https://doi.org/10.48047/AFJBS.6.16.2024.3994-4025

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Enhancing economic water productivity of garlic (*Allium sativum L.*) under both surface and drip irrigation systems by using bio-stimulants

Naglaa H. Hussien[*], Maha A. El-Bialy[**], I. M. Abouelgalagel[*], and A.M.I. Meleha[**]

[*] Department of Potato and Vegetative Propagated Vegetables, Horticulture Research Institute, Agricultural Research Center (ARC), Giza 12619, Egypt

[**] Water Management Research Institute, National Water Research Center, P.O. Box 13621/5, Delta Barrage, Cairo, Egypt

Corresponding author. E-mail: mahaaly000@gmail.com; naglaahamada08@gmail.com; ibrahimaboelglagel@gmail.com; melehaa12@gmail.com.

Volume 6, Issue 16, Dec 2024

Received: 15 Oct 2024

Accepted: 25 Nov 2024

Published: 09 Dec 2024

doi:10.48047/AFJBS.6.16.2024.3994-4025

Abstract

During the two winter seasons of 2020-21 and 2021-22, the research was carried out on the Nile Delta., Egypt, clayey soil to assess the use of a modern drip irrigation system and foliar spraying with some biostimulants, with an emphasis on yield traits, relative water saved, storability of garlic for (*Allium sativum L.*), and economic evaluations. The findings indicated that the drip irrigation system and foliar spray biostimulants exhausted a significant improvement in all garlic traits compared with the control. Foliar spraying with yeast at 2 g l^{-1} gave the highest values for plant height, leaf number per plant, leaf area, bulb diameter**,** bulb fresh weight, total yield, total sugar, total flavonoids, total phenols, K%, Na% and K/Na ratio traits for the two garlic growing seasons. In addition, Ascorbic acid application (0.2 gl^{-1}) and yeast (2 g l^{-1}) achieved the lowest weight loss (%) of stored garlic bulbs during the storage period. Regarding the relative water saved and economic water productivity, drip irrigation and biostimulants, in particular, yeast extract or compost tea, may have higher initial costs, but they can also result in higher yields and water savings, which can provide greater economic advantages.

Keywords: *Allium sativum*, Bio-stimulants, Drip irrigation system, Water Saved, Economic Water Productivity.

1- INTRODUCTION

Garlic is a common cooking spice that is grown and used throughout the world. Consuming garlic and its byproducts strengthens the immune system and reduces the diabetes risk, hear disease, and cancer. Garlic also has antibacterial, antifungal, and anti-aging qualities. In recent years, medicinal or functional garlic global demand has led to the introduction of new goods, including garlic oil, black garlic, aged garlic, and inulin in the markets (Sunanta *et al*., 2023). In addition, it reduces the incidence of diseases because it is considered the source of proteins, vitamins, minerals, fibers, and total phenolic and sulphuric compounds, moreover contains considerable amounts of different antibiotics, nutrients, amino acids, and enzymes (Collin, 2004; Martins *et al*., 2016; Diriba Shiferaw, 2017). In the age of building pyramids, about 2780-2100 B.C., garlic was grown and consumed in ancient Egypt and considered one of Egypt's main export commodities, regarding exportation and local consumption. Therefore, Egypt is greatly competitive in the foreign markets for garlic export. Egyptian garlic is exported to Arab, African, Eastern, and Western Europe countries (Awad, 2019).

The recent international scenario highlights the need to adopt sustainable agriculture with eco-friendly agricultural practices (Fawzy *et al*., 2012). In modern agriculture, the use of bio-stimulants, polyamines, and vitamins as a safe natural source of plant growth regulators, reduces soil contamination and improves plant resistance and tolerance to environmental stresses (Kowalczyk and Zielony, 2008). Farmers are using plant biostimulants in agriculture more and more because they produce good results and are a sustainable alternative. Plant bio-stimulants, ultimately lead to better use of water resources and less chemical fertilizer and pesticide in crops, due to the increase of the vigor of plants, the efficiency of nutrients, and the capacity to tolerate stresses (Mayara *et al*., 2020). Plant bio-stimulants can be environmentally friendly and improve various macronutrients in lettuce (*Lactuca sativa L.)* (Yaseena and Hajos, 2022).

Compost tea has an abundance of soluble mineral nutrients, organic compounds that plants can readily absorb, and useful microbes that significantly affect the plant rhizosphere. In addition to enhancing the soil's physical-chemical characteristics and inhibiting certain plant diseases. In this regard, Abd ElRahman *et al*., (2017); and Osman *et al*., (2021) showed that sugar beet (*Beta vulgaris L*.) sprayed with compost tea increased root fresh weight/plant, sucrose, purity percentage, and yield, meanwhile, impurities content reduced. It has favorable effects on plant growth and is considered a soil physical, physiological amendment, and biochemical processes (Gharib *et al*., 20011; Meshref *et al*., 2010).

Ascorbic acid also referred to as vitamin C, plays an essential role in plant development regulation by actively taking part in physical, physiological, and biochemical processes. It is a powerful antioxidant, that is vital for plant development and growth as well as oxidative stress defense (Smirnoff, 2018; Mehmood *et al*., 2024). on the other hand, Citric acid is a crucial component of the tricarboxylic acid cycle and is involved in plant energy generation, nutrient transport, and stress tolerance (Sánchez *et al.,* 2018).

Spirulina is a photosynthetic, multicellular blue-green microalga. Microalgae extracts are mostly composed of natural bioactive materials high in mineral elements, gibberellins, auxins, cytokinins, abscisic acid, proteins, carbs, and vitamins. Foliar spray of algae-based biostimulants in crop production is an optimistic and sophisticated agricultural practice because it is eco-friendly and helps to improve crop yield. (Bella *et al*., 2021).

Yeast is a natural source of cytokinins, which promote cell division and production of proteins, nucleic acids, and chlorophyll. It contains carbohydrates, amino acids, protein, and vitamins (Wanas, 2006). The foliar spray with yeast had a substantial effect on the vegetative development, yield, and bulb quality of garlic (Dawa *et al.*, 2012; Shalaby and El-Ramady, 2014). Ali, *et al*., (2017) discussed foliar spray with bio-stimulants such as yeast extract and antioxidants like salicylic acid and ascorbic acid effects on garlic plants, and how these treatments influence plant growth, yield, and bulb quality. The findings recommended that salicylic acid appears to have a more pronounced effect on enhancing garlic growth compared to yeast extract. However, the combination of yeast extract at 3% and salicylic acid at 200 ppm yielded the greatest overall results for garlic growth, yield, and bulb quality. While ascorbic acid has a supportive role but is less effective than the other two treatments. Other yeast effects on plant growth and yield of some vegetable crops, Eggplant, broad bean, and other crops, yeast extract, and ascorbic acid foliar application increased the vegetative growth (Helal *et al*., 2005; El-Khair and Khalil, 2014El-Tohamy *et al.,* 2008; El-Khair and Khalil, 2014).

Garlic typically thrives in a Mediterranean climate, which Egypt's climate resembles. However, it can also be grown in cooler climates. Garlic prefers well-drained, fertile soils rich in organic matter (Mclaurin *et al.,* 2009; Voss, 2010). It can grow on various soil types, but sandy loam is ideal for optimal bulb development (Raslan, *et al.,* 2015). Garlic is typically planted in the cooler months, specifically from late September to October, as it is a winter crop in Egypt. The climate allows for a growing season that extends into the spring, with harvesting occurring from late spring to early summer (Hanna, *et al*., 2023); Raslan, *et al.,* 2015). Egyptian garlic varieties, such as the Balady, Chinese, and Sids-40, are popular choices due to their adaptability and yield potential. In Egypt, garlic irrigation methods are designed to maximize water efficiency and crop yield, especially given the country's arid climate i.e. (Surface and Drip Irrigation, Subsurface Drip Irrigation, Sprinkler Irrigation, and Traditional Flood Irrigation). Each method has advantages and is chosen based on factors like water availability, soil type, and specific crop requirements (Abd El-Hady and Eldardiry, 2016; Hiekal, 2021; Abd - Elrahman *et al*, 2017).

Garlic production in Egypt is the highest in the world, with significant export potential. The production is primarily for local consumption, but the surplus is exported to various countries. In recent years, garlic production in Egypt has been substantial, with reports indicating around 396,000 tons in 2022 (https://www.freshproducemea.com). The net return per acre for garlic cultivation is favorable, estimated at around 15.87 thousand pounds, making it an attractive crop for farmers. Despite high production, farmers often face challenges related to marketing margins, where intermediaries take a significant share of profits. Efforts should be made to educate farmers on direct marketing strategies to improve their returns (Hanna, *et al.*, 2023).

Drip irrigation systems have been found to significantly increase the productivity of Garlic in Egypt. (Elhagarey, 2020) demonstrated that innovative porous drippers can save irrigation water by up to 72.4% and increase garlic yield by up to 23.5 tons/ha. Similarly, (Abd El-Latif, 2017) found that drip irrigation at 100% of ETp significantly increased garlic yield compared to surface irrigation. Furthermore, (Abd El-Hady and Eldardiry 2016) highlighted the role of organic manure in maximizing garlic yield and water productivity under a drip irrigation system. These studies collectively suggest that a drip irrigation system can enhance garlic productivity on old lands in Egypt. The economic feasibility of garlic production under bio-activators and drip irrigation was evaluated in multiple studies. The use of bio-stimulants and appropriate levels of irrigation under drip irrigation systems were found to improve garlic productivity and quality (Badawy, *et al*., 2019). Drip irrigation resulted in superior bulb yield, water use efficiency, and net returns compared to surface irrigation (Gupta, *et al*., 2022). The combination of drip irrigation with biofertilizers showed significant impacts on cucumber *(Cucumis sativus L.)* yield and economic returns (Boas, *et al*., 2011). Overall, the use of drip irrigation and bio- activators showed positive effects on garlic production, leading to improved economic outcomes. In terms of economic efficiency, water production as water usage per unit of crop yield may be a useful indicator. For instance, the irrigation cost per unit of water can be significantly less with efficient systems, allowing farmers to allocate resources more effectively (Elhagarey, 2014).

Higher-quality crops can fetch better market prices, further boosting profitability for growers. Due to its many applications in food processing, exports, and consumption, garlic is a high-value marketable crop (AL-Otayk *et al*., 2009; Eleshmawiy *et al.,* 2010). About 16 757 hectares are under cultivation in Egypt, and 348 230 tons were produced overall in the 2021 growing season (FAO, 2023). Adopting modern irrigation systems such as drip irrigation for garlic cultivation in Egypt's old lands can lead to significant economic benefits. These include reduced production costs, improved water use efficiency, and potentially higher profitability despite variations in yield. As Egypt continues to face water scarcity challenges, these irrigation innovations are crucial for sustainable agricultural practices and economic viability in garlic production.

Research indicates that costs can decrease by 29% to 54% depending on the crop type when using drip irrigation compared to surface irrigation, which incurs higher costs due to inefficiencies in water use and increased salinity management needs (Moursy *et al.*, 2023). Water usage is more effectively managed with drip irrigation, which is critical in Egypt due to ongoing water scarcity issues. This method allows for targeted watering, minimizing waste, and optimizing the use of available water resources. The increased water use efficiency translates into higher profitability, as farmers can produce more garlic per unit of water consumed (Elhagarey *et al.*, 2024).

While surface irrigation may yield higher productivity under certain conditions, It has been demonstrated that drip irrigation enhances total water productivity. This means that even if the total yield is slightly lower, the efficiency of water use can lead to greater economic returns per liter of water used. This is particularly beneficial in areas with medium salinity, where managing soil conditions is essential for crop health (Moursy *et al.*, 2023.).

Still, very few researchers offer such types of measures for specific small-scale crops. Thus, measuring the economic water productivity of garlic and evaluating the effects of various irrigation systems and biostimulant applications on this indicator and the average garlic yield are the primary objectives of this study.

2- MATERIALS AND METHODS

2.1. Experimental site description:

The experimental field is located near the Kafr El-Sheikh Governorate in Egypt (Latitude: 31°6'N/Longitude: 30° 56' E), El-Qarda water requirements research station, Water

Management Research Institute, National Water Research Center during 202. Before plantation, randomized soil samples were taken from three distinct soil depths (0-30 cm) to determine some chemical and physical properties in accordance to Page *et al.* (1982) and Klute (1986), Table (1). The soil has a clay texture, containing 48.6 % clay, 25.83% silt, and 22.81% sand, and its salinity ranges from 3.5-4.5 dsmcm^{-1} in a 1:5 soil paste extract, as indicated by the pH number (7.4). It tends to be alkaline.

Table 1. Some chemical and physical properties of the experiment site soil

year	Cations (meq/l)				Anions (meq/l)			EC dSm (S.P.E 1:5)	pH (S.S 1:2.5)
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	So_4^{--}		
2020/21	1.8	2.26	5.36	0.14	3.2	3.53	3.24	0.988	7.42
2021/22	1.67	2.24	5.09	0.12	2.8	3.13	3.13	0.894	7.33
depth	Particle size distribution				Soil moisture constants			O.M (%)	
	Clay%	Silt%	Sand%	Text.	FC%	WP%	AW%		
0-30	48.6	25.83	22.81	Clayey	44.59	24.24	20.36	1.23	

S.P.E: soil paste extract, S.S: soil suspension, O.M = organic matter, FC: field capacity, WP: wilting point, AW: available water

2.2. Experimental procedures and treatments design

Garlic cloves (Balady cv) were obtained from the Vegetative Propagated Vegetables Department, Agricultural Research Center, Giza, Egypt. Garlic cloves were sowed on 20th October in the first and second seasons. The usual agricultural practices were applied as recommended for the marketable production of garlic in the area.

A randomized complete block design in a factorial was used (RBCD), in which each experiment consisted of 12 plots and 3 replicates, each was 6 m width x 11m length with separated furrows at 0.6 m where the irrigation systems as main factor A (Flood irrigation system and drip irrigation system), and five bio-stimulants as well as control, as factor B; distributed as follows: Tap water (control), Compost tea (20 l fed^{-1}), Ascorbic acid (0.2 gl^{-1}), Citric acid (0.2 g l^{-1}), Spirulina extract (1.0 ml l^{-1}), and Dry yeast (2.0 gl^{-1}). Compost tea, Spirulina extract, and Dry yeast chemical composition are shown in Tables, 2-A, 2-B, and 2-C.

Table (2- A). Chemical and microbiological analyses of compost tea

para meter	PH	EC (dS./m)	Total N%	Total P%	Total K%	Total count of bacteria (CFU/ml)	Total count of fungi (cfu/ml)	Total count of actinomycetes (CFU/ml)
Value	7.14	2.83	0.34	0.08	0.56	$8.7x10^{6}$	$7.7x10^{4}$	1.1x10

Table (2-B). Protein, amino acids, and mineral contents of the dried cells of Spirulina platensis

Amino acid	(%)	Amino acid	(%)
Aspartic	3.40	Arginine	1.96
Tyrosine	1.14	Alanine	2.62
Threonine	1.76	Proline	1.17
Phenylalanine	1.77	Valine	2.09
Serine	1.22	Cysteine	1.71
Histidine	0. 45	Isoleucine	1.59
Glutamic	3.52	Methionine	1.05
Lysine	1.55	Lucien	2.55
Glycine	1.82	Total protein 36.4	36.4
Potassium (ppm)	189.7	3 Manganese	7.7
Phosphorus (ppm)	52.3	Iron	20.5

Table (2-C). Yeast extract Chemical analysis according to Morsi *et al*., 2008

Amino acids mg/100g dry weight		Mineral mg/100g dry weight		Vitamins mg/100g dry weight	
Arginine	1.99	Total N	7.23	Vit.B1	**2.23**
Histidine	2.63	P2O5	51.68	Vit.B2	**1.33**
Isoleucine	2.31	K2O	34.39	Vit.B5	**19.56**
Leucine	2.09	MgO	5.76	Vit.B6	**1.25**
Lysine	2.95	CaO	3.05	Vit.B7	**0.09**
Methionine	0.72	SiO2	1.55	Vit.B8	**0.26**
Phenylalanine	2.01	SO2	0.49	Vit.B9	**4.36**
Threonine	2.09	NaCl	0.30	Vit.B12	**0.15**
Tryptophan	0.45	Fe	0.92	Nicotinic acid	**39.88**
Valine	2.19	Ba	157.5	Pamino benzoic acid	**9.23**
Glutamic acid	2.00	Co	67.8	Carbohydrates	**23.2**
Serine	1.59	Pd	438.6	Glucose	**13.33**
Aspartic acid	1.33	Mn	81.3		
Cystine	0.23	Zn	335.6		
Proline	1.53				
Tyrosine	**1.49**				

Spraying of biostimulant treatments; started after one month of the planting date and was repeated three times with two weeks in between in both seasons. Yeast extract was prepared as 2.0 g of dry yeast and dissolved in warm water. Then sugar was added, and the mixture was left warm overnight for fermentation. For yeast reproduction, water was added to one-liter final volume. Compost tea was obtained from the Agricultural Microbiology Department and Spirulina extract was obtained from the Algae Department, Soils, Water and Environment Research Institute Sakha Agricultural Research Station

2.3. Irrigation Water Applied and Saved

A flowmeter was installed on the pump delivery of the surface irrigation system (furrow surface irrigation) unit to determine the applied water amount to the experimental plots. In the drip irrigation system, a surface diesel pump with an engine power of 30 hp was used with a discharge of 35 m^3 h^{-1}, and the distance between the laterals was 1 meter (emitter distance 30 cm, emitter discharge 4 liters/hour). The actual irrigation water needs for various irrigation systems can be determined using specific equations that account for factors such as evapotranspiration, and effective rainfall, and the characteristics of the irrigation it was determined for surface irrigation using the following equation:

$$\text{AIW} = \text{ETc} / \text{Ea}$$

where AIW = The depth of applied irrigation water, actual evapotranspiration (ETc). Ea = application efficiency (60%).

For drip irrigation, the modified following equation found by Morad *et al* (2012) was used

$$\text{IRa} = \frac{[(\theta_{fc} - \theta_r) \times d] + lf}{E_s}$$

Where:

IRa; total actual irrigation water needs (mm/intervals), θ_{fc}; soil moisture content at field capacity (%), θ_r; soil moisture content (%) under soil conditions, d; depth of soil layer (20 cm for the first stage, and 40 cm for the final stage), Es; system efficiency in percentage, and Lf; leaching factor. (The volumetric moisture content of the soil was determined using a profile prob).

2.4. Calculate Relative Water Savings:

To find the relative water savings when switching from one irrigation system to another, we used the formula:

Relative Water Savings = [(Water applied (tap water under traditional surface irrigation system) – (Water applied new system)] /Water applied (tap water under traditional surface)

2.5. Economic Water Productivity (EWP)

EWP provides an economic measure of how efficiently a crop utilizes water to generate revenue. Higher EWP indicates more efficient water use. EWP can be used to compare the economic performance of different irrigation strategies like full irrigation vs. deficit irrigation.

To calculate the economic water productivity (EWP) of a crop, you can use the following formula Talpur, *et al*., (2023),Tewelde. (2019).

EWP ($/m³) = Gross income ($/ha) / Total water supplied (m³/ha)

Where; Gross income is the total revenue generated from selling the crop yield and byproducts, gross income ($/ha) can be obtained by multiplying the crop yield by the market price per unit.

Total water supplied is the sum of irrigation water applied and effective rainfall during the growing season.

2.6. Plants data enrollment

Ten randomly chosen plants from each replication were used to record the vegetative characteristics: plant height (cm), number of leaves per plant (cm2), and leaf area per plant (cm2). The bulb diameter (cm), bulb fresh weight (g), and total yield were also recorded as yield attributes. Garlic bulbs' chemical parameters; total sugar (mg/g D.W.) was calculated using Forsee's (1938) method; total phenolic (mg/g D.W.) was measured using the colorimetric method and reported by Swain and Hillis (1959); total flavonoids (mg/g D.W.) was calculated using a method by Park et al. (2008); K (%), Na (%), and k/Na ratio were determined using a flame photometer by Brown and Lilliland's (1946) method.

Storability of garlic bulb, after curing, 2 kg of cured garlic bulbs was taken from every treatment and stored at normal room conditions. Bulb weight loss was determined at 60, 120, and 180 days of storage period according to the common method used in agricultural research as follows:

Bulb weight loss (%) = [(initial weight of storage bulb - weight at sampling date)/initial weight of storage bulb] x100.

Statistical analysis

Data was subjected to statistical analysis of variance according to Gomez and Gomez (1984). The significantly differed means were compared using Duncan's Multiple Range Test (1955) at a 5% probability level using COSTAT software. Charts were created in Microsoft Excel 2016. The Pearson correlation coefficients were calculated for the two seasons to investigate the relationship between the studied traits that were visualized by SPSS software (IBM SPSS).

3- RESULTS

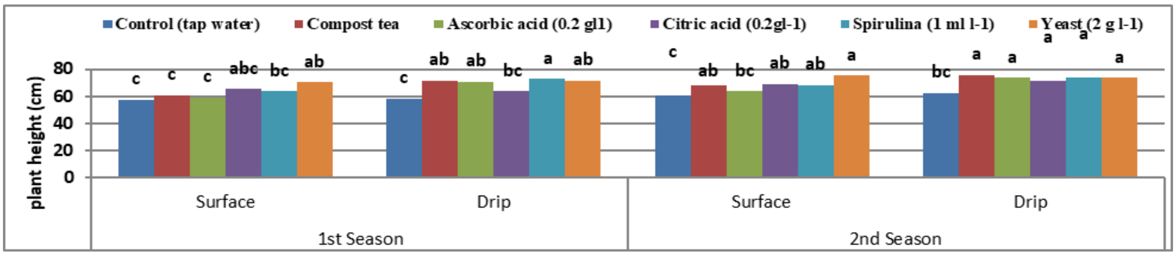
3.1. Vegetative growth and yield traits

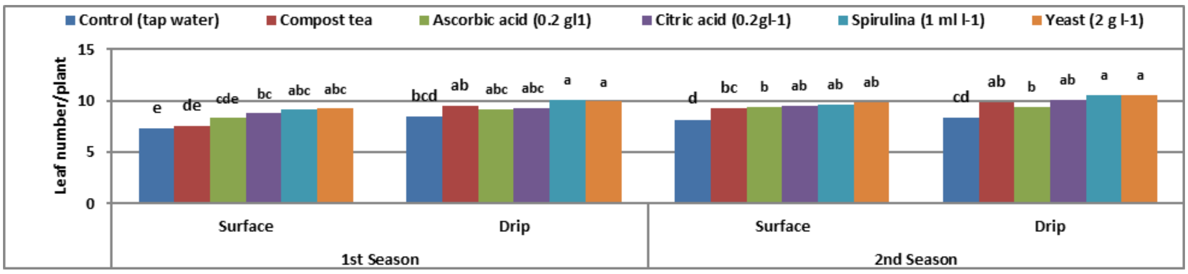
The mean performance of the irrigation system and bio-stimulants for vegetative growth (plant height, leaf number per plant, and leaf area per plant) are revealed in Table 3. From the data presented, irrigation systems exhibited highly significant effects for vegetative growth traits for both growing seasons. The drip irrigation system gave higher vegetative growth values compared to the surface irrigation system. For stimulant application treatments, spraying of yeast achieved the highest vegetative growth values in comparison with untreated plants in the two growing seasons.

Table 3. Mean effect of irrigation systems and bio-stimulants application on vegetative growth traits of garlic during 2020/2021 and 2021/2022 seasons.

Treatment		Plant height (cm)		Leaf number/plant		Leaf area/plant (cm^2)	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Irrigation system	**Surface**	62.56 b	67.39 b	8.39 b	9.33 b	390.3 b	440.89 b
	Drip	68.03a	71.69 a	9.41 a	9.83 a	432.6a	465.46 a
Biostimulants	**Ctrl (tap water)**	58.67 c	61.33c	7.89 c	8.25 c	254.5 c	258.4 c
	Composttea	64.76 b	71.72 ab	8.53 bc	9.5 6 ab	433.7 ab	499.7 ab
	Ascorbicacid	64.78 b	68.61 b	8.76 b	9.45 b	404.8 b	475.6 b
	Citric acid	64.50 b	70.28 ab	9.04 ab	9.84 ab	433.2 ab	463.9 b
	Spirulina	68.17 ab	70.95 ab	9.59 a	10.13 ab	457.2 b	502.7 b
	Yeast	70.89 a	74.33 a	9.58a	10.22 a	485.14 a	518.7 a

Means followed by the same letter within a column are not significant (P < 0.05) according to Duncan's Multiple Range Test





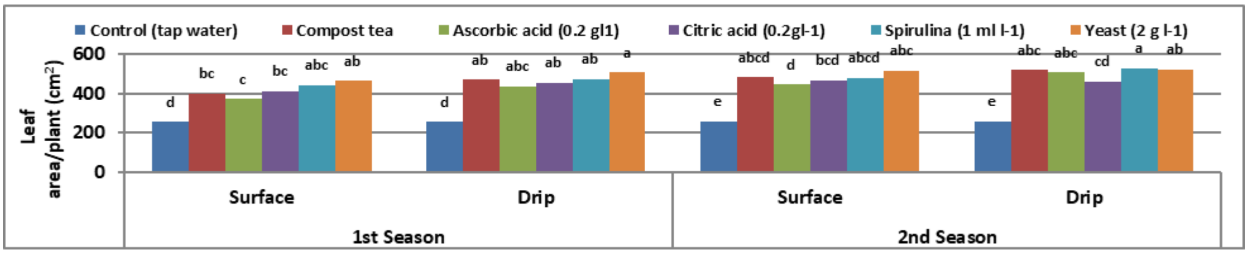


Figure 1. *Interaction effect of irrigation systems and bio-stimulants application on vegetative growth traits of garlic plants during the 2020/2021 and 2021/2022 seasons*

From the data shown in Fig. 1, which presents the interaction between the irrigation system and bio-stimulants on vegetative growth, it can be noticed that plants sprayed with spirulina and yeast extract in the two irrigation systems have better values of plant height, leaf number per plant, and leaf area per plant than the other treatments and in comparison, with the control treatment in the two growing seasons.

The same trend was noticed for studied yield traits (bulb diameter, bulb fresh weight, and total yield), in Table 4. Whereas, it can be concluded that the drip irrigation system gave the highest values for all studied yield traits compared to surface irrigation.

Table 4. Mean effect of irrigation systems and bio-stimulant application on yield traits of garlic during the 2020-21 and 2021-22 seasons.

Treatments		Bulb diameter (cm)		Bulb fresh weight(g)		Total yield (ton / ha)	
		1st Season	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	2nd Season
Irrigation system	**Surface**	4.45 b	4.59b	53.53 b	58.14 b	17.83 a	18.31a
	Drip	4.66 a	4.82a	54.72 a	59.99 a	17.67 a	18.26a
Bio-stimulants	**Control (tap water)**	3.89 c	4.12 c	44.61 c	47.48 d	15.26 d	15.83c
	Compost tea	4.67 ab	4.92 ab	62.14 a	65.03 a	18.79 a	18.95a
	Ascorbic acid	4.54b	4.73 ab	54.31 b	58.48 c	18.05 bc	18.60 ab
	Citric acid	4.46b	4.53 b	53.75 b	57.58 c	17.62 c	18.19 b
	Spirulina	4.88 a	4.89 ab	55.03 b	62.16 b	18.24 ab	18.88 a
	Yeast	4.91 a	5.01a	54.92 b	63.67ab	18.52 ab	19.21a

Also, the maximum bulb diameter, maximum bulb fresh weight, and maximum total yield were recorded under spraying of compost tea, spirulina, and yeast extract during the first and second garlic growing seasons.

Concerning the interaction effect between irrigation system and biostimulants treatments on bulb fresh weight, bulb diameter, and total yield, Fig. 2, it can be stated that interaction showed high significance values regarding bulb fresh weight in the case of compost tea with drip irrigation system in both seasons**.** Furthermore, for the bulb diameter parameter, under the surface irrigation system, plants sprayed with compost tea, spirulina, and yeast gave the highest bulb diameter in both seasons.

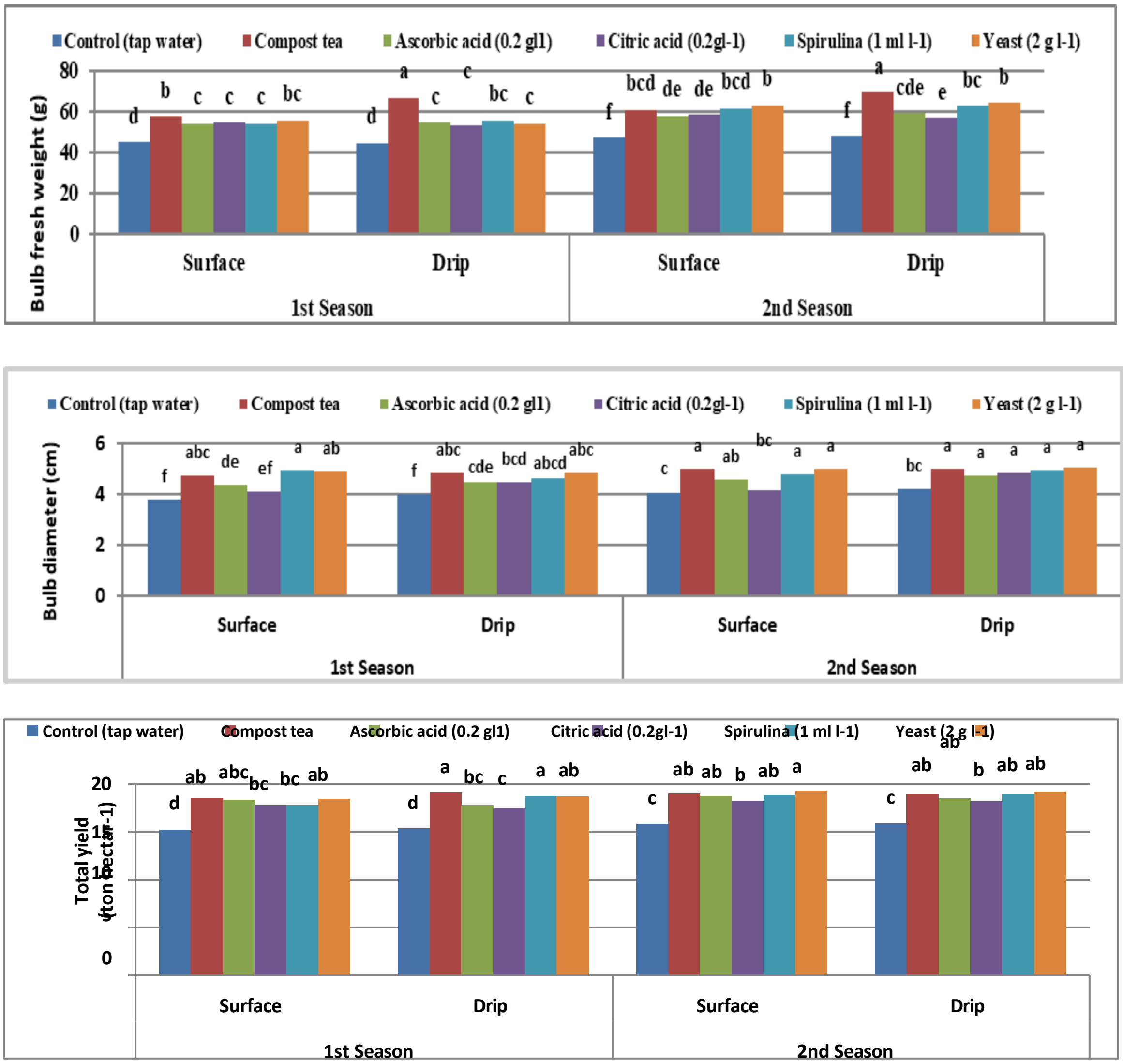


***Figure** 2. Interaction effect of irrigation systems and bio-stimulants application on yield traits of garlic plants during 2020-21 and 2021-22 seasons.*

In addition, plants sprayed with compost tea with the drip irrigation gave the highest values among other treatments in both growing seasons. In the same way, plants sprayed with compost tea, ascorbic acid, and yeast gave the highest total yield under the surface irrigation system in both seasons, and the plants sprayed with compost tea, spirulina, and yeast gave the highest yield under a drip irrigation system in both seasons.

3.2. Physicochemical traits

Table 5 presents some of the Garlic Physicochemical parameters (total sugar, total flavonoids, and total phenols) which are measured under irrigation systems and bio-stimulants. From the Table 5 and fig 3, the total sugar, total flavonoids, and total phenols increased under the drip irrigation system during the two seasons compared with the surface irrigation system which produced the lowest values in the two seasons. Moreover, spraying with yeast recorded the highest values for total sugar and total flavonoids in comparison with the other treatments and control in both seasons, whereas spraying of ascorbic acid, citric acid, spirulina, and yeast gave the highest total phenols in both seasons. The interaction between the irrigation system and biostimulant treatments, total sugar, total flavonoids, and total phenols, are presented in Fig 3.

Table 5. Mean effect of irrigation systems and bio-stimulants application on some chemical traits of garlic during the 2020-21 and 2021-22 seasons.

Treatment		Total sugar (mg/g D.W)		Total flavonoids (mg/g D.W)		Total phenols (mg/g D.W)	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Irrigation system	**Surface**	49.17b	53.48b	235.11b	244.19b	8.3b	8.77b
	Drip	55.17a	57.46a	247.62a	259.99a	8.78a	9.17a
Bio-stimulants	**Control (tap water)**	46.2c	51.35c	220.77d	229.72d	7.13b	7.57c
	Compost tea	50.13bc	53.98bc	239.37bc	262.06ab	7.63b	8.26b
	Ascorbic acid	51.7 bc	54.33bc	226.48cd	236.30cd	8.91a	9.29a
	Citric acid	55.22ab	57.02ab	251.18ab	251.23bc	9.18a	9.50a
	Spirulina	51.88bc	56.11ab	250.6 ab	263.14ab	8.94a	9.29a
	Yeast	57.9a	60.04 a	259.77a	270.09a	9.48a	9.90a

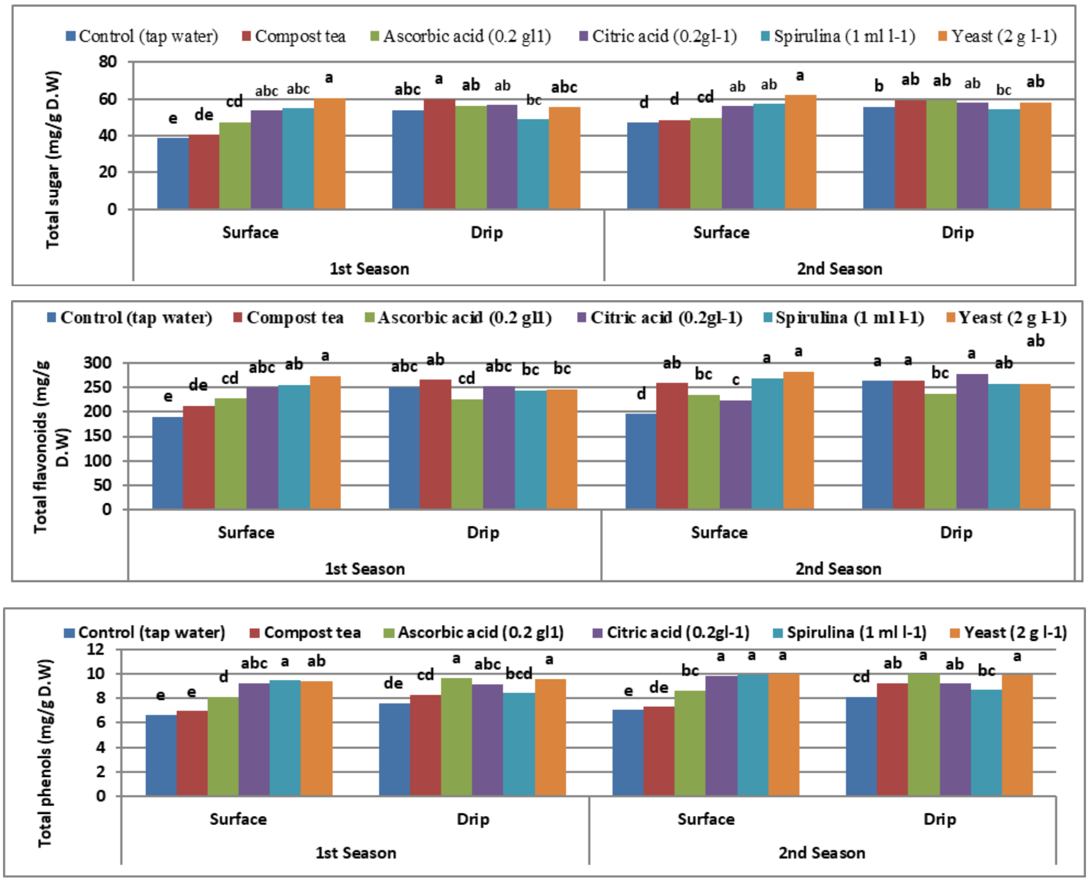


Figure 3: *Interaction effect of irrigation systems and bio-stimulants application on some chemical traits of garlic plants during the 2020-21 and 2021-22 seasons*

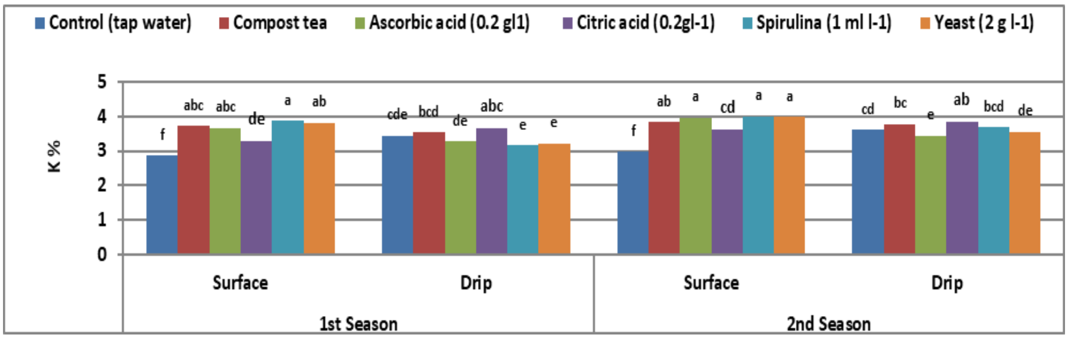
Results indicated that plants sprayed with yeast under surface irrigation gave the highest total sugar in both seasons, also both of yeast and compost tea gave the highest values under drip irrigation in both seasons. For the total flavonoids, it was noticed that, under the surface irrigation, plants sprayed with citric acid, spirulina, and yeast gave the highest values compared with other biostimulant treatments (ascorbic acid, compost tea, and the control) in both seasons. But there was no significant difference among bio-stimulants under drip irrigation in both seasons, Fig. 3**.** Likewise**,** plants sprayed with spirulina and yeast gave the highest total phenols under the surface irrigation in both seasons. Meanwhile, plants sprayed ascorbic acid and yeast gave the highest total phenols (mg/g D.W) under the drip irrigation system in both seasons**.**

Likewise, the K (%), Na (%), and k/Na ratios were estimated under irrigation systems and bio-stimulant application (Table 6). It can be concluded that, in comparison with the drip irrigation system, the higher values for K (%), and K/Na ratio were achieved under the surface irrigation system in the two seasons. Whereas, vice versa for Na (%) values which are the higher values achieved with drip irrigation system. On the other hand, sprayed garlic plants with compost tea significantly increased K percentage and K/Na ratio in both seasons, followed by sprayed with ascorbic acid, citric acid, spirulina, and yeast, while the control recorded the lowest values in these respects in both seasons. On the contrary, Na percentage increased under control (tap water) in comparison with other bio-stimulants.

Table 6: Effect of irrigation systems and bio-stimulants application on some chemical traits of garlic during the two tested seasons of the 2020-21 and 2021-22 seasons

Treatment		K (%)		Na (%)		K/Na ratio	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Irrigation system	Surface	3.53 a	3.72 a	1.53 b	1.69 b	2.48 a	2.27 a
	Drip	3.37 b	3.64 b	1.69 a	1.82 a	2.15 b	2.06 b
Bio- stimulants	Control (tap water)	3.15 b	3.29 c	2.15 a	2.14 a	2.12 b	1.55 d
	Compost tea	3.62 a	3.80 ab	1.38 b	1.59 c	3.01 a	2.55 a
	Ascorbic acid	3.46 a	3.69 b	1.51 b	1.68 bc	2.33 b	2.20 bc
	Citric acid	3.47 a	3.72 ab	1.58 b	1.78 b	2.24 b	2.12 c
	Spirulina	3.50 a	3.83 a	1.47 b	1.63 bc	2.43 b	2.36 ab
	Yeast	3.51 a	3.75 ab	1.58 b	1.75 b	2.28 b	2.18 bc

Concerning the interaction among irrigation systems and bio-stimulants on the K (%), Na (%), and K/Na, plants sprayed with spirulina and yeast gave the highest K percentage under the surface irrigation system in both seasons. On the other hand, plants sprayed with citric acid gave the highest values under the drip irrigation system in both seasons. For Na percentage, the drip irrigation system and control (tap water) displayed the greatest values of Na percentage in both seasons. Moreover, under the surface irrigation system, compost



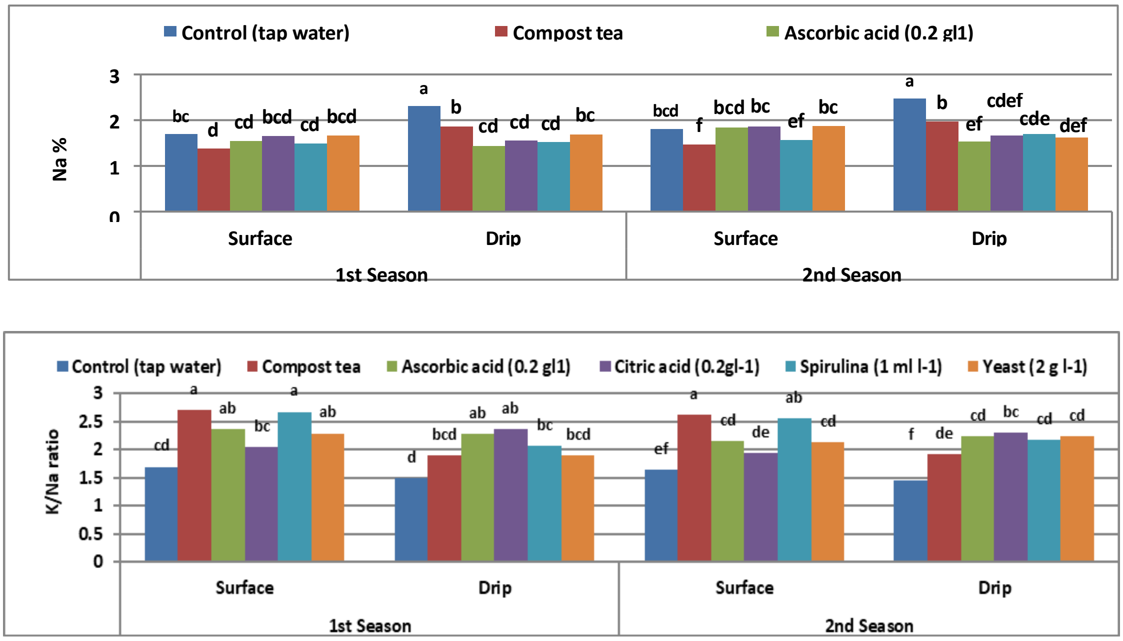
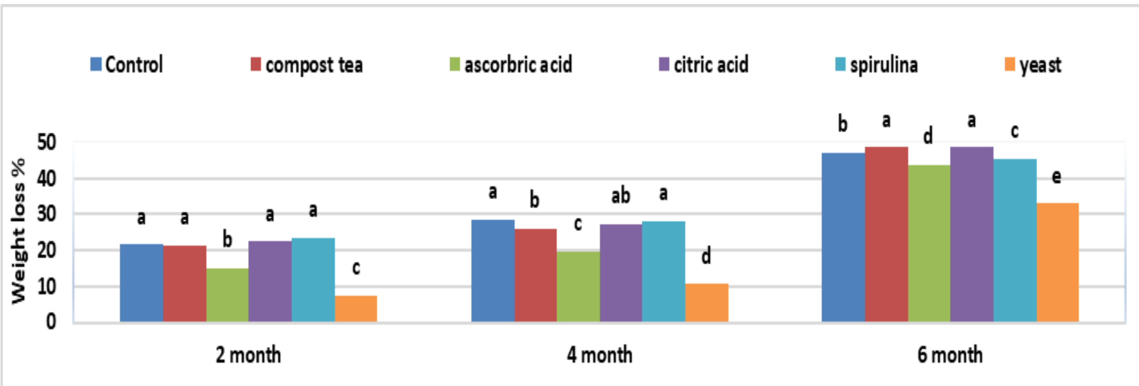


Figure 4: *Interaction effect of irrigation systems and bio-stimulants application on some chemical traits of garlic plants during the 2020-21 and 2021-22 seasons.*

tea and spirulina displayed the maximum numbers of K/Na ratio in both seasons, Fig. 4

3.3. Storability of garlic bulb:

Garlic storability was noticeably influenced by the irrigation system and bio-stimulants (Fig. 5). The weight loss percentage of stored garlic bulbs was significantly different among the bio-stimulants and the irrigation system (Fig.5). There was no significant difference between the two irrigations after two months but, drip irrigation gave the lowest values after four and six months. Using ascorbic acid (0.2 gl^{1}) and yeast (2 g l^{-1}) reflected the lowest values of weight loss (%) of stored garlic after two, four, and six months compared to control and other bio-stimulants, Fig. 5. The interaction between irrigation system and bio-stimulants showed that the yeast extract and ascorbic acid under drip irrigation gave the lowest values of weight loss during storage period after two, four, and six months (Fig. 6).



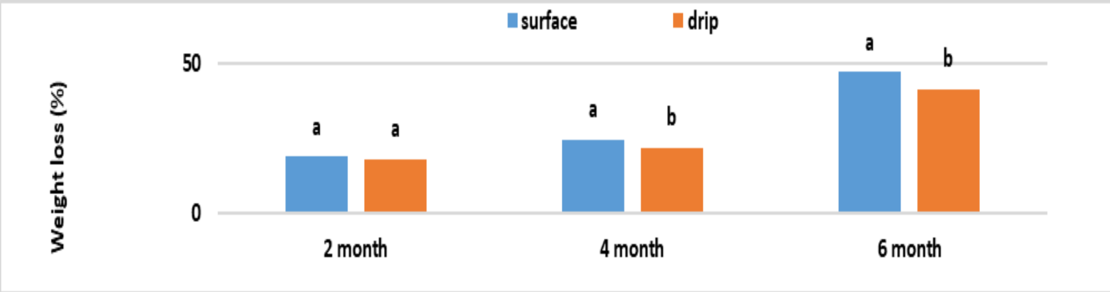


Figure 5. *Effect of irrigation system and bio-stimulants on weight loss of garlic bulb during storage condition after 2, 4, 6 months.*

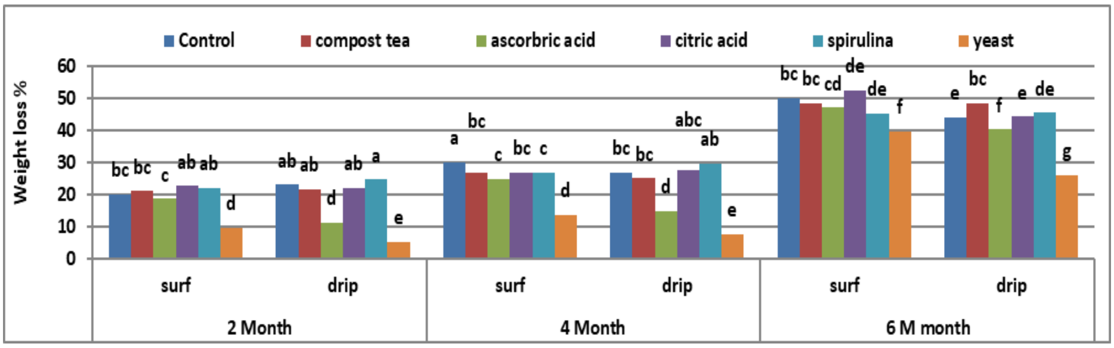


Figure 6. *Interaction effect of irrigation system and bio-stimulants weight loss percentage of garlic bulb during storage period after 2, 4, and 6 months.*

3.4. . Applied Irrigation Water and relative water saved

From data shown in Tab. 7, it can be concluded that the drip irrigation consumed less amounts of applied irrigation water (2135.68 and 2140.28 m^3 ha^{-1}) as compared with the surface irrigation system (4015.95 and 4072.27 m^3 ha^{-1}) in the first and second seasons of Garlic growing seasons, respectively. Whereas, the applied irrigation water amounts varied from 2131.00 m^3 ha^{-1} (drip irrigation, with Ascorbic acid) to 4067.28 m^3 ha^{-1} (surface irrigation, with control tap water) in the first season and from 2107.14 to 4197.62 m^3 ha^{-1} for the same treatments in the second season.

Table 7 presents data on the amount of irrigation water used in different systems during the garlic growing seasons. The drip irrigation system used significantly less water, with recorded amounts of 2135.68 m^3/ha in the first season and 2140.28 m^3/ha in the second season. In contrast, the surface irrigation system consumed much more water, with figures of 4015.95 m^3/ha in the first season and 4072.27 m^3/ha in the second season. This table presents the relative water saved when using different irrigation systems and biostimulants, compared to a control treatment (which typically involves no additional biostimulants). It quantifies how much less water was utilized in each treatment relative to the control. In the case of the surface irrigation system, there was a water saving of 1.51% during the first growing season.

Table 7. Amounts of applied irrigation water, and relative saved water for two irrigation systems

Treatments		Water Applied (m3/ha.)		Average	Relative Water Saved (%)		Average
Irrigation systems	Bio-stimulants	1st Season	2nd Season		1st Season	2nd Season	
Surface	Control	4067.28	4080.31	4073.8	-	-	-
	Compost tea	4010.50	4082.14	4046.32	1.40	-0.04	0.68
	Ascorbicacid	4011.00	4083.33	4047.17	1.38	-0.07	0.65
	Citric acid	4001.50	4060.71	4031.11	1.62	0.48	1.05
	Spirulina	4000.00	4057.14	4028.57	1.65	0.57	1.11
	Yeast	4005.40	4070.00	4037.7	1.52	0.25	0.89
Average		4015.95	4072.27	4044.1	1.26	0.20	0.73
Drip	Control	2133.60	2116.67	2125.14	47.54	48.12	47.83
	Compost tea	2135.70	2108.81	2122.26	47.49	48.32	47.90
	Ascorbic acid	2131.00	2197.62	2164.31	47.61	46.14	46.87
	Citric acid	2139.90	2195.00	2167.45	47.39	46.21	46.80
	Spirulina	2135.00	2107.14	2121.07	47.51	48.36	47.93
	Yeast	2138.90	2116.43	2127.67	47.41	48.13	47.77
Average		2135.68	2140.28	2137.98	47.49	47.55	47.52

However, in the second season, there was a slight reduction in water savings, recorded at 0.24%, which indicates a negligible increase in water usage compared to the control. When averaged over the two seasons, the overall water saving for this treatment was 0.88%. In contrast, the drip irrigation system exhibited significantly greater water efficiency. A remarkable water saving of 47.49% in the first season and 47.55% in the second season was achieved under this system. When averaged the two seasons, the water saving was 47.52%, this indicates that the drip irrigation system, regardless of the biostimulant used, was much more effective in conserving water compared to the surface irrigation system.

3.5. Economic evaluation of foliar application with the bio-stimulants under the two irrigation systems

The budgets for different bio-activators under each irrigation system are shown in table 8 and 9. The results show that the total cost of using a drip irrigation system (2488.64 and3054.44$/ha) is higher than under a surface irrigation system (2423.28and 2784.45/ha) in both seasons, respectively. The citric acid (0.2gl^{-1}) under the drip irrigation system was the highest cost (5086.08 and$5656.15) among the other treatments in both seasons, respectively. The lowest values (1814.88and $2235.41) were with using tap water (control) under a surface irrigation system in both seasons, respectively. From the data tabulated in Tab. 8and 9, it was clear that the mean values of the net return were 14532.27 and $11361.96 $/ha under the surface irrigation system and14615.25 and 11171.12 $/ha under the drip irrigation system during 2020/21 and 2021/22 seasons respectively.

Concerning bio-activator spraying, data showed that within each irrigation system, bio-activator application in general resulted in increasing the net return. Adding compost tea achieved the highest values of net return (16372.82and 12852.35$/ha) under drip irrigation in the first season and under surface irrigation in the second season, respectively. The lowest values (11668.21and 8268.63$/ha*)* were with adding Citric acid (0.2gl^{-1}) under the drip irrigation system in both seasons, respectively. It is clear from the data exhibited in Tab. 8 and 9 that water returns are almost similar for the two irrigation systems (3.9 $/m^3 in 2020/21 and 6.5 $/m^3 in 2021/22). As mentioned previously, adding bioactive stimulants increased such values. The spirulina had the highest water return value (7.50 $/m^3) value under the drip irrigation system in the first season and under the surface irrigation system i.e., (5.78$/m^3) in the second season. And with tap water (control) had the lowest water return values (3.13 and 3.19$/m^3) under both surface and drip irrigation systems respectively in the first season and under drip irrigation system only in the second season i. e., (2.39$/m^3), respectively.

Table 8. Crop Budgets for using biostimulants under different irrigation systems (2020/21)

Operation	**Total costs ($)**											
Bio-stimulants	**Control (tap water)**		**Compost tea**		**Ascorbic acid (0.2 gl1)**		**Citric acid (0.2gl-1)**		**Spirulina**		**Yeast**	
Irrigation system	**Surface**	**Drip**	**Surface**	**Drip**	**Surface**	**Drip**	**Surface**	**Drip**	**Surface**	**Drip**	**Surface**	**Drip**
Water applied	4067.28	2133.6	4010.5	2135.7	4011	2131	4001.5	2139.9	4000	2135	4005.4	2138.9
Total revenue	14550.26	14664.3	17765.9	18267.6	17600.0	17074.29	17074.29	16754.29	17074.29	17942.86	17668.57	17920.00
Seeds	127.71	127.71	127.71	127.71	127.71	127.71	127.71	127.71	127.71	127.71	127.71	127.71
land preparation	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50
Fertilization												
Spraying	0.00	0.00	1.60	1.60	319.28	319.28	3192.8	3192.85	40.89	1.28	63.86	63.86
Superphosphate	40.89	40.89	40.89	40.89	40.89	40.89	40.89	40.89	40.89	40.89	40.89	40.89
N-fertilizer	90.10	90.10	90.10	90.10	90.10	90.10	90.10	90.10	90.10	90.10	90.10	90.10
Labor	31.95	31.95	38.34	38.34	38.34	38.34	38.34	38.34	38.34	38.34	38.34	38.34
Weeds control	51.12	51.12	51.12	51.12	51.12	51.12	51.12	51.12	51.12	51.12	51.12	51.12
Irrigation	7.64	10.64	7.64	10.64	7.64	10.64	7.64	10.64	7.64	10.64	7.64	10.64
Harvest	63.90	63.90	63.90	63.90	63.90	63.90	63.90	63.90	63.90	63.90	63.90	63.90
Total variable costs	463.81	466.81	471.80	474.80	789.49	792.49	3663.1	3666.05	511.10	474.48	534.06	537.0
Fixed costs	675.53	744.50	675.53	744.50	675.53	744.50	675.53	744.50	675.53	744.50	675.53	744.5
Rent	675.53	675.53	675.53	675.53	675.53	675.53	675.53	675.53	675.53	675.53	675.53	675.5
Total costs	1814.9	1886.8	1822.9	1894.8	2140.6	2212.52	5014.1	5086.08	1862.2	1894.5	1885.1	1957
Net return	12735.4	12777	15943	16372	15459	14861	12060	11668	15212	16048.	15783.	15962
Water return ($/m^3)	3.13	3.19	3.97	4.09	3.86	3.71	5.65	5.46	7.14	7.50	7.39	7.46

Table 9. Crop Budgets for using biostimulants under different irrigation systems (2021/22)

Operation	Total costs ($)											
Bio-stimulants	Control (tap water)		Compost tea		Ascorbic acid (0.2 gl1)		Citric acid (0.2gl-1)		Spirulina		Yeast	
Irrigation system	Surface	Drip	Surface	Drip	Surface	Drip	Surface	Drip	Surface	Drip	Surface	Drip
Water applied	4080.3	2116.6	4082.1	2108.8	4083.3	2197.6	4060.7	2195	4057.1	2107	4070	2116.
Total revenue	12613.9	12215	15140.6	15216.6	14912.6	14190.7	14533	13925	15026.6	14913	12651.98	14893.6
Seeds	159.57	159.57	159.57	159.57	159.57	159.57	159.57	159.57	159.57	159.5	159.57	159.5
Land preparation	53.19	53.19	53.19	53.19	53.19	53.19	53.19	53.19	53.19	53.19	53.19	53.19
Fertilization												
Spraying	0.00	0.00	1.33	1.60	265.96	319.28	2659.5	3192.8	46.81	1.28	53.19	53.19
Superphosphate	46.81	46.81	46.81	46.81	46.81	46.81	46.81	46.81	46.81	46.81	46.81	46.81
N-fertilizer	89.36	89.36	89.36	89.36	89.36	89.36	89.36	89.36	89.36	89.36	89.36	89.36
Labor	26.60	31.95	38.34	38.34	38.34	38.34	38.34	38.34	38.34	38.34	38.34	31.91
Weeds control	21.28	51.12	51.12	51.12	51.12	51.12	51.12	51.12	51.12	51.12	51.12	42.56
Irrigation	8.07	11.25	8.07	11.25	8.07	11.25	8.07	11.25	8.07	11.25	8.07	11.25
Harvest	53.19	53.20	53.19	53.20	53.20	53.20	53.20	53.20	53.20	53.20	53.20	53.20
Total variable costs	458.07	496.45	500.99	504.44	765.63	822.13	3159.2	3695.6	546.48	504.1	552.86	541.0
Fixed costs	893.62	1014.7	893.62	1014.7	893.62	1014.7	893.62	1014.7	893.62	1014.	893.62	1014
Rent	893.62	945.74	893.62	945.74	893.62	945.74	893.62	945.74	893.62	945.74	893.62	945.74
Total costs($/ ha)	2245.3	2456.9	2288.2	2464.8	2552.8	2782.5	4946.4	5656.1	2333.7	2464	2340.1	2501
Net return($/ ha)	10369	9758	12852	12752	12360	11408	9586	8269	12693	12448	10311.88	12392.1
Water return ($/m^3)	2.54	2.39	3.15	3.14	3.05	2.80	4.53	3.92	5.78	5.67	4.89	5.86

3.6. Correlation coefficient analysis of variances among the studied traits

According to the statistical analysis of the data on morphophysiological traits, a strong and significant correlation was confirmed on all of the studied parameters at a 5% probability level, based on Duncan's Multiple Range Test (1955) conducted on combined data of the two seasons (Tab. 10). The interacting effect of compost tea, ascorbic acid, citric acid, spirulina extract, dry yeast, and tap water (control) was significant for all morphophysiological traits at a 5% probability level.

There was a significant positive correlation between bulb fresh weight, total yield per plant, and all the other traits in this study except the weight loss. Plant height exhibited positive significant and highly positive correlations with leaf number plant^{-1}, plant leaf area, total yield, bulb fresh weight, bulb diameter, total flavonoids, total phenols, and total sugars as well as significant and negative correlation with bulb weight loss. Leaf number plant^{-1} exhibited highly positive significant correlations with plant leaf area, total yield, bulb fresh weight, bulb diameter, total flavonoids, total phenols, and total sugars as well as significant and negative correlations with weight loss.

Plant leaf area exhibited positive significant and highly positive significant correlations with total yield, bulb F.W., bulb diameter, K%, K/Na ratio, total flavonoids, total phenols, and total sugars as well as highly negative significant and negative significant correlation with Na% and weight loss. Total yield exhibited highly positive significant correlations with bulb F.W., bulb diameter, K%, K/Na ratio, total flavonoids, total phenols, and total sugars as well as highly negative significant correlation with Na%. Bulb F.W. exhibited highly positive significant correlations with bulb diameter, K%, K/Na ratio, total flavonoids, total phenols, and total sugars as well as a negative significant correlation with Na%.

Bulb diameter exhibited highly positive significant correlations with K%, K/Na ratio, total flavonoids, total phenols, and total sugars as well as a negative significant correlation with Na% and weight loss. Na% exhibited a highly negative significant correlation with the K/Na ratio. K% exhibited a highly positive significant correlation with the K/Na ratio and total flavonoids. Total flavonoids exhibited a highly positive significant correlation with total phenols and total sugars. Total phenols showed a highly positive significant correlation with total sugars as well as a highly negative significant correlation with weight loss. Total sugars exhibited a negative significant correlation with weight loss.

Table 10. Correlation coefficients for parameters measured of garlic plant cultivation experiment, (combined data of 2020-21 and 2021-22).

	Plant height	**Leaves number/ plant**	**Plant leaf area**	**Total yield**	**Bulb F.W.**	**Bulb diameter**	**Na%**	**K %**	**K/Na ratio**	**Total flavonoids**	**Total phenols**	**Total sugars**	**weight loss**
Plant height	1												
Leaves number/plant	0.665	1											
Plant leaf area	0.772	0.802	1										
Total yield	0.653	0.605	0.836	1									
Bulb F.W.	0.661	0.588	0.822	0.856	1								
Bulb diameter	0.523	0.555	0.702	0.731	0.718	1							
Na%	-0.299	-0.256	-0.517	-0.512	-0.36	-0.414	1						
K%	0.067	0.234	0.362	0.492	0.44	0.513	-0.113	1					
K/Na ratio	0.231	0.271	0.533	0.602	0.44	0.556	-0.84	0.603	1				
Total flavonoids	0.411	0.507	0.469	0.389	0.423	0.492	0.213	0.566	0.121	1			
Total phenols	0.556	0.595	0.614	0.445	0.406	0.424	-0.156	0.245	0.207	0.467	1		
Total sugars	0.573	0.53	0.501	0.299	0.363	0.333	0.233	0.301	-0.058	0.747	0.77	1	
weight loss	-0.401	-0.389	-0.388	-0.293	-0.199	-0.412	0.134	0.015	-0.075	-0.201	-0.491	-0.38	1

4- DISCUSSION

Garlic (Allium sativum L.) has a reputation in various cultures as a preventive and curative medicinal herb, and it has played key dietary and medicinal functions throughout history. (Sunanta *et al*., 2023). Yeast achieved the highest values for all evaluated traits compared to untreated plants in both growing seasons, and that is may because yeast contains many nutrients that produce compounds similar to growth regulation, such as auxins, gibberellins, and cytokinins (Fawzi ***et al***., 2012, a). Yeast extract is one type of plant-based Biostimulant that outperforms plant growth regulators and soil conditioners. It is also rich in amino acids, nutrients, and vitamins (Tab. 2-C), easy to use, and environmentally friendly (Xi, *et al.*, 2019). These results agree with Badawy *et al.,* (2019) who found that the plant height, the leaves per plant numbers, and the leaf area per plant were significantly affected by irrigation treatments and the use of bio-stimulants. Among different treatments, the increased plant height, leaf number per plant, and leaf area per plant under spraying of yeast at 2 g l^{-1} and drip irrigation system were probably due to its effects on cell division, elongation, enlargement, chlorophyll formation, protein, and nucleic acid synthesis (Francesca *et al.*, 2020). In addition, Nassar *et al.,* (2016) indicated that a decline in Leucaena vegetative growth exposed to salinity stress can be recovered by the simulative impact of yeast extract.

Moreover, spraying of yeast (2 g l^{-1}) recorded the uppermost values for total sugar (mg/g D.W) and total flavonoids, compared with untreated plants in both seasons, while spraying of ascorbic acid (0.2 g l^{-1}), citric acid (0.2gl^{-1}), spirulina (1 ml l^{-1}), and yeast (2 g l^{-1}) gave the highest total phenols (mg/g D.W) in both seasons.

The beneficial effect of compost tea could attributed to the valuable extract of plant microorganisms such as biostimulants and growth-promoting chemicals, which promote plant metabolisms (Table 2-A). Furthermore, rich elements present in compost tea, such as nitrates and potassium, may be released during its disintegration. Furthermore, the positive impact of compost tea can be attributed to the direct contribution to photosynthesis, cell respiration, protein polymerization, and other enzymatic (Al-Jbawi and Abbas, 2013; Naidu *et al*., 2013; Villecco *et al.,* 2020; Osman *et al.,* 2021).

In addition, sprayed garlic plants with compost tea significantly increased the K percentage and K/Na ratio in both seasons. These are in harmony with the consequences that show that the total content of N, P, and K in leaves and bulbs, and total carbohydrates in garlic bulbs, increased as a result of foliar application with bio-stimulants (Ahmed, 2015).

Most spirulina extracts are composed of naturally occurring bioactive substances that contribute to plant growth and productivity, such as gibberellins, auxins, cytokinins, abscisic acid, proteins, carbohydrates, and vitamins (Table 2-B). Additionally, it includes amino acids, which are important for metabolism, nutritional intake, translocation, detoxification from heavy metals and toxins, production of vitamins and chlorophyll, and stress alleviation (Bashir *et al.*, 2018).

El-Tohamy *et al*. (2008), on Eggplant, stated that yeast foliar resulted in a significant increment in cytokinins, N, P, and K contents in leaves especially at the high level of yeast compared to untreated plants. Similar trends were reported in the positive effects of the application of yeast on Sweet Pepper, Snap bean, Potato, Cucumber, and garlic plants (Ghoname *et al*, 2010; Ahmed *et al*, 2011).

From the study results it can be presented a conclusion that the drip irrigation achieved the highest values for all studied traits, compared to the surface irrigation. On the other side, for biostimulant application, based on our observations, all foliar application treatments (compost tea, ascorbic acid, citric acid, spirulina extract, and yeast) have the potential to enhance garlic growth and yield characteristics in both seasons, as compared with control (Tab. 3, 4, 5 and 6).

Additionally, from the results obtained, on yield attributes, the maximum bulb diameter, maximum bulb fresh weight, and maximum total yield were recorded under spraying of compost tea and yeast (2 g L^{-1}) during the two garlic growing seasons, and that increments of bulb weight might be due to modification of the source-sink relationship by the use of growth regulators (Rakesh *et al*., 2022). In addition, the positive effect of dry yeast may be attributed to the increase in plant nutrient contents, amino acids, vitamin B, and cytokinins (Farid, 1996).

Furthermore, vitamins and amino acids increase the metabolic processes and the levels of endogenous hormones, which affect the final bulb's weight and size (Abdullah, 2010). These results are in harmony with Badawy *et al*., (2019) who showed that bio-stimulants especially humic can increase and improve the yield and quality of garlic and save irrigation water, and Govind *et al*. (2015) who confirmed that garlic yield increments are due to plant bio-regulators application. Also, similar trends, as previously, were reported for several crops like cucumber, and potato (Ahmed *et al*., 2013). In the same way, using ascorbic acid and yeast reflected the minimum values of total weight loss percentage of stored garlic for two, four, and six months, compared to control and other bio-stimulants. The obtained results are in harmony with Ahmed (2015) who found that foliar application of dry yeast (3 and 4 g l^{-1}) and chitosan (4 and 6 ml l^{-1}) can be recommended to improve productivity, quality, and storability of garlic plants grown in clay loamy soil.

Studies and research have demonstrated that the use of bio-stimulants greatly improves garlic growth, production, and quality characteristics (Badawy *et al.,* 2019). Essential macro-micronutrients included in these bio-stimulants, such as fulvic and humic acids, have a good effect on plant characteristics like bulb diameter and total yield (Tarafdar, 2022). Moreover, it has been demonstrated that bio-stimulants improve plant development, yield, and quality while lowering the requirement for excessive chemical fertilizers, which results in reduced production expenses (Anjum et al., 2014).

When compared to surface irrigation, drip irrigation produced considerably higher yield traits, such as maximum bulb diameter, fresh weight, and total yield. These findings are in alignment with Calvo, *et al*., (2014) who stated that drip irrigation delivers water directly to the root zone of plants, minimizing evaporation and runoff. This method is particularly advantageous in regions facing water scarcity, enabling farmers to use less water while maintaining or increasing crop yields.

Tables 8 and9 present an economic evaluation of the different biostimulants applied under two irrigation systems, providing insights into the cost-effectiveness of using these treatments in agricultural practices. biostimulants enhance irrigation efficiency by improving water use, reducing water requirements, and increasing yields, ultimately leading to better economic returns (Calvo *et al.,* 2014; Rouphael, and Colla, 2020).

The research indicates that using biostimulants in conjunction with drip irrigation can lead to increased farmer income and net returns. This economic advantage can motivate farmers to invest in these practices for better profitability. As noted in the document, the application of biostimulants like compost tea and yeast extract resulted in higher yield traits, such as bulb diameter and total yield, particularly under drip irrigation systems. Higher yields can translate into increased revenue, which can offset the costs of biostimulants and irrigation systems. This is particularly important in the context of global water scarcity and the need for sustainable food production systems.

1- CONCLUSION

The paper presents a comprehensive study on the effects of different irrigation systems and biostimulant treatments on garlic cultivation, focusing on yield traits, relative water saved, and economic evaluations. a summary of the information displayed in the following:

- Drip irrigation significantly outperformed surface irrigation in terms of yield traits, including maximum bulb diameter, bulb fresh weight, and total yield. The drip irrigation system consistently provided higher values for all studied yield traits across both growing seasons.
- The application of biostimulants such as compost tea, spirulina, and yeast extract resulted in enhanced growth parameters and yield traits compared to the control (tap water). Notably, yeast extract showed the highest effectiveness in improving bulb fresh weight and total yield
- The economic analysis revealed that while the initial costs of drip irrigation and biostimulants may be higher, the resulting increases in yield and water savings can lead to better economic returns.
- The budgets for different biostimulants showed varying costs and revenues, emphasizing the importance of selecting cost-effective treatments for maximizing profitability.
- A strong correlation was observed among the studied morphophysiological traits, indicating that improvements in one parameter (e.g., plant height, leaf area) were associated with enhancements in others, ultimately leading to better overall plant performance.

In conclusion, farmers looking to enhance their economic viability should consider implementing drip irrigation alongside effective biostimulants especially, yeast extract or compost tea to maximize yield, improve water efficiency, and achieve better economic outcomes.

2- REFERENCES

Abd El-Hady, M., and Eldardiry, E.I. (2016). Maximize crop water productivity of garlic by modified fertilizer management under drip irrigation. *International Journal of Chem. Tech. Research*, *9*(5), 144-150.

Abd El-Latif, K.M., and Abdelshafy, A.A. (2017) Response of garlic productivity to surface and drip systems and irrigation amounts. *Middle East Journal of Agriculture Research*, *6*(4), 981-995.

Abd-El-Rahman, M.M.A., El-Ftooh, A.A.A., and Ghonema, M.A. (2017). Response of some sugar beet varieties to foliar spraying with compost tea and its relationship with two sugar beet insects, beet fly, (Pegomya mixta Vill.) and tortoise beetle (Cassida vittata Vill.) under newly reclaimed sandy soil. Menoufia J. Plant Prod., 2: 53-63.

Ahmad A., Blasco B., and Martos V. (2022). Combating salinity through natural plant extracts based biostimulants: a review. *Frontiers in Plant Science*, *13*, 862034.

Ahmed, A.A., Abd El-Baky, M.M.H., Helmy, Y.I. and Shafeek, M.R. (2013) Improvement of potato growth and productivity by application of bread yeast and manganese. J. Appl. Sci., Res., 9 (8), 4896-4906

Ahmed, A.A., Abd El-Baky, M.M.H., Zaki, M.F., and Abd El-Aal, F.S. (2011). Effect of foliar application of active yeast extract and zinc on growth, yield and quality of potato plant (Solanum tuberosum L.). *J. Appl. Sci. Res*, *7*(12), 2479-2488.

Ahmed, M.E.M., and Farm, E. (2015). Response of garlic plants (Allium sativum L.) to foliar application of some bio-stimulants. *Egypt. J. Hort*, *42*(1), 613-625.

Ali, M.A.M. (2017). Effect of some bio-stimulants on growth, yield and bulb quality of garlic grown in newly reclaimed soil, new Valley-Egypt. Journal of Plant Production, 8(12), 1285-1294.

Al-Jbawi, E., and Abbas, F. (2013). The effect of length during drought stress on sugar beet (Beta vulgaris L.) yield and quality. Persian Gulf Crop Prot., 2, 35–43.

Al-Otayk, S., Motawei, M. I., and El-Shinawy, M. Z. (2009). Variation in productive characteristics and diversity assessment of garlic cultivars and lines using DNA markers. Journal of Meteorology, Environment and Arid land Agriculture Sciences, 20(1).

Anjum, K., Ahmed, M., Baber, J. K., Alizai, M. A., Ahmed, N., and Tareen, M. H. (2014). Response of garlic bulb yield to bio-stimulant (bio-cozyme) under calcareous soil. *Life Sciencie International Journal*, *8*(1-4), 3058-3062.

Awad, R.A. (2019). Economic study for the production and marketing of garlic crop in Egypt (study case for Beni Suef governorate). Egyptian Journal of Agricultural Research, 97(4), 875-903.

Badawy A., Zahran M.M.A., and Hefzy, M.M. (2019). Effect of irrigation level and bio-stimulants on productivity and quality of garlic (Allium sativum l) in calcareous soils. Fayoum Journal of Agricultural Research and Development, 33(1), 90-101.

Bashir, A.; Rizwan, M., Ali, S.; Rehman, M.; Ishaque, W.; Atif Riaz, M., and Maqbool A. (2018). Effect of foliar-applied iron complexed with lysine on growth and cadmium (Cd) uptake in rice under Cd stress. Environmental Science and Pollution Research, 25, 20691-20699.

Bella, E.L.; Baglieri, A., Rovetto, E.I.; Stevanato, P.; and Puglisi, I. (2021). Foliar spray application of Chlorella vulgaris extract: Effect on the growth of lettuce seedlings. Agronomy, Vol. 11. 10.3390/agronomy1102030.

Bello, A. S., Saadaoui, I., and Ben-Hamadou, R. (2021). “Beyond the source of bioenergy”: microalgae in modern agriculture as a biostimulant, biofertilizer, and anti-abiotic stress. *Agronomy*, *11*(8), 1610.

Boas, R. C. V., Pereira, G. M., Reis, R. P., Lima Junior, J. A. D., and Consoni, R. (2011). Viabilidade econômica do uso do sistema de irrigação por gotejamento na cultura da cebola. *Ciência e agrotecnologia*, *35*, 781-788.

Brown, J. G., and Lilleland, O. M. U. N. D. (1946). Rapid determination of potassium and sodium in plant materials and soil extracts by flame photometry.

Calvo, P., Nelson, L., and Kloepper, J. W. (2014). Agricultural uses of plant biostimulants. Plant and soil, 383, 3-41.

Collin, H. A. (2004). Garlic and cardiovascular disease. In Functional Foods, Cardiovascular Disease and Diabetes (pp. 240-260). Woodhead Publishing.

Dawa, K. K., Radwan, E. A. A, and. Mansour, F. Y. O (2012). Effect of chicken manure levels, biofertilizers and some foliar application treatments on garlic. 1. Plant growth and leaf pigments. J. Plant Production, Mansoura Univ., 3(3): 571-586.

Diriba-Shiferaw, G. (2017). Comparative study of different compound fertilizers on garlic (Allium sativum L.) productivity under various soils and seasons. Global Journal of Science Frontier Research: D Agriculture and Veterinary, 17(1).

Duncan, D. B. (1955). Multiple range and multiple F-tests. Biometrics 11: 1-42. Eleshmawiy, K. H., ElSharif, L. M., Hassan, H. B., Saafan, A. M. (2010). Potentials of the economic expansion in the production and export of Egyptian garlic. Nat. Sci., 8: 279- 287

Abd El-Hady, M. and Eldardiry (2016). Maximize Crop Water Productivity of Garlic by Modified Fertilizer Management Under Drip Irrigation. International Journal of ChemTech Research, 9(5): 144-150.

Elhagarey, M. E. (2014). Design and Manufacture of Pottery Dripper for the Use of Saline Water in Irrigation Systems. Journal of Agriculture and Veterinary Science,7, 70-80.

Elhagarey, M. E. (2020). Evaluating of drip irrigation systems for maximizing water use efficacy for garlic in desertsoilinal-sadat area in Egypt. Plant Archives, 20 (2): 9211-9220.

Elhagarey, M.E. & Kashay, C. (2024). Environmental and economic returns for the development and management of innovations in modern irrigation systems in Egypt. Journal of Applied and Natural Science, 16(2), 653 - 662. https:// doi.org/10.31018/jans.v16i2.5382

El-Khair, E. E. A., and Khalil, A. M. M. (2014). Effect of foliar application with some bio-stimulants on yield, volatile oil and storability of garlic plant grown in sandy soil. AJCS 8(2):271-275

El-Tohamy, W. A., El-Abagy, H. M., and El-Greadly, N. H. M. (2008). Studies on the effect of putrescine, yeast and vitamin C on growth, yield and physiological responses of eggplant (Solanum melongena L.) under sandy soil conditions. Australian Journal OF Basic and Applied Sciences. 2(2): 296-300.

FAO. 2023. Food and Agriculture Organization of the United Nations.

Fatty, S. L. and Farid, S. (1996). Effect of some chemical treatments, yeast preparation and royal Jelly on some vegetable crops growing in late summer season to induce their ability towards better thermal tolerance. J. Agric. Sci., Mansoura Univ., 25(4): 2215-2249.

Fawzy, Z. F., El-Shal, Z. S., Li YunSheng, L. Y., Zhu OuYang, Z. O., and Sawan, O. M. (2012). Response of garlic (Allium sativum, L.) plants to foliar spraying of some bio-stimulants under sandy soil condition. Journal of Applied Sciences Research, 8(2): 770-776.

Forsee, W. T. (1938). Determination of sugar in plant materials a photoelectric method. Indus. Eng. Chem. Anal. Ed. 10: 411-418.

Francesca, S., Arena, C., Hay Mele, B., Schettini, C., Ambrosino, P., Barone, A., and Rigano, M. M. (2020). The use of a plant-based biostimulant improves plant performances and fruit quality in tomato plants grown at elevated temperatures. *Agronomy*, *10*(3), 363.

Gharib, H. S. and El-Henawy, A. S. (2011). Response of sugar beet (Beta vulgaris, L.) to irrigation Regime, Nitrogen rate and Micronutrients application. Alexandria. Alexandria Science Exchange Journal, 32 (2) , 140-156.

Ghoname, A. A., El-Nemr, M. A., Abdel-Mawgoud, A. M. R., and El-Tohamy, W. A. (2010). Enhancement of sweet pepper crop growth and production by application of biological, organic and nutritional solutions. *Research Journal of Agriculture and Biological Sciences*, *6*(3), 349-355.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research, 2nd ed. Wiley, New York, 680

Govind, S. M., Kumawat, R., Pal, A., Kumar, S., & Saha, S. (2015). Improvement of growth, yield and quality of garlic (Allium sativum l.) cv. g-282 through a novel approach. *Bio Science*, *10*(1), 23-27.

Gupta, R., Kulmi, G. S., and Sarathe, A. (2022). Scheduling of drip irrigation system for garlic crop in Malwa region of Madhya Pradesh, India. Plant Archives, 22(1), 421-424.

Hanna, D. M., Mohammed, D. E., and Mohammed, E. (2023). Production and Marketing Efficiency of Garlic Crop In Egypt. Iosr Journal of Economics and Finance Vol. 14(5): 01-09. https://www.iosrjournals.org/iosr-jef/papers/Vol14-Issue5/Ser-.3/A1405030109.

Helal, F. A. , El Zeiny, O. A. H. and El Saaed. S. A. (2005). Performance of faba bean (Visia faba L.) cultivars and their response to spray with some foliar fertilizers and yeast. Egypt. J. Of Appl. Sci., 20 (8B): 555-473.

Hiekal, H. A. (2021). Modernization drip irrigation systems to improve fodder crops production and rationalizing groundwater in north Sinai - Egypt: case study. Misr journal of agricultural engineering, 39 (1): 51 – 70.

Klute A. (1986). Methods of soil analysis: physical and mineralogical properties. Part I, ASA-SSSA.

Kowalczyk, K., Zielony, T., and Gajewski, M. (2008). Effect of Aminoplant and Asahi on yield and quality of lettuce grown on rockwool. In *Conf. of biostimulators in modern agriculture* (pp. 7-8).

Martins, N., Petropoulos, S., and Ferreira, I.C. (2016). Chemical composition and bioactive compounds of garlic (Allium sativum L.) as affected by pre-and post-harvest conditions: A review. Food chemistry, 211, 41-50.

Mclaurin, W. J., Adams, D. B., and Eaker, T. H. (2009). Garlic production for the gardener. https://extension.uga.edu/publications/detail.html?number=C854&title=garlic-production-for-the-gardener.,

Mehmood A., Naveed K., Liu K., Harrison M.T., Saud S., Hassan S., Fahad S. 2024. Exogenous application of ascorbic acid improves the physiological and productive traits of Nigella sativa. Heliyon, 10(7).

Meshref, H. A., Rabie, M. H., El-Ghamry, A. M. and El-Agamy, M. A. (2010). Maximizing utilization of compost addition using foliar compost extract and humic substances in alluvial soil. Journal of Soil Science and Agricultural Engineering, Mansoura University, 1, 957-971. https://doi.org/10.21608/jssae.2010.75464

Morad, M. M., Abdel-Aal, E. I. A., Moursy, M. A. M. (2012). Water saving with the use of different irrigation systems under Egyptian conditions. Misr Journal of Agricultural Engineering, 29(3), 1047-1066.

Morsi, M. K., El-Magoli, B., Saleh, N. T., El-Hadidy, E. M. and Barakat, H.A. (2008). Study of antioxidants and anticancer activity licorice Glycyrrhiza glabra extracts. Egyptian J. Nutr. And Feeds, 2(33): 177-203.

Moursy, M. A. M., ElFetyany, M., Meleha, A. M. I., and El-Bialy, M. A. (2023). Productivity and profitability of modern irrigation methods through the application of on-farm drip irrigation on some crops in the Northern Nile Delta of Egypt. Alexandria Engineering Journal, 62, 349-356.

Naidu, Y., Meon, S., and Siddiqui, Y. (2013). Foliar application of microbial-enriched compost tea enhances growth, yield and quality of muskmelon (Cucumis melo L.) cultivated under fertigation system. Scientia Horticulturae, 159, 33–40. https://doi.org/10.1016/j. scienta.2013.04.024

Nassar, R. M., Shanan, N. T., and Reda, F. M. (2016). Active yeast extract counteracts the harmful effects of salinity stress on the growth of leucaena plant. Scientia Horticulturae, 201, 61-67.

Osman, H. S., Rady, A. M., Awadalla, A., Omara, A. E. D., and Hafez, E. M. (2022). Improving the antioxidants system, growth, and sugar beet quality subjected to long-term osmotic stress by phosphate solubilizing bacteria and compost tea. *International Journal of Plant Production*, *16*(1), 119-135.

Page, A. L (Ed.). (1982). Methods of soil analysis. Part 2. Chemical and microbiological properties (pp. 1159-pp).

Park, Y. S., Jung, S. T., Kang, S. G., Heo, B. G., Arancibia-Avila, P., Toledo, F., ... & Gorinstein, S. (2008). Antioxidants and proteins in ethylene-treated kiwifruits. *Food Chemistry*, *107*(2), 640-648.

Rakesh, S., Medda, P. S., Dutta, B., Ghosh, A., and Khalko, S. (2022). Influence of Various Plant Growth Regulators on Growth and Yield of Garlic (Allium sativum L.) under Terai Region of West Bengal. Journal Crop and Weed, 11(2):67-71.

Raslan, M., AbouZid, S.F., Abdallah, M.M., and Hifnawy, M.S. (2015). Studies on garlic production in Egypt using conventional and organic agricultural conditions. African Journal of Agricultural Research, 10, 1631-1635.

Rouphael, Y., and Colla, G. (2020). Biostimulants in agriculture. Frontiers in plant science, 11, 40.

Sánchez, E., López-Lefebre, L.R., García, P. C., Rivero, R. M., Ruiz, J. M., and Romero, L. (2018). Proline metabolism in response to highest nitrogen dosages in green bean plants (Phaseolus vulgaris L. cv. Strike). Journal of Plant Physiology, 229, 92-99.

Shalaby, T.A.,and El-Ramady H. (2014). Effect of foliar application of bio-stimulants on growth, yield, components, and storability of garlic ('Allium sativum'L.). Australian Journal of Crop Science, 8(2), 271-275.

Shehata, S. A., Fawzy, Z. F., and El-Ramady, H. R. (2012). Response of cucumber plants to foliar application of chitosan and yeast under greenhouse conditions. Australian J. Basic Appl. Sci., 6 (4), 63-71.

Singh, H. D., Maji, S., and Kumar, S. (2014). Influence of plant bio-regulators on growth and yield of garlic (Allium sativum L.). International Journal of Agricultural Sciences, 10 (2): 546-549.

Smirnoff, N. (2018). Ascorbic acid metabolism and functions: A comparison of plants and mammals. Free Radical Biology and Medicine, 122, 116-129.

Sunanta, P., Kontogiorgos, V., Pankasemsuk, T., Jantanasakulwong, K., Rachtanapun, P., Seesuriyachan, P., and Sommano, S. R. (2023). The nutritional value, bioactive availability and functional properties of garlic and its related products during processing. Frontiers in Nutrition, 10.

Swain, T., and Hillis, W. E.(1959). The phenolic constituents of Prunus domestica. I. The quantitative analysis of phenolic constituents. J. Sci. Food Agric. 10: 63 –68.

Talpur, Z., Zaidi, A. Z., Ahmed, S., Mengistu, T. D., Choi, S. J., and Chung, I. M. (2023). Estimation of Crop Water Productivity Using GIS and Remote Sensing Techniques. *Sustainability*, *15*(14), 11154.

Tarafdar, J. C. (2022). Bio-stimulants for sustainable crop production. In New and Future Developments in Microbial Biotechnology and Bioengineering (pp. 299-313). Elsevier.

Villecco, D., Pane, C., Ronga, D., and Zaccardelli M. (2020). Enhancing the sustainability of tomato, pepper and melon nursery production systems by using compost tea spray applications. Agronomy, 10(9), 1336.

Voss, and Ronald E. (July 1995). "Small Farm News Archive". UC Davis Small Farm Center. Archived from the original on March 13, 2007. Retrieved April 14, 2010.

Wanas, A. L. (2006). Trails for improving growth and productivity of tomato plants grown in winter. Annals of Agric. Sci., Moshtohor, 44(3): 466-471.

Xi, Q., Lai, W., Cui, Y.,Wu, H., and Zhao, T. (2019). Effect of yeast extract on seedling growth promotion and soil improvement in afforestation in a semiarid chestnut soil area. Forests, 10(1), 76.

Yanni, Y. G., Elashmouny, A. A., and Elsadany, A. Y. (2020). Differential response of cotton growth, yield and fiber quality to foliar application of Spirulina platensis and urea fertilizer. Asian J. Adv. Agric. Res, 12(1), 29-40.

Yaseen, A. A., and Takacs-Hajos, M. (2022). The effect of plant bio-stimulants on the macronutrient content and ion ratio of several lettuce (Lactuca sativa L.) cultivars grown in a plastic house. South African Journal of Botany, 147, 223-230.