		K (%)	
		S1	S2	S1	S2	S1	S2
50 %RR	**Control**	2.22 fg	2.24 f	0.336 f	0.325 g	1.40 d	1.38 f
	HA	2.33 e	2.35 e	0.354 e	0.332fg	1.52bcd	1.50cde
	Biochar	2.25 ef	2.17 fg	0.350 ef	0.346 ef	1.55 a-d	1.53cde
	HA+ biochar	2.13 g	2.15 g	0.362de	0.353 e	1.59 a-d	1.57bcd
75%RR	**Control**	2.88 d	2.91 d	0.366de	0.360de	1.47 cd	1.44 ef
	HA	2.95bcd	2.98 cd	0.378cd	0.375cd	1.49 cd	1.56bcd
	Biochar	2.90cd	2.93 d	0.385c	0.380 c	1.63abc	1.60 a-d
	HA+ biochar	3.05 ab	3.08 ab	0.395c	0.390 c	1.70 ab	1.67 ab
100%RR	**Control**	2.95bcd	2.99 cd	0.426 b	0.420 b	1.52bcd	1.48 def
	HA	2.99bcd	3.03 bc	0.435ab	0.433ab	1.64abc	1.60bcd
	Biochar	3.00abc	3.04 bc	0.440ab	0.436 a	1.68abc	1.62abc
	HA+ biochar	3.10 a	3.14 a	0.449 a	0.446 a	1.76 a	1.72 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Table 18. Effect of interaction between nitrogen levels and some soil conditioner on bulb quality of garlic after harvesting during 2020/2021 and 2021/2022 seasons

Treatments		Total soluble solids (TSS)		Dry matter (DM%)		Pungency as pyruvic acid (µmol/gm FW)	
		S1	S2	S1	S2	S1	S2
50 %RR	**Control**	27.22 g	26.20 g	26.40 i	27.20 g	1.19 h	1.23 j
	HA	28.72 f	27.70 f	29.38 h	28.60 f	1.62 g	1.46 i
	Biochar	29.20 ef	28.15 f	30.35 g	30.22de	1.77 fg	1.64 h
	HA+ biochar	31.30b-d	29.45 e	32.18 e	31.70c	1.98 e	2.09 de
75%RR	**Control**	29.25 ef	28.20 f	30.27 g	29.14 ef	1.78 f	1.81 g
	HA	30.65cd	29.55 e	31.28 f	30.52 d	2.27 cd	1.91 fg
	Biochar	31.35bcd	30.35d	33.15 d	32.17c	1.26 h	1.99 ef
	HA+ biochar	32.30 b	31.25bc	34.22c	32.35c	2.18 d	2.22 d
100%RR	**Control**	30.20de	29.15 e	32.89de	32.18c	1.95 e	2.21 d
	HA	31.75bc	30.64cd	33.98c	34.28b	2.37 c	2.42 c
	Biochar	32.40 b	31.60 b	35.89b	35.19b	2.81 b	2.79 b
	HA+ biochar	33.55 a	32.50 a	37.46 a	37.40 a	3.12 a	2.98 a

S1= 2020/2021 season , S2=2021/2022 season, RR= recommended rate , HA=humic acid at 10 kg /fad. and biochar at 5m^3/fed.

Recommendation

It could be concluded that, under clay soil and under the same conditions, the use of N at 100% RR equals 120 kg N/fed., treated with humic acid at 10 kg/fed., and biochar at 5 m^3/fed., resulted in the greatest bulb quality and improvements in growth and total yield/fad. On the other hand, relative gains in total yield were observed (4.97 and 5.38%) when N was applied at 75% RR and treated with humic acid at 10 kg/fed., and biochar at 5 m^3/fed., as opposed to the interaction between N at 100% only in the first and second seasons, which resulted in a 25% reduction in mineral nitrogen.

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تأثير حمض الهيومك والبيوشار على المحصول والجودة للثوم تحت مستويات مختلفه من التسميد النيتروجينى

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أجريت تجربتين حقليتين في شتاء 2021/2020 و 2022/2021 بمزرعة التجارب الزراعية بالجميزة. التابعه لمعهد بحوث البساتين بمحافظة الغربية (وسط الدلتا، مصر) لدراسه تأثير التسميد النتروجيني عند 50 و 75 و 100% من المعدل الموصى به والتى تساوى 60 و 90 و 120 كجم/فدان على التوالي ومعاملة التربة ببعض محسنات التربة (حمض الهيوميك بمعدل 10 كجم/فدان، الفحم الحيوي بمعدل 5 م^3/فدان، والهيوميك بمعدل 10 كجم/فدان + الفحم الحيوي بمعدل 5 م^3/فدان) بالإضافة إلى معامله المقارنه بدون اضافات على نمو النبات وامتصاص العناصر والمحصول وجودة الأبصال لصنف الثوم. سدس 40 باستخدام نظام الري بالغمر في التربة الطينية، سجلت معامله تسميد نباتات الثوم بنسبة 100% والتى تساوي 120 كجم نيتروجين/فدان ومعامله التربة بخليط حمض الهيوميك بمعدل 10 كجم/فدان والفحم الحيوي بمعدل 5 م^3/فدان تأثير معنوي على نمو النبات (ارتفاع النبات، عدد أوراق النبات، قطر العنق والبصلة، وكذلك الوزن الغض والجاف للبصلة والأوراق والوزن الكلي الغض والجاف)، نسب كل من النيتروجين، الفسفور، البوتاسيوم والممتص منهم بواسطه أوراق نباتات الثوم بعد 135 يوم من الزراعة ، وأعطى أعلى قيم المحصول ومكوناته (القابل للتصدير، التسويقي، المحصول الكلى للفدان، ومتوسط وزن البصلة)، وكذلك جودة الأبصال (المحتوى من نسب كل من النيتروجين، الفسفور، البوتاسيوم ، المواد الصلبة الذائبة الكليه ، محتوى المادة الجافة، والحرافه). علاوة على ذلك، فإن التفاعل بين النيتروجين بمعدل 75% من الموصى به وخليط حامض الهيوميك والفحم الحيوي أعطى أفضل النتائج لزيادة كفاءة استخدام النيتروجين وكانت الزيادات النسبية في المحصول الكلي حوالي (4.97 و 5.38%) مقارنة بالتفاعل بين النيتروجين بمعدل 100% من الموصى به فقط في الموسمين على التوالى وانخفاض فى النيتروجين المعدني بنسبة 25%

الكلمات الإسترشادية: الثوم ، النيتروجين ، الفحم الحيوى ، نمو النبات ، المحصول وجوده البصله

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