The Future of Agriculture

FSA

Article

Alleviate the Adverse Effect of Irrigation with Drainage Water on Garlic Plants by Using Glycine Betaine and Sodium Nitroprusside

Abd El Aal, A. M. H.* and Nermeen A. E. Abd El Wadod

Potato and Vegetatively Propagated Vegetables Department, Horticulture Research Institute, Agricultural Research Center (ARC), Giza, Egypt .

https://doi.org/10.37229/fsa.fja.2025.11.27

***Corresponding author:** drplantscience@gmail.com

Future Science Association

Available online free at
www.futurejournals.org

Print ISSN: 2687-8151

Online ISSN: 2687-8216

Received: 20 September 2025
Accepted: 10 November 2025
Published: 27 November 2025

Abstract: This experiment was conducted during the two consecutive winter seasons of 2022/2023 and 2023/2024 at the Experimental Farm of Vegetable Crops, Medicinal and Aromatic plants, Horticulture Research Institute, Agricultural Research Center, Dokki, Giza, Egypt, to study the effect of irrigation with saline water and foliar applications of glycine betaine (GB) and sodium nitroprusside (SNP) on vegetative growth, chemical composition and yield of two garlic cultivars (Sids-40 and Balady) grown in sandy soil under drip irrigation system. Treatments were the combination among two cultivars and two foliar treatments and four saline irrigation water treatments; *i.e*., 1000, 2000, 3000 and 4000 ppm (prepared by diluted drainage water of Karun lake, Fayoum Governorate) and tap water of E.C 256 ppm as control. The results emphasized that all measured growth characteristics decreased gradually as garlic plants were irrigated with saline water up to 4000 ppm. Balady cultivar recorded higher vegetative growth and N and K uptake values. On the other hand, Sids-40 cultivar recorded the higher values of neck diameter, bulb diameter and average cloves weight. The higher significant proline content and protein % recorded with the Balady cultivar Thus, Balady cultivar was more salt-tolerant compared with Sids-40 cultivar. As the saline water level increased above 1000 ppm the vegetative growth and yield decreased. The saline water level of 1000 ppm significantly increased the vegetative growth, chemical content and the yield in both seasons. The triple interaction among the Balady cultivar, saline level of 1000 ppm and the foliar application of GB improved the plant length, leaves number/plant, leaves area, leaves dry weight, bulb fresh weight, bulb dry matter, chlorophyll content and the bulb weight yield, while the highest significant content of proline was obtained by Balady cultivar, saline level of 4000 ppm and the foliar application of GB in both seasons.

Keywords: Garlic, saline water, proline, yield component.

1. Introduction

Garlic (*Allium sativum* L.) which belongs to family *Alliaceae* is one of the oldest vegetable crops under cultivation in the world. It is come in the second most important crops cultivated and used among

alliums after onion. Garlic cloves commonly used as a spice or condiments as well as many medical purposes (contains Allicin in di allyle di sulfide form). Increasing garlic production has become great necessary to meet the ever increased demand of exportation and local consumption **(El-Hifny, 2010)**. It has been used for medical and culinary purposes all over the world since ancient times **(Al-Safadi and Faoury, 2004)**. Egypt is one of the greatest world green garlic producers, ranking fourth after China, India and Bangladesh **(FAO, 2025)**. Furthermore, Egypt became the fifth-largest exporter of green garlic in 2023 **(FAO, 2025).** In 2023 the annual production reached 563 thousand tons of garlic **(MALR, 2025).**

Otherwise, the Egyptian society is suffering from overpopulation so it is a necessity to reclaim more new lands, especially in the desert area, which may have a high concentration of salts as a result of the rarity of rain. Also, Egypt's share of the River Nile water, which is the principal source of irrigation cannot provide the quantities needed to cultivate these new areas. It is important to look for other sources of water that could be used for irrigation without harmful effects on both soil and field crops such as the agricultural drainage water or the mixture between this water and the river Nile water. The drainage water is considered the second resource of water that may be reused in irrigation after the groundwater. In Egypt it represents about 17.4 billion cubic meters per year (**Abbott and El-Quosy, 1998**).

Salinity is one of the main environmental factors limiting plant growth and productivity. It is estimated that about one third of the world's cultivated land is affected by salinity **(Velmurugan *et al.*, 2020).** Plants developing in such conditions face two challenges: extracting water from a soil with a negative osmotic potential and coping with potentially harmful sodium and chloride ions in high concentrations **(Cushman *et al.*, 1990).** Plant response to salinity differs from one crop species to another, ranging from tolerant plants such as cotton, sugar beet and barley to sensitive ones such as garlic, onion and carrot **(FAO, 1994).**

The ability of plants to maintain a high K^+/Na^+ ratio is one of the primary determinants of plant salt tolerance. Salt stress is toxic to plants and induces metabolic changes such as loss of chloroplast activity, a decrease in photosynthetic rate, and an increase in photorespiration rate **(Parida and Das, 2005**).

Sodium nitroprusside (SNP) is commonly used as a nitric oxide (NO) donor in plants, low concentrations of SNP could protect plants against oxidative stress because under the SNP treatment, lipid peroxidation decreased and pigment loss was ameliorated. NO is associated with induced plant tolerance to salinity **(Molassiotis *et al.*, 2010)**. For instance, under salinity conditions, the exogenous NO can enhance salt tolerance by stimulating proton-pump activities and Na^+/H^+ antiport in the tonoplast, and increasing the K^+/Na^+ ratio **(Wang *et al.*, 2011)**. Although the relationship between NO and ROS (Reactive Oxygen Species) has been revealed, it is not a straight forward positive correlation. Therefore, it's urgent to further understand the physiological mechanisms between NO and NaCl tolerance, and probe into the methods for increasing salinity stress tolerance in plants. Sodium nitroprusside (SNP) is a donor of NO in inducing salinity tolerance in plants **(Dong *et al.*, 2014)**.

Glycine betaine GB is a small organic metabolite soluble in water and nontoxic at higher concentrations can potentially play a crucial role in effective protection against salt stress **(Chen and Murata, 2008)**. Application of GB to non-accumulator plants may be a possible alternative approach for tolerance against multiple abiotic stresses (**Yang and Lu, 2005**). In addition, glycine betaine is well-known as a compatible solute that plays a pivotal role in the process of osmotic adjustment in different organisms including higher plants, salt stress up-regulates the enzymes involved in proline and betaine biosynthesis in several plant species (**Hoque *et al.*, 2007a and b**).

Therefore, this study aimed to test the application effect of sodium nitroprusside and glycine betaine to increase the tolerance of garlic cultivars Sids-40 and Balady which are irrigated with drainage water.

2. Materials and Methods

This investigation was carried out at the Experimental Farm of Vegetable Crops, Medicinal and Aromatic plants, Horticulture Research Institute, Agricultural Research Center. Dokki, Giza, Egypt during the two successive winter seasons of 2022/2023 and 2023/2024.

The experiment contained 30 treatments which were the combination among two garlic cultivars (Balady and Sids-40), five salt concentrations (control, 1000, 2000, 3000 and 4000 ppm) and three concentrations of Sodium nitroprusside (SNP) or Glycine betaine (GB) (0.0, 0.1 mM/l. SNP and 2 mM/l. GB).

The treatments were arranged in a split split plot design with three replicates, each replicate contained four pots of each treatment where cultivars randomly distributed in the main plots, saline water concentrations as a sub plot and the foliar application of SNP and GB arranged as a sub sub plot. Uniformed cloves were soaked in running water for 24 hour before planting and planted in pots, each pot planted with four garlic cloves on the 28th of September 2022/2023 and 2023/2024 seasons, respectively. Garlic cloves were obtained from Potato and Vegetatively Propagated Vegetables Research Department, Horticulture Research Institute, Ministry of Agriculture, Dokki, Giza, Egypt. After germination, the treatments were initiated at 21 days after plantation. The Glycine betaine ($C_7H_{16}N_2O_4$–GB) of Sigma Aldrich and the Sodium nitroprusside [Na_2(Fe (CN)5NO).2H_2O -SNP] of Prolabo were used.

The sand culture technique (**Hewitt, 1952**) was used in this investigation. The crude sand was sieved through a 20-mesh sieve. Then the sieved sand was soaked for three days in 5% hydrochloric acid. The sand was subsequently washed by a current of tap water for three days to get rid of any activity, afterwards, the sand was dried by air. Plastic pots of 40 centimeters in depth were used each pot contained 15 kg of washed sand, which filled it up to five centimeters from its upper edge. The chemical properties of the soil before sowing are presented in Table 1.

Table (1). The chemical properties of pot sand soil in the two seasons of 2022/2023 and 2023/2024

Season	PH	E.C dS/m	CaCO%	Anions (Meq/L)				Cations (Meq/L)			
				SO_4^{-2}	Cl^-	HCO_3^-	CO_3^-	K^+	Na^+	Mg^{+2}	Ca^+
2022	8.7	0.70	1.2	0.01	0.4	0.8	-	0.26	0.23	-	0.72
2023	8.3	0.65	1.6	0.93	0.9	0.7	-	0.37	0.67	-	1.49

The field capacity of the experimental soil was determined by the pressure cooker methods at 1/3 atm. according to **Israelson and Hanson (1962**). It was found to be 2.9% (on dry weight basis). The wilting point of the soil was found to be 1.56% as determined by the pressure membrane apparatus at 15 atm. **(Israelson and Hanson, 1962)**. Plants were irrigated with tap water till complete germination; hence forward, plants were irrigated with nutrient solutions **(Hoagland and Arnon, 1950)**. Molar stock solutions of pure salts were prepared separately in distilled water kept for the preparation of nutrient solutions. The nutrient solution was prepared just before application to the pots by dilution with tap water. Four levels of saline water were used which were 1000, 2000, 3000 and 4000 beside the control tap water at 254 ppm. The saline water was prepared by diluting water brought from Karon lake, El Fayoum Governorate, the required levels. This water was analyzed for determining its E.C, anions and cations contents in both seasons (Table 2).

The treated plants with foliar application of SNP 0.1mM/L. and GB 2 mM/L. were sprayed after 30 days from planting every week up to the end of the season while the control plants sprayed with tape water.

The irrigation treatments with saline water were 1 liter/pot every two days to maintain soil water content at the range 60-65% of water holding capacity. The control pots were irrigated with tap water at the same time of saline treatments. All pots were irrigated with tape water (254 ppm) after each four

saline irrigation treatments to prevent the accumulation of salinity in the soil then the plants were left to grow under the different salinization levels.

Table (2). The chemical properties of Karon lake water in the two seasons of 2022/2023and 2023/2024

Season	PH	E.C mohhos	E.C ppm	S.A.R	R.S.C	S.S.P %	Anions Meq/L				Kations Meq/L			
							So_4^{-2}	Cl^-	HCO_3^-	CO_3^-	K^+	Na^+	Mg^{+2}	Ca^+
2022	8.3	48	30720	43.3	-107.1	73.3	70	365	4.1	0.8	3.6	324.3	86	26
2023	8.1	52	33280	43.1	-113	71.9	53.3	407.5	12	-	7.8	340	110	15

Recorded Data

1- Plant growth

A random sample of four plants from each sub plot was taken at 150 days after planting and the following data were recorded:

a. Vegetative growth characteristics

Plant length (cm), number of leaves/plants, leaf area/plant (cm^2), neck diameter (cm), bulb diameter (cm), leaves fresh weight/plant (g) and bulb fresh weight (g), and dry matter (g).

Leaf area (cm^2) determined by cutting out of ten leaf discs from each sample by using a cork borer and then drying the discs in oven at 70 C° tell discs reached to constant weight. The Leaf area was calculated according to the following formula:

$$\text{Leaf area } (cm^2) = \frac{\text{Disk area} \times \text{No. of disks} \times \text{Leaves dry weight}}{\text{Disks dry weight}}$$

b. Chemical characteristics

Leaf dry weight / plant (g), bulb dry matter (%) was determined by drying the bulb slices at 70 C° for 72 hours according to the method of **Dogras *et al.* (1991)**, Leaf chlorophyll reading (SPAD): it was determined using eight leaves after 150 days from planting date, using a digital chlorophyll meter, Minolta SPAD-502, (Minolta Company, Japan) was used. The SPAD readings were used as relative values for chlorophyll content. Free Proline content in leaves at 150 days after planting was determined according to the method of **Bates *et al.* (1973)**

2- Yield components

The harvesting process carried out after 180 days from planting in both seasons and the following data were recorded:

Bulb fresh weight, number of cloves/bulbs, average cloves weight, neck diameter and Bulb diameter.

Bulb quality

Total nitrogen percent was determined by modified micro Kjeldahl method as described by **Plummer (1971)** in dry matter of the bulb, Phosphorus was determined colorimetrically according to the method of **Jackson (1973)** in dry matter of the bulb, **Potassium and sodium**: both potassium and sodium content in mg/g dry weight were determined by flamphotometer as indicated by **Chapman and Pratt (1961)** in dry matter of the bulb and **Protein**: the bulb protein content in mg/g dry weight was determined by using the conversion factor (N X 6.25) as described by **Pregl (1945).**

Statistical analysis

Data were subjected to proper statistical analysis according to Statistix® 9 **(Analytical software 2008).** Analysis of variance (ANOVA) and comparison of means was conducted with least significant differences (LSD) at $p > 0.05$.

3. Results

The data shown in Table 3 indicated that the Balady cultivar recorded the highest significant plant length, leaves number and leaves area/ plant; whereas, the Sids-40 cultivar gave the highest significant values of neck diameter and bulb diameter in both seasons.

The presented data in Table 3, also cleared that the highest values of the vegetative characters resulted from irrigation with saline water at 1000 ppm, while the different saline concentrations above 1000 ppm induced a significant negative effect on these characters.

In the same table the highest significant values of vegetative growth characters recorded with glycine betaine (GB).

The interaction effect between the cultivars and the different salinity levels was true in all the growth characters in both studies seasons. The highest plant height and leaves area / plant recorded with the Balady cultivar irrigated with 1000 ppm with mention that the highest number of leaves showed with the Balady cultivar irrigated with 1000 ppm and control in both seasons. Whereas the highest neck diameter and bulb diameter recorded with the Sids-40 cultivar irrigated with 1000 ppm.

The interaction between the studied cultivars and the foliar spray of the SNP and GB were significantly effective at all the examined seasons. The highest plant height was obtained from Balady cultivar When treated with GB in both seasons while the largest leaves area resulted from the same treatment in the second season only. However, in the first season Balady cultivar sprayed with SNP gave the largest leaves area / plant. Also, the highest leaves number was obtained from the Balady cultivar sprayed with GB followed by the Balady cultivar sprayed with SNP. The obtained data in the same table also showed that the highest significant record of neck diameter and bulb diameter resulted from the Sids-40 cultivar sprayed with GB. This highest values of neck diameter in the first season followed by Sids-40 cultivar sprayed with SNP.

Concerning the interaction between the saline water levels and the foliar application of SNP and GB. The saline level of 1000 ppm treated with GB recorded the highest significant values for all growth characters, except leaves number in the first season which have the highest values in 1000 ppm salinity level treated with SNP. In the first season there were no significant differences in the leaves number between control and saline level of 1000 ppm sprayed with SNP or GB. The saline level of 1000 ppm treated with GB followed by the saline level of 1000 ppm treated with SNP gave the highest plant length in both seasons and neck diameter in the first season only. Furthermore, GB ameliorates the negative effect of saline water above 1000 ppm on plant length, leaves number, leave area and bulb diameter.

Results presented in Table 4 cleared that the triple interaction of two garlic cultivars, different saline levels and foliar application of SNP and GB led to significant on most growth characters in both seasons. The interaction between the Balady cultivar, saline level of 1000 ppm and the foliar application of GB or SNP played a significant role in improving the plant height, leaves number / plant and leaves area. However, there were no significant differences on leaves number in both seasons as a result of the interaction between the Balady cultivar, saline levels of control or 1000 ppm and foliar application of SNP or GB. The triple interaction of the Sids-40 cultivar, saline level of 1000 ppm and the foliar application of SNP or BG gave a significant enhancement in the neck diameter. The triple interaction of the Sids-40 cultivar, saline level of 1000 ppm and the foliar application of SNP or BG and the triple interaction of the Sids-40 cultivar, saline level of control and the foliar application of BG gave a significant improve in the bulb diameter in both seasons. The foliar application of GB gave better results of plant length leaves number, leaf area, nick diameter and bulb diameter for both cultivars in both seasons under 4000 ppm salinity.

Table (3). Effect of cultivars, saline water and foliar application of sodium nitroprusside (SNP) and glycine betaine (GB) and bilateral the interaction between them on morphological characters of garlic at 150 days after planting during 2022/2023 and 2023/2024 seasons

Cultivar	Saline water	Tret.	Plant length (cm)		Number of leaves/plant		Leaf area (cm^2)		Neck diameter (cm)		Bulb diameter (cm)	
			2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Balady			49.85	48.44	8.34	7.06	486.71	471.61	0.93	0.85	3.35	2.92
Sids-40			37.94	35.60	6.97	5.53	434.67	419.19	1.06	0.90	4.63	4.20
LSD			0.95	1.14	0.29	0.31	0.72	1.22	0.05	0.03	0.04	0.04
	Control		50.78	49.59	8.56	7.06	469.35	461.69	1.02	0.91	4.15	3.72
	1000		55.77	54.17	8.83	7.50	490.74	479.89	1.11	0.99	4.48	4.07
	2000		42.06	40.37	7.28	6.06	465.07	442.75	0.90	0.87	3.94	3.52
	3000		36.89	34.44	7.11	5.56	445.21	426.60	0.99	0.82	3.84	3.37
	4000		33.96	31.53	6.50	5.33	428.09	416.08	0.95	0.79	3.84	3.12
LSD			1.49	1.80	0.46	0.44	1.26	1.93	0.06	0.01	0.07	0.06
		0	41.03	39.16	7.20	5.83	459.54	443.22	0.93	0.84	3.87	3.41
		SNP	43.49	41.58	7.78	6.27	457.95	446.86	1.00	0.88	3.99	3.57
		GB	47.15	45.31	7.98	6.80	461.58	446.12	1.04	0.92	4.11	3.70
LSD			1.16	1.39	0.36	0.37	0.88	1.49	0.07	0.01	0.05	0.05
Balady	**Control**		56.79	56.96	9.56	7.78	499.12	492.61	0.99	0.89	3.56	3.12
	1000		64.54	63.67	9.56	8.22	526.62	515.34	1.04	0.93	4.10	3.72
	2000		48.44	46.73	7.83	7.22	485.63	465.77	0.07	0.84	3.20	2.79
	3000		41.22	39.44	7.67	6.11	466.36	450.61	0.99	0.80	3.17	2.65
	4000		38.24	35.39	7.11	6.00	445.82	433.71	1.04	0.78	2.74	2.32
Sids-40	**Control**		44.78	42.22	7.56	6.33	439.58	430.77	0.82	0.92	4.75	4.32
	1000		47.00	44.67	8.11	6.67	454.85	444.43	0.91	1.05	4.86	4.42
	2000		35.68	34.00	6.72	4.89	444.52	419.72	0.98	0.90	4.68	4.25
	3000		32.56	29.44	6.56	5.00	424.06	402.58	1.07	0.84	4.50	4.09
	4000		29.67	27.67	5.89	4.67	410.36	398.45	1.02	0.80	4.34	4.91
LSD			2.11	2.55	0.66	0.67	1.78	2.73	0.10	0.08	0.09	0.08
Balady		**0**	46.20	44.93	7.93	6.87	478.18	473.06	0.88	0.81	3.24	2.75
		SNP	50.23	48.37	8.43	7.07	489.75	476.20	0.93	0.85	3.35	2.92
		GB	53.12	52.02	8.67	7.27	486.20	565.56	0.98	0.89	3.48	3.08
Sids-40		**0**	35.87	33.40	6.47	4.80	440.90	413.38	0.98	0.86	4.51	4.08
		SNP	36.76	34.80	7.13	5.47	426.16	417.51	1.08	0.91	4.63	4.21
		GB	41.18	38.60	7.30	6.33	436.96	426.68	1.11	0.94	4.74	4.32
LSD			1.64	1.97	0.51	0.53	1.38	2.11	0.08	0.02	0.07	0.06
	Control	**0**	48.70	46.45	8.33	6.83	455.14	456.99	0.97	0.85	3.98	3.55
		SNP	51.68	50.32	8.50	7.00	474.28	462.32	1.03	0.92	4.18	3.74
		GB	51.97	52.00	8.83	7.33	478.62	465.76	1.06	0.95	4.30	3.88
	1000	**0**	51.60	50.67	8.50	6.83	484.33	469.94	0.94	0.95	4.31	3.87
		SNP	57.22	55.33	9.17	7.33	489.58	479.80	1.15	0.98	4.47	4.04
		GB	58.50	56.50	8.83	8.33	498.30	489.92	1.22	1.05	4.67	4.30
	2000	**0**	39.33	37.62	6.83	5.50	470.63	447.73	0.86	0.83	3.85	3.52
		SNP	41.90	40.27	7.25	6.17	459.27	445.24	0.91	0.87	3.95	3.54
		GB	44.95	43.22	7.75	6.50	465.33	435.27	0.93	0.90	4.01	3.61
	3000	**0**	35.33	33.50	6.83	5.17	467.24	429.23	0.96	0.80	3.84	3.26
		SNP	34.50	32.33	7.00	5.33	436.08	426.73	0.98	0.82	3.79	3.40
		GB	40.83	37.50	7.50	6.17	432.30	423.82	1.02	0.85	3.87	3.45
	4000	**0**	30.20	27.58	5.50	4.83	420.38	412.22	0.91	0.75	3.39	2.98
		SNP	32.17	29.67	7.00	5.50	430.54	420.20	0.95	0.79	3.55	3.12
		GB	39.50	37.33	7.00	5.67	433.35	415.82	0.99	0.83	3.68	3.25
LSD			2.59	3.12	0.80	0.82	2.19	3.34	0.12	0.03	0.12	0.10

Table (4). Triple the interaction effect among cultivars, saline water and foliar application of sodium nitroprusside (SNP) and glycine betaine (GB) on morphological characters of garlic at 150 days after planting during 2022/2023 and 2023/2024 seasons

Cultivar	Saline water	Treat.	Plant length (cm)		Number of leaves/plant		Leaf area (cm^2)		Neck diameter (cm)		Bulb diameter (cm)	
			2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Balady	control	0	53.73	51.90	9.33	7.33	476.54	479.85	0.94	0.84	3.30	2.86
		SNP	59.03	58.97	9.67	8.00	509.33	498.27	1.00	0.89	3.60	3.15
		GB	57.60	60.00	9.67	8.00	511.48	499.71	1.03	0.93	3.77	3.34
	1000	0	57.20	58.33	9.00	7.67	512.29	510.47	0.98	0.88	3.87	3.44
		SNP	67.43	66.00	9.67	8.33	536.63	516.02	1.02	0.92	4.09	3.67
		GB	69.00	66.67	10.00	8.67	530.95	519.52	1.12	1.00	3.34	4.04
	2000	0	44.33	42.23	7.33	6.67	470.60	479.97	0.76	0.81	3.12	2.70
		SNP	48.67	46.53	7.83	7.67	491.54	471.01	0.84	0.84	3.21	2.81
		GB	52.33	50.43	8.33	7.33	494.75	446.34	0.86	0.87	3.27	2.86
	3000	0	40.67	39.67	7.67	6.33	495.26	460.90	0.88	0.77	3.32	2.58
		SNP	38.33	36.00	7.67	5.67	460.23	451.79	0.91	0.80	3.07	2.67
		GB	44.67	42.67	7.67	6.33	443.58	439.15	0.93	0.83	3.11	2.69
	4000	0	35.07	31.50	6.33	6.33	436.23	434.13	0.84	0.74	2.57	2.19
		SNP	37.67	34.33	7.33	5.67	451.01	443.92	0.88	0.78	2.77	2.32
		GB	42.00	40.33	7.67	6.00	450.24	423.07	0.93	0.82	2.89	2.45
Sids-40	control	0	43.67	41.00	7.33	6.33	433.74	434.14	1.00	0.87	4.66	4.23
		SNP	44.33	41.67	7.33	6.00	439.23	426.37	1.05	0.95	4.77	4.33
		GB	46.33	44.00	8.00	6.67	445.76	431.81	1.08	0.97	4.83	4.41
	1000	0	46.00	43.00	8.00	6.00	456.37	429.40	0.90	1.01	4.74	4.30
		SNP	47.00	44.67	8.67	6.33	442.54	443.58	1.28	1.05	4.84	4.41
		GB	48.00	46.33	7.67	8.00	465.65	460.32	1.32	1.10	4.99	4.55
	2000	0	34.33	32.00	8.00	4.33	470.66	415.48	0.95	0.85	4.58	4.13
		SNP	35.13	34.00	6.67	5.67	427.00	419.47	0.97	0.90	4.70	4.26
		GB	37.57	36.00	7.67	6.67	435.90	424.21	1.01	0.93	4.75	4.37
	3000	0	30.00	27.33	6.00	4.00	439.22	397.57	1.04	0.82	4.36	3.94
		SNP	30.67	28.67	6.33	5.00	411.94	401.68	1.06	0.84	4.51	4.13
		GB	37.00	32.33	7.33	6.00	421.03	408.49	1.10	0.86	4.64	4.21
	4000	0	25.33	23.67	4.67	3.33	404.54	390.31	0.99	0.77	4.20	3.78
		SNP	26.67	25.00	6.67	5.33	410.07	396.47	1.02	0.81	4.33	3.91
		GB	37.00	34.33	6.33	5.33	416.46	408.57	1.05	0.83	4.48	4.05
LSD			3.66	4.41	1.01	0.98	3.09	4.72	0.18	0.05	0.16	0.14

The results in Table 5 reflect a significant increase in leaves fresh weight, leaves dry weight, bulb dry weight, chlorophyll content and proline content with the Balady cultivar but this increase didn't reach to significant level in the bulb fresh weight in both seasons. The same data showed that the saline water level of 1000 ppm positively increase all the characters except the proline content which increased significantly with saline level of 4000 ppm in the both seasons. Generally, all the characters recorded that highest values with the BG foliar application.

Table (5). Effect of cultivars, saline water and foliar application of sodium nitroprusside (SNP) and glycine betaine (GB) and bilateral the interaction between them on fresh and dry weight, chlorophyll and proline content of garlic plants at 150 days after planting during 2022/2023 and 2023/2024 seasons

Cultivar	saline water	Treat.	leaves fresh weight (g)		leaves dry weight (g)		Bulb fresh weight (g)		Bulb dry matter %		Chlorophyll content (spad)		Proline content (µ mole/g)	
			2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Balady			70.02	68.72	15.54	14.34	38.85	35.80	22.43	21.91	73.99	72.43	39.52	38.39
Sids-40			63.74	62.44	12.47	10.73	38.60	36.02	20.93	19.94	73.39	72.20	36.20	34.66
LSD			0.64	0.65	0.28	0.32	N.S	N.S	0.14	0.21	0.18	0.20	0.46	0.46
	control		66.81	65.71	14.45	12.64	41.39	38.84	22.97	22.45	76.14	74.78	16.29	14.69
	1000		68.23	67.13	15.12	13.45	43.49	41.08	24.45	23.78	79.89	78.16	27.73	26.58
	2000		67.46	65.26	14.12	12.60	39.75	37.48	21.22	20.41	72.64	71.06	34.63	32.91
	3000		66.63	65.61	13.92	12.72	35.77	32.20	20.38	19.39	70.71	69.72	50.04	48.43
	4000		65.29	64.19	12.42	11.27	33.22	29.95	19.40	18.59	69.06	67.84	60.59	60.01
LSD			1.01	1.02	0.34	0.39	0.46	0.64	0.22	0.34	0.29	0.31	0.73	0.73
		0	64.99	63.67	13.13	12.09	37.41	34.42	20.36	19.65	70.88	69.33	32.40	31.03
		SNP	67.18	65.86	14.09	12.31	38.70	35.94	21.65	21.04	73.71	72.31	37.58	36.44
		GB	68.48	67.21	14.79	13.22	40.06	37.38	23.04	22.08	76.47	75.30	43.60	42.11
LSD			0.79	0.79	0.43	0.50	0.36	0.49	0.17	0.26	0.22	0.24	0.57	0.57
Balady	**control**		71.69	70.59	15.60	14.03	40.10	37.48	24.04	23.97	76.09	74.49	16.53	14.83
	1000		72.06	70.96	17.90	16.32	44.31	41.95	25.20	24.87	80.83	78.73	27.97	26.85
	2000		70.40	68.10	15.35	14.61	39.22	36.69	21.80	21.19	72.81	70.83	35.48	33.57
	3000		68.04	67.10	14.93	13.93	35.99	31.93	20.91	20.26	70.84	69.96	51.62	51.07
	4000		67.93	66.83	13.89	12.83	34.60	30.95	20.21	19.24	69.35	68.11	66.01	65.64
Sids-40	**control**		61.92	60.82	13.29	11.25	42.68	40.21	21.90	20.92	76.18	75.06	16.06	14.54
	1000		64.39	63.29	12.33	10.59	42.66	40.21	23.70	22.69	78.95	77.59	27.49	26.32
	2000		64.52	62.42	12.88	10.58	40.27	38.27	20.63	19.62	72.48	71.29	33.77	32.25
	3000		65.22	64.12	12.91	11.52	35.55	32.47	19.84	18.52	70.59	69.48	48.47	45.78
	4000		62.64	61.54	10.95	9.72	31.84	28.96	18.59	17.94	68.78	67.56	55.18	54.39
LSD			1.43	1.44	0.62	0.71	0.65	0.90	0.31	0.48	0.41	0.44	1.03	1.03
Balady		**0**	68.48	67.14	14.67	13.83	37.49	34.46	21.14	20.71	71.33	69.61	33.58	32.40
		SNP	70.10	68.76	15.60	14.05	38.62	35.61	22.37	22.10	73.91	72.33	39.47	38.27
		GB	71.48	70.24	16.34	15.16	40.42	37.32	23.78	22.92	76.72	75.34	45.51	44.51
Sids-40		**0**	61.50	60.20	11.60	10.34	37.33	34.37	19.57	18.59	70.44	69.05	31.21	29.65
		SNP	64.25	62.95	12.58	10.58	38.78	36.26	20.92	19.99	73.52	72.29	35.69	34.61
		GB	65.48	64.18	13.24	11.27	39.70	37.44	22.30	21.25	76.22	75.25	41.69	39.70
LSD			1.11	1.12	0.48	0.55	0.50	0.70	0.24	0.37	0.32	0.34	0.80	0.80
	control	**0**	65.93	64.83	13.50	11.98	39.96	37.36	22.08	21.77	73.53	72.03	14.36	12.73
		SNP	66.43	65.33	14.53	12.47	41.74	38.94	22.85	22.16	76.09	74.56	16.41	14.87
		GB	68.06	66.96	15.31	13.48	42.48	40.24	23.98	23.25	78.79	77.74	18.11	16.46
	1000	**0**	66.13	65.03	14.13	13.35	42.14	39.45	23.17	22.09	77.35	75.51	19.93	18.49
		SNP	68.09	66.99	15.21	13.03	43.00	40.94	24.41	24.31	80.35	78.77	27.61	26.10
		GB	70.46	69.36	16.01	13.99	45.33	42.84	25.77	24.95	81.97	80.21	35.65	35.16
	2000	**0**	65.65	63.45	13.40	12.14	38.26	35.71	19.79	19.30	70.95	68.99	27.59	26.11
		SNP	68.08	65.88	14.07	12.57	39.57	37.34	21.21	20.38	72.62	70.80	34.62	32.52
		GB	68.65	66.45	14.88	13.08	41.42	39.40	22.65	21.55	74.37	73.40	41.67	40.10
	3000	**0**	63.15	62.05	12.87	12.16	35.34	31.39	19.12	18.15	67.83	66.68	45.17	43.98
		SNP	67.89	66.79	14.00	12.39	35.79	32.35	20.32	19.71	70.49	69.72	50.35	49.07
		GB	68.86	68.00	14.91	13.63	36.18	32.85	21.69	20.30	73.83	72.76	54.61	52.23
	4000	**0**	64.10	63.00	11.77	10.79	31.35	28.19	17.64	16.93	64.77	63.44	54.93	53.83
		SNP	65.40	64.30	12.64	11.11	33.41	30.11	19.44	18.67	69.02	67.70	58.90	59.63
		GB	66.36	65.26	12.85	11.92	34.89	31.57	21.12	21.17	73.40	72.37	67.95	66.58
LSD			1.76	1.77	0.75	0.87	0.80	1.10	0.38	0.58	0.50	0.54	1.27	1.26

The bilateral interaction between the two garlic cultivars (Balady and Sids-40 *cvs*) and the different salinity levels showed the highest significant leaves (fresh and dry weight), bulb (fresh and dry weight) and chlorophyll content recorded by Balady cultivar irrigated with 1000 ppm. However, there was no significant deference in leaves fresh weight between Balady irrigated with control or saline level of 1000 ppm. While, the highest proline content recorded with the Balady cultivar irrigated with saline level of 4000 ppm.

The bilateral interaction between the Balady cultivar and the foliar application GB gave the highest significant values of all growth characters except with bulb fresh weight in the second season. No difference between the results of the interaction between Balady cultivar and foliar application of GB and the interaction between Sids-40 and the foliar application of GB.

Data outlined in Table 5 cleared that the heaviest significant leaves fresh weight, bulb fresh weight, bulb dry weight and the highest significant chlorophyll content in both seasons were obtained by the interaction between saline level of 1000 ppm and the foliar application of GB. There was no significant difference between saline level of 1000 ppm or the control with the foliar application of GB in both seasons. However, at the highest level of salinity (4000 ppm) GB gave higher values of leave fresh weight, leave dry weight, bulb fresh weight, bulb dry weight, chlorophyll and proline content than 4000 ppm without GB. Furthermore, the highest values of proline content mentioned with the saline level of 4000 ppm and foliar application of GB.

The interaction between Balady cultivar, saline water level of 1000 ppm and SNP or GB and the interaction between Balady cultivar, saline water level of control and GB did not enhance any significant differences on the leaves fresh weight in the both seasons (Table 6). In general, the Balady cultivar irrigated with saline level of 1000 ppm and treated with foliar application of GB recorded the highest significant level of leaves dry weight, bulb fresh weight and bulb dry matter. The highest leaves dry weight values had recorded with the interaction of Balady cultivar, saline level of 1000 ppm and the foliar application treatments GB in both seasons. For the bulb dry matter results showed that that the obvious triple interaction values obtained by Balady cultivar, saline level of 1000 ppm and the foliar application of SNP in the second season only. Data in the same table referred to that the highest chlorophyll content found with the interaction between Balady or Sids-40 irrigated with saline water level of 1000 ppm and the foliar application of GB in both seasons. Moreover, GB alleviate the dramatic effects of higher levels of salinity above 1000 ppm on bulb fresh weight, bulb dry weight, chlorophyll content and proline content for both cultivars. However, the highest significant values of proline content were found with the interaction between Balady cultivar, saline water level of 4000 ppm and the foliar application of GB in the two seasons.

Concerning yield and its components, data presented in Table 7 indicated that the two garlic cultivars have significant variation due to the application of the saline water levels and the foliar application of SNP and GB. Balady cultivar recorded the highest bulb weight and cloves number / bulb compared to Sids-40, which gave the highest significant values of cloves average weight, neck diameter and bulb diameter in both seasons. Concerning the different saline water levels data cleared that the saline water level of 1000 ppm gave the highest significant values of all the yield characters while the highest cloves average weight was found with the control (tap water) in the first season but in the second season there was no difference between the control or saline levels of 1000 ppm. The results indicated that there was significant variation between control, and the foliar application of SNP and GB. GB treatment gave the highest Bulb weight, cloves / plant, neck diameter and bulb diameter in both seasons, while the heaviest cloves average weight was true with the control followed by SNP in the first season only but in the second season the control gave the highest significant record.

The interaction between the two garlic cultivars and the different saline water levels was significant. The Balady cultivar which watered with the saline level of 1000 ppm gave the highest bulb weight and cloves number / bulb in both seasons, whereas the highest values of neck diameter and bulb diameter shown with the Sids-40 cultivar irrigated with 1000 ppm. Results also showed that the highest significant values of the cloves average weight were given by Sids-40 cultivar which irrigated with saline water levels of control or 1000 ppm in the both seasons (Table 7).

Table (6). Triple the interaction effect among cultivars, saline water and foliar application of sodium nitroprusside (SNP) and glycine betaine (GB) on fresh and dry weight, chlorophyll and proline content of garlic plants at 150 days after planting during 2022/2023 and 2023/2024 seasons

Cultivar	saline water	Treat.	leaves fresh weight (g)		leaves dry weight (g)		Bulb fresh weight (g)		Bulb dry matter %		Chlorophyll content (spad)		Proline content (µ mole/g)	
			2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Balady	control	0	70.11	69.01	14.60	12.99	39.25	37.02	23.42	24.06	73.29	71.71	14.46	12.54
		SNP	70.71	69.61	15.32	13.66	40.17	37.02	23.91	23.60	75.97	74.03	16.95	15.48
		GB	74.25	73.15	16.89	15.45	40.89	38.40	24.80	24.26	79.03	77.74	18.19	16.46
	1000	0	70.34	69.24	16.53	16.05	42.71	39.64	24.13	23.37	78.94	77.12	20.11	18.80
		SNP	72.16	71.06	17.83	15.91	43.19	41.16	25.22	25.38	81.26	79.24	27.67	26.36
		GB	73.67	72.57	19.34	17.00	47.04	45.04	26.24	25.87	82.30	79.83	36.11	35.39
	2000	0	69.68	67.38	14.85	13.95	37.61	35.06	20.36	20.18	71.27	68.49	27.90	26.49
		SNP	70.25	67.95	15.61	14.35	38.99	36.44	21.99	21.37	72.68	70.50	34.80	32.15
		GB	71.26	68.96	15.61	15.54	41.07	38.58	23.04	22.04	74.48	73.52	43.74	42.07
	3000	0	65.31	64.21	14.18	13.58	35.66	31.60	19.77	19.00	67.94	66.96	45.95	45.41
		SNP	69.21	68.11	15.16	13.70	35.93	31.91	20.59	20.59	70.44	69.98	52.00	51.63
		GB	69.60	68.99	15.47	14.49	36.38	32.28	22.36	21.19	74.14	72.94	56.91	56.18
	4000	0	66.98	65.88	13.18	12.56	32.23	29.00	18.04	16.92	65.23	63.77	59.49	58.75
		SNP	68.19	67.09	14.08	12.61	34.83	31.53	20.15	19.58	69.18	67.89	65.92	65.71
		GB	67.63	67.53	14.40	13.32	36.74	32.32	22.45	21.23	73.63	72.66	72.60	72.45
Sids-40	control	0	61.76	60.66	12.40	10.97	40.67	37.69	20.75	19.47	73.77	73.36	14.26	12.91
		SNP	62.14	61.04	13.74	11.29	43.31	40.85	21.79	20.71	76.21	75.09	15.87	14.26
		GB	61.87	60.77	13.73	11.51	44.07	42.09	23.16	22.60	78.54	77.73	18.04	16.46
	1000	0	61.91	60.81	11.73	10.65	41.57	39.27	22.21	20.81	75.76	73.89	19.76	18.19
		SNP	64.02	62.92	12.59	10.14	42.80	40.72	23.59	23.24	79.45	78.30	27.28	25.83
		GB	67.26	66.16	12.67	10.98	43.62	40.64	25.30	24.03	81.64	80.59	35.18	34.94
	2000	0	61.62	59.52	11.95	11.34	38.90	36.36	19.21	18.42	70.62	69.50	27.28	25.72
		SNP	65.91	63.81	12.54	10.80	40.14	38.24	20.43	19.39	72.56	71.09	34.44	32.89
		GB	66.04	63.94	14.15	10.62	41.76	40.22	22.26	21.06	74.25	73.29	39.60	38.13
	3000	0	60.98	59.88	11.55	10.73	35.02	31.17	18.46	17.30	67.72	66.41	44.39	42.54
		SNP	66.57	65.47	12.83	11.07	35.65	32.79	20.06	18.84	70.53	69.45	48.70	46.51
		GB	68.11	67.01	14.36	12.76	35.99	33.43	21.01	19.41	73.51	72.57	52.32	48.28
	4000	0	61.22	60.12	10.35	9.02	30.47	27.38	17.24	16.94	64.31	63.11	50.37	48.91
		SNP	62.61	61.51	11.20	9.61	31.99	28.69	18.74	17.75	68.85	67.51	51.87	53.55
		GB	64.10	63.00	11.30	10.51	33.05	30.82	19.78	19.12	73.17	72.07	63.30	60.70
LSD			2.48	2.50	1.07	1.23	1.13	1.56	0.54	0.83	0.71	0.76	1.79	1.79

Table (7). Effect of cultivars, saline water and foliar application of sodium nitroprusside (SNP) and glycine betaine (GB) and bilateral the interaction between them on bulb characters of garlic at harvest time during 2022/2023 and 2023/2024 seasons

Cultivar	saline water	Treat.	Bulb weight (g)		Cloves number/bulb		Cloves average weight (g)		Neck diameter (cm)		Bulb diameter (cm)	
			2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Balady			66.68	64.07	32.82	31.40	2.06	2.07	0.79	0.55	4.12	3.27
Sids-40			56.92	54.09	15.52	14.22	3.67	3.75	0.82	0.60	5.22	4.31
LSD			0.53	0.55	0.36	0.41	0.06	0.06	0.01	0.01	0.04	0.04
	control		67.14	64.68	25.79	24.53	3.05	3.09	0.85	0.62	4.78	3.87
	1000		69.06	67.32	27.55	26.29	2.94	3.06	0.92	0.70	5.08	4.35
	2000		63.41	61.31	25.00	23.43	2.84	2.91	0.81	0.58	4.60	3.69
	3000		56.32	52.43	22.62	21.41	2.70	2.67	0.72	0.49	4.50	3.57
	4000		53.07	49.66	19.84	18.40	2.80	2.82	0.71	0.48	4.40	3.47
LSD			0.84	0.87	0.56	0.65	0.10	0.09	0.02	0.02	0.07	0.06
		0	57.68	55.42	22.10	20.93	2.93	2.99	0.78	0.55	4.50	3.65
		SNP	61.98	58.84	24.21	22.88	2.87	2.91	0.80	0.57	4.67	3.78
		GB	65.74	62.98	26.17	24.62	2.80	2.83	0.83	0.60	4.84	3.93
LSD			0.65	0.67	0.44	0.50	0.08	0.07	0.01	0.02	0.05	0.05
Balady	**control**		70.52	68.59	36.11	34.56	1.95	1.98	0.85	0.61	4.22	3.30
	1000		72.12	70.22	38.55	37.27	1.87	1.89	0.91	0.67	4.73	4.07
	2000		68.11	65.50	34.00	32.79	2.01	2.00	0.81	0.58	4.01	3.10
	3000		63.59	60.15	30.29	29.04	2.11	2.08	0.69	0.46	3.78	2.98
	4000		59.07	55.90	25.13	23.34	2.37	2.41	0.69	0.45	3.79	2.89
Sids-40	**control**		63.76	60.77	15.48	14.49	4.14	4.20	0.86	0.63	5.34	4.43
	1000		66.01	64.42	16.55	15.30	4.01	4.24	0.94	0.73	5.44	4.62
	2000		58.70	57.13	16.00	14.08	3.67	3.81	0.80	0.59	5.18	4.29
	3000		49.04	44.71	14.96	13.79	3.28	3.25	0.75	0.52	5.12	4.15
	4000		47.06	43.42	14.55	13.45	3.23	3.23	0.73	0.51	5.02	4.06
LSD			1.19	1.23	0.80	0.91	0.14	0.13	0.02	0.03	0.08	0.09
Balady		**0**	62.49	60.83	30.08	28.94	2.12	2.14	0.77	0.54	3.91	3.10
		SNP	66.78	63.75	32.91	31.40	2.06	2.07	0.78	0.54	4.13	3.25
		GB	70.78	67.63	35.46	33.85	2.01	2.02	0.81	0.58	4.33	3.45
Sids-40		**0**	52.87	50.01	14.13	12.92	3.74	3.85	0.78	0.56	5.09	4.20
		SNP	57.19	53.93	15.51	14.36	3.68	3.75	0.82	0.60	5.21	4.31
		GB	60.69	58.33	16.88	15.39	3.59	3.65	0.85	0.63	5.35	4.41
LSD			0.92	0.95	0.62	0.71	0.11	0.10	0.02	0.02	0.08	0.07
	control	**0**	63.45	61.39	24.22	23.18	3.12	3.14	0.83	0.60	4.61	3.71
		SNP	67.56	64.29	25.66	24.18	3.07	3.14	0.85	0.61	4.78	3.86
		GB	70.41	68.36	27.50	26.23	2.94	3.01	0.88	0.65	4.95	4.02
	1000	**0**	64.94	64.65	25.44	24.29	3.04	3.22	0.88	0.65	4.84	4.18
		SNP	68.88	66.80	27.50	26.01	2.97	3.09	0.93	0.71	5.05	4.32
		GB	73.38	70.52	29.72	28.56	2.81	2.88	0.96	0.75	5.37	4.54
	2000	**0**	58.38	56.73	22.89	21.62	2.84	2.99	0.79	0.56	4.47	3.61
		SNP	63.74	61.48	25.27	24.29	2.82	2.90	0.80	0.58	4.62	3.70
		GB	68.10	65.73	26.83	24.40	2.86	2.84	0.83	0.60	4.70	3.78
	3000	**0**	53.06	49.82	20.33	19.18	2.79	2.78	0.69	0.48	4.36	3.43
		SNP	56.01	51.50	22.83	21.72	2.66	2.59	0.70	0.47	4.50	3.55
		GB	59.89	55.98	24.72	23.34	2.65	2.62	0.77	0.52	4.63	3.72
	4000	**0**	48.58	44.51	17.65	16.40	2.85	2.83	0.68	0.47	4.24	3.33
		SNP	53.72	50.16	19.77	18.23	2.82	2.82	0.73	0.49	4.41	3.49
		GB	56.91	54.32	22.11	20.57	2.73	2.80	0.72	0.48	4.56	3.60
LSD			1.46	1.51	0.98	1.12	0.17	0.16	0.03	0.03	0.12	0.10

The interaction between the two garlic cultivars and the foliar application of SNP and GB was significant with all the yield characters in both seasons. The highest significant values of bulb weight and cloves number / plant recorded with Balady cultivar the treatment of GB whereas, the highest values of neck diameter and bulb diameter found with the Sids-40 cultivar treated with the foliar application of GB in the both seasons. However, the highest cloves average weight values scored with Sids-40 cultivar with foliar application of control or SNP in both seasons. Also, the highest significant result of all the yield characters in Table 7 recorded with the saline water 1000 ppm with the foliar application of GB in both seasons, except the cloves average weight which recorded the highest results with the saline water levels of control or 1000 ppm with foliar application of control or SNP in the both seasons. Furthermore, GB foliar application significantly ameliorate the effect of high level of salinity (above 1000 ppm) on yield characteristics (Table 7).

The highest significant results of bulb weight found with the Balady cultivar watered with saline water of 1000 ppm and sprayed by GB in the first season only while in the second season the highest values recorded with Balady cultivar irrigated with control or 1000 ppm of the saline water which sprayed with GB in the second season (Table 8). Furthermore, the highest significant cloves number / plant indicated with Balady cultivar watered with 1000 ppm saline water level which sprayed with GB in the both seasons. Although the highest cloves average weight values found with Sids-40 cultivar irrigated with control or 1000 ppm and sprayed with control or SNP in both seasons. The highest significant values of neck diameter showed with Sids-40 irrigated with 1000 ppm and sprayed with GB in the both seasons. The resulted indicate that the highest bulb diameter found with Sids-40 cultivar irrigated with 1000 ppm level and sprayed with GB in the both studied seasons.

The obtained results indicate that there was a proportional significant increase in nitrogen, potassium, K^+/Na^+ ratio and protein percent with the Balady cultivar (Table 9). However, Sodium content was significantly higher in Sids-40 cultivar The saline level of 1000 ppm gave the highest nitrogen, potassium, and protein percentage in the both seasons, whereas the saline water level of 256 ppm (tap water) recorded the highest values of potassium and K/Na ratio. The highest sodium content gained by saline water level of 4000 ppm. In general, all the chemical characters of bulbs at the harvest time cleared that the highest values found with the foliar application of GB except the sodium content which recorded in plants which did not receive any foliar application (control).

The bilateral interaction between Sids-40 cultivar irrigated with saline water of 1000 ppm gave the highest content of nitrogen, phosphorus and protein percentage in both seasons (Table 9). The highest content of potassium scored with the both garlic cultivars which watered with tap water 256 ppm, while the two garlic cultivars gave the highest values of sodium content with the saline water level of 4000 ppm in both seasons.

The results of interaction between the garlic cultivars and foliar application of SNP or GB indicated that Balady cultivar treated with GB gave the highest content of nitrogen, phosphorous, nitrogen, K/Na ratio and protein percentage in both seasons with concern that there no significant differences in nitrogen content in Balady cultivar, which treated with SNP or GB in the second season only. The highest significant content of sodium found with Sids-40 sprayed with control treatment the both seasons. The interaction between the different saline water levels and the foliar application of SNP or GB shown in Table 9 illustrated that the highest phosphorous content found with saline water level of 1000 ppm with the foliar application of GB, while the best records of phosphorus content was given with the saline water level of 1000 ppm sprayed with GB. The potassium highest content and the K^+/Na^+ ratio found with the irrigation with tap water and spayed GB with mention that there was no significant between the tap water sprayed with SNP or GB in the first season. Otherwise, the highest significant sodium content was observed with the saline water level of 4000 ppm in the control treatment of foliar application.

Table (8). Triple the interaction effect among cultivars, saline water and foliar application of sodium nitroprusside (SNP) and glycine betaine (GB) on bulb characters of garlic at harvest time during 2022/2023 and 2023/2024 seasons.

Cultivar	saline water	Treat.	Bulb weight (g)		Cloves number/bulb		Cloves average weight (g)		Neck diameter (cm.)		Bulb diameter (cm.)	
			2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Balady	control	0	65.99	64.83	34.33	32.90	1.92	1.97	0.86	0.61	4.02	3.09
		SNP	70.64	68.20	35.88	34.23	1.97	1.99	0.84	0.60	4.22	3.30
		GB	74.92	72.73	38.11	36.56	1.97	1.99	0.85	0.61	4.42	3.50
	1000	0	67.37	67.15	36.00	34.79	1.87	1.93	0.87	0.62	4.38	3.83
		SNP	71.26	68.97	38.77	36.90	1.84	1.78	0.89	0.67	4.71	4.02
		GB	77.72	74.54	40.88	40.12	1.90	1.86	0.97	0.74	5.10	4.37
	2000	0	63.49	62.05	31.11	30.12	2.04	2.06	0.83	0.60	3.86	3.03
		SNP	69.21	65.66	34.44	33.68	2.01	1.95	0.78	0.54	4.04	3.08
		GB	71.63	68.78	36.44	34.56	1.97	2.00	0.82	0.59	4.13	3.20
	3000	0	60.31	58.39	26.77	25.79	2.26	2.27	0.66	0.46	3.71	2.84
		SNP	62.83	58.32	30.55	29.54	2.06	1.97	0.66	0.42	3.87	2.95
		GB	67.62	63.74	33.5	31.79	2.02	2.01	0.74	0.50	4.04	3.15
	4000	0	55.28	51.72	22.18	21.12	2.49	2.45	0.64	0.40	3.59	2.74
		SNP	59.94	57.62	24.88	22.67	2.41	2.54	0.73	0.48	3.81	2.90
		GB	62.01	58.37	28.33	26.23	2.19	2.23	0.69	0.45	3.97	3.03
Sids-40	control	0	60.91	57.95	14.11	13.45	4.32	4.31	0.80	0.58	5.20	4.34
		SNP	64.48	60.37	15.44	14.12	4.18	4.28	0.85	0.62	5.34	4.42
		GB	65.90	63.98	16.88	15.90	3.92	4.03	0.92	0.70	5.48	4.54
	1000	0	62.50	62.14	14.88	13.79	4.21	4.51	0.89	0.67	5.30	4.53
		SNP	66.51	64.62	16.22	15.12	4.10	4.30	0.79	0.74	5.39	4.62
		GB	69.03	66.50	18.55	17.01	3.72	3.91	0.95	0.76	5.63	4.71
	2000	0	53.27	51.42	14.66	13.12	3.64	3.92	0.75	0.53	5.08	4.20
		SNP	58.26	57.29	16.11	14.90	3.62	3.85	0.82	0.63	5.19	4.31
		GB	64.57	62.68	17.22	14.23	3.75	3.69	0.84	0.61	5.27	4.35
	3000	0	45.80	41.25	13.88	12.56	3.31	3.29	0.73	0.50	5.00	4.02
		SNP	49.18	44.67	15.11	13.90	3.26	3.21	0.74	0.52	5.12	4.14
		GB	52.15	48.22	15.88	14.90	3.28	3.24	0.79	0.55	5.23	4.30
	4000	0	41.87	37.29	13.11	11.67	3.21	3.20	0.72	0.53	4.89	3.91
		SNP	47.51	42.70	14.66	13.79	3.24	3.10	0.73	0.49	5.01	4.08
		GB	51.80	50.26	15.88	14.90	3.26	3.38	0.75	0.51	5.15	4.17
LSD			2.07	2.13	1.38	1.58	0.24	0.22	0.05	0.05	0.17	0.15

Table (9). Triple the interaction effect among cultivars, saline water and foliar application of sodium nitroprusside (SNP) and glycine betaine (GB) on bulb chemical contents of garlic at harvest time during 2022/2023 and 2023/2024 seasons

Cultivar	saline water	Treat.	N %		P (mg/g dry weight)		K (mg/g dry weight)		Na (mg/g dry weight)		K^+/Na^+ ratio		Protein %	
			2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Balady			2.63	2.14	2.421	2.093	14.88	14.22	14.20	13.95	1.08	1.05	16.46	13.36
Sids-40			2.48	1.97	2.416	2.088	14.65	14.03	14.97	14.56	1.00	0.98	15.53	12.32
LSD			0.01	0.01	NS	NS	0.06	0.07	0.16	0.17	0.02	0.01	0.07	0.09
	control		2.80	2.30	2.66	2.312	17.42	16.79	12.44	12.57	1.41	1.34	17.50	14.40
	1000		2.84	2.35	2.697	2.377	16.04	15.47	13.48	12.78	1.20	1.22	17.74	14.68
	2000		2.58	2.08	2.578	2.233	14.87	14.36	14.97	14.42	1.00	1.00	16.10	13.01
	3000		2.37	1.85	2.274	1.948	13.27	12.43	15.48	15.35	0.86	0.81	14.82	11.58
	4000		2.21	1.68	1.887	1.583	12.22	11.60	16.57	16.17	0.74	0.72	13.81	10.49
LSD			0.02	0.02	0.02	0.02	0.09	0.11	0.25	0.26	0.02	0.02	0.11	0.14
		0	2.51	2.00	2.322	1.987	14.54	13.92	15.48	15.07	0.96	0.95	15.70	12.51
		SNP	2.57	2.06	2.409	2.091	14.71	14.15	14.52	14.19	1.04	1.02	16.05	12.89
		GB	2.60	2.10	2.523	2.193	15.04	14.31	13.76	13.51	1.11	1.08	16.24	13.11
LSD			0.01	0.02	0.01	0.02	0.07	0.09	0.19	0.20	0.02	0.11	0.09	0.11
Balady	**control**		2.79	2.30	2.636	2.307	17.38	16.78	12.13	12.00	1.44	1.40	17.46	14.36
	1000		2.82	2.32	2.669	2.332	16.28	15.82	12.82	12.23	1.27	1.30	17.63	14.51
	2000		2.66	2.16	2.568	2.207	15.04	14.57	14.39	13.94	1.05	1.05	16.60	13.51
	3000		2.51	2.00	2.309	1.980	13.36	12.28	15.23	15.42	0.88	0.80	15.66	12.48
	4000		2.39	1.91	1.923	1.641	12.32	11.67	16.41	16.16	0.76	0.73	14.94	11.91
Sids-40	**control**		2.80	2.31	2.676	2.317	17.46	16.80	12.74	13.14	1.37	1.28	17.53	14.45
	1000		2.85	2.38	2.724	2.421	15.80	15.12	14.14	13.33	1.12	1.14	17.84	14.86
	2000		2.50	2.00	2.588	2.260	14.69	14.16	15.54	14.89	0.95	0.96	15.60	12.52
	3000		2.24	1.71	2.239	1.916	13.17	12.58	15.72	15.28	0.84	0.82	13.98	10.69
	4000		2.03	1.45	1.851	1.525	12.11	11.53	16.72	16.17	0.73	0.72	12.68	9.06
LSD			0.02	0.03	0.03	0.03	0.13	0.16	0.35	0.37	0.03	0.03	0.16	0.19
Balady		**0**	2.58	2.08	2.309	1.980	14.64	14.03	15.13	14.78	0.99	0.99	16.16	13.03
		SNP	2.65	2.15	2.416	2.096	14.82	14.31	14.06	13.83	1.09	1.07	16.54	13.43
		GB	2.67	2.18	2.537	2.205	15.16	14.34	13.41	13.24	1.15	1.11	16.69	13.60
Sids-40		**0**	2.44	1.92	2.335	1.995	14.44	13.82	15.82	15.36	0.94	0.92	15.24	11.98
		SNP	2.49	1.98	2.403	2.087	14.60	14.00	14.99	14.56	1.00	0.98	15.56	12.35
		GB	2.53	2.02	2.509	2.181	14.91	14.28	14.11	13.78	1.07	1.05	15.79	12.62
LSD			0.02	0.02	0.02	0.03	0.10	0.13	0.27	0.29	0.03	0.02	0.12	0.15
	control	**0**	2.73	2.23	2.570	2.231	17.28	16.61	13.08	13.01	1.32	1.28	17.04	13.92
		SNP	2.80	2.32	2.672	2.332	17.39	16.75	11.95	12.48	1.46	1.35	17.51	14.49
		GB	2.87	2.37	2.725	2.372	17.59	17.00	12.28	12.22	1.44	1.40	17.94	14.80
	1000	**0**	2.80	2.30	2.610	2.286	15.76	15.22	14.25	13.31	1.11	1.15	17.47	14.39
		SNP	2.85	2.36	2.700	2.392	15.96	15.42	13.38	12.51	1.20	1.24	17.84	14.74
		GB	2.87	2.39	2.780	2.452	16.41	15.77	12.81	12.52	1.29	1.26	17.91	14.93
	2000	**0**	2.53	2.06	2.503	2.154	14.65	14.16	15.91	15.24	0.92	0.93	15.82	12.84
		SNP	2.57	2.07	2.556	2.207	14.80	14.36	15.09	14.74	0.99	0.98	16.05	12.93
		GB	2.63	2.12	2.673	2.339	15.16	14.56	13.91	13.27	1.09	1.10	16.43	13.27
	3000	**0**	2.34	1.82	2.173	1.827	12.96	12.12	16.20	16.32	0.80	0.75	14.63	11.38
		SNP	2.40	1.87	2.265	1.942	13.22	12.66	15.58	14.98	0.85	0.85	14.99	11.70
		GB	2.38	1.87	2.383	2.074	13.63	12.50	14.65	14.75	0.93	0.85	14.86	11.68
	4000	**0**	2.17	1.60	1.755	1.439	12.07	11.50	17.94	17.48	0.67	0.66	13.53	10.00
		SNP	2.22	1.69	1.853	1.582	12.19	11.57	16.61	16.25	0.74	0.71	13.85	10.59
		GB	2.25	1.74	2.053	1.727	12.39	11.71	15.15	14.77	0.82	0.79	14.07	10.88
LSD			0.02	0.04	0.03	0.04	0.16	0.20	0.43	0.46	0.04	0.04	0.19	0.23

Nitrogen content and protein percent had no significant variation in the triple interaction between the Balady cultivar irrigated with saline water levels of 256 ppm (control) or 1000 ppm with the foliar application of GB and Sids-40 cultivar irrigated with 256 ppm and sprayed by GB or Sids-40 cultivar which irrigated with saline water level of 1000 ppm and all the foliar application treatments (control, SNP or GB) in both seasons (Table 10). The phosphorus content recorded the highest significant values with Balady cultivar irrigated with 1000 ppm which sprayed with GB and the sids-40 which watered with 1000 ppm and treated with GB in the first season and with the treatment SNP and GB in the second season. The highest recorded values of potassium recorded with the Balady cultivar watered with tap water sprayed with GB and with the Sids-40 irrigated with tap water sprayed with SNP or GB in both seasons. In otherwise the highest significant results of sodium content given with Balady cultivar irrigated with 4000 ppm and sprayed with control treatment. The view of the obtained values in the same table cleared that the Balady cultivar watered with tape water and sprayed with SNP or GB gave the highest K/Na ratio in both seasons.

Table (10). Triple the interaction effect among cultivars, saline water and foliar application of sodium nitroprusside (SNP) and glycine betaine (GB) on bulb chemical contents of garlic at harvest time during 2022/2023 and 2023/2024 seasons

Cultivar	saline water	Treat.	N (%)		P (mg/g dry wight)		K (mg/g dry wight)		Na (mg/g dry wight)		K^+/Na^+ ratio		Protein %	
			2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Balady	control	0	2.71	2.23	2.557	2.229	17.20	16.62	12.98	12.45	1.33	1.34	16.94	13.92
		SNP	2.80	2.30	2.647	2.309	17.32	16.69	11.57	11.80	1.50	1.42	17.50	14.35
		GB	2.87	2.37	2.713	2.382	17.61	17.04	11.85	11.77	1.49	1.45	17.94	14.81
	1000	0	2.75	2.25	2.577	2.236	15.92	15.49	13.50	12.61	1.18	1.23	17.17	14.08
		SNP	2.83	2.33	2.673	2.319	16.13	15.77	12.62	11.96	1.28	1.32	17.71	14.58
		GB	2.88	2.38	2.757	2.442	16.78	16.21	12.34	12.12	1.37	1.34	18.02	14.87
	2000	0	2.59	2.11	2.507	2.152	14.82	14.27	15.25	14.69	0.97	0.97	16.17	13.17
		SNP	2.65	2.26	2.543	2.155	14.79	14.68	14.23	14.05	1.05	1.04	16.54	13.48
		GB	2.73	2.22	2.653	2.312	15.34	14.76	13.70	13.08	1.12	1.13	17.08	13.87
	3000	0	2.49	1.98	2.187	1.846	13.06	12.14	16.06	16.93	0.81	0.72	15.56	12.38
		SNP	2.53	2.02	2.323	2.002	13.39	12.75	15.42	14.65	0.87	0.87	15.83	12.63
		GB	2.50	1.99	2.417	2.092	13.62	11.95	14.22	14.68	0.96	0.81	15.60	12.44
	4000	0	2.39	1.86	1.730	1.436	12.21	11.62	17.87	17.25	0.68	0.68	14.94	11.61
		SNP	2.42	1.94	1.893	1.692	12.30	11.65	16.44	16.69	0.75	0.70	15.10	12.11
		GB	2.37	1.92	2.147	1.796	12.46	11.73	14.92	14.56	0.84	0.81	14.79	12.02
Sids-40	control	0	2.74	2.23	2.593	2.232	17.36	16.59	13.17	13.58	1.32	1.22	14.13	13.92
		SNP	2.80	2.34	2.697	2.356	17.45	16.82	12.32	13.16	1.42	1.28	17.52	14.63
		GB	2.87	2.37	2.737	2.362	17.57	16.70	12.72	12.67	1.38	1.34	17.94	14.79
	1000	0	2.84	2.35	2.643	2.336	15.59	14.94	15.00	14.01	1.04	1.06	17.77	14.69
		SNP	2.87	2.38	2.727	2.466	15.78	15.07	14.14	13.07	1.12	1.15	17.96	14.90
		GB	2.85	2.40	2.803	2.462	16.03	15.34	13.27	12.92	1.21	1.19	17.79	14.98
	2000	0	2.48	2.00	2.500	2.156	14.47	14.05	16.57	15.79	0.87	0.89	15.48	12.52
		SNP	2.49	1.98	2.570	2.259	14.63	14.05	15.94	15.43	0.92	0.91	15.56	12.38
		GB	2.52	2.03	2.693	2.366	14.97	14.36	14.12	13.47	1.06	1.06	15.77	12.67
	3000	0	2.19	1.66	2.160	1.809	12.85	12.11	16.34	15.72	0.78	0.77	13.69	10.38
		SNP	2.26	1.72	2.207	1.882	13.04	12.57	15.74	15.31	0.83	0.82	14.15	10.78
		GB	2.26	1.75	2.350	2.056	13.63	13.05	15.08	14.82	0.90	0.88	14.11	10.92
	4000	0	1.94	1.34	1.780	1.442	11.93	11.39	18.01	17.72	0.66	0.64	12.13	8.40
		SNP	2.01	1.45	1.813	1.472	12.08	11.49	16.78	15.81	0.72	0.72	12.59	9.06
		GB	2.13	1.56	1.960	1.659	12.32	11.70	15.37	14.99	0.80	0.78	13.34	9.73
LSD			0.04	0.05	0.05	0.06	0.23	0.28	0.61	0.65	0.06	0.05	0.27	0.33

4. Discussion

The result of growth characters (plant length, leaves number/plant, leaf area/plant, leaves fresh and dry weight, neck diameter, bulb diameter and chlorophyll content in the leaves) were in agreement with those reported by **Al-Harbi *et al.* (2002), Kaya *et al.* (2002), Munns, (2005), Parida and Das (2005), Zaki *et al.* (2009), Al-Zohiri (2009), Abo El-Fadel and Mohamed (2013) and Shama *et al.* (2016)**. These characteristics gradually decreased as the saline water level increase over 1000 ppm. Furthermore, the obtained results of neck diameter, bulb diameter, bulb fresh weight and bulb dry mater are in harmony with those obtained by **Al-Zohiri (2009), Abo El-Fadel and Mohamed (2013) and Shama *et al.* (2016).** The reduction in vegetative characters were stated by **Munns and Termatt (1986) and Hayat *et al.* (2008)** they illustrated that this reduction could be attributed to the osmotic and a nutritional effect of salinity, which interfered with the cell membrane permeability. However, long term exposure of roots to high salt concentration make the plants suffer from drought **(Bernstien, 1975),** reduced water and nutrient availability, make direct toxic effect of different ions because of imbalance of mineral nutrition **(Bower, 1976),** changing in nutrient forms in the soil and competition between cations and anions **(Bernstein, 1981).** Other causes are more related to the plant itself which affect its ability to absorb water or directly affect the plant biochemical processes due to toxicity, increase in cellular salt content which creates unsuitable environment for cellular biochemistry **(Cheeseman, 1988)**, minimized photosynthesis due to reduction in stomatal conductance and increasing stomatal limitations to CO_2 uptake **(Pascale and Barbieri, 1995),** changed the enzymatic activities in the plant **(Abd El-Razik, 1996),** inhibited the production of chlorophyll and carotene in leaves, induced calcium and magnesium nutritional deficiencies due to high sodium concentration and influenced the respiratory pathway in roots **(Abel and Mackenzie, 1964).** Salt stress has toxic effects on plants and lead to metabolic changes, like loss of chloroplast activity, decreased photosynthetic rate and increased photorespiration rate which then leads to an increased reactive oxygen species production **(Parida and Das, 2005)**. The inhibited production of chlorophyll and carotene in leaves, induced calcium and magnesium nutritional deficiencies due to high sodium concentration and influenced the respiratory pathway in roots **(Abel and Mackenzie, 1964).**

Concerning the increase in physical and chemical characteristics of garlic plants due to the irrigation with saline water up to 1000 ppm, it is well known that the salt tolerance of any crop may be appraised according to three criteria: (1) the ability of the crop to survive on saline medium, (2) the resulted yield of the crop developed on this medium and (3) the relative yield on a non-saline one under similar growing conditions **(Ayers, 1952).** However, the maximum amount of salts under which garlic grow safely and gave the highest significant bulb development and yield was 1000 ppm. In this concern, it was reported that many plants have a special and distinguishing feature which enable their growth to be improved by low levels of salt but beyond certain level growth is reduced **(Ruskin *et al.*, 1990).** Furthermore, in a series of investigations which pointed that there are many plants require some amounts of salts in their growth medium this salt positively promotes plant growth, enhances productivity and improves quality than salt free conditions **(Pasternak, 1987 and Gupta, 1990).** In the same respect, on potato **Ramadan *et al.* (2003)** and **Abd El Aal (2010)** stated that the low saline level up to 1500 ppm enhance the chlorophyll content in leaves and significantly decrement with the increase in saline water level. Physiologically, sodium chloride which is the main salt in saline water plays an important role through ionic Na+ that is absorbed by plants in this form. Thus, studies showed the importance of sodium as an essential element for a group of plants exhibiting the so-called hatch-slack pathway of carbohydrate metabolism. These studies threw light on crops stimulated by applications of sodium either when there was adequate supply of potassium or when there was deficiency in this element. So, crops responding largely to sodium fertilization in the presence of adequate potassium were for example celery, sugar beet, Swiss chard, table beet and turnip while those responding in absence of potassium were lettuce, onion, barely, potato, soybean, spinach, squash and strawberry **(Tisdale and Nelson, 1975).**

The proline content in leaves results is in harmony with those obtained by **Ramadan *et al.* (2003) and Abd El Aal (2010).** However, the accumulation of proline content could be used as a biochemical marker for the increase in salt tolerance of plants **(Martinez *et al.*, 1996).** Furthermore, **Mahmoudi *et al.* (2010)** stated that proline protect plants against salinity and other abiotic stresses.

Concerning the response of the two tested varieties; Balady cultivar exhibited better response than Sids40 this might be due to the genetic variations between cultivars and their capacity to use environmental resources, particularly light, CO2, water, and nutrients. In the same respect, **Abo El-Fadel and Mohamed (2013)** reported that the Balady cultivar gave higher yield quality than Sids-40 irrigated with different saline water levels. The yield characters results were in agreement with those obtained by **Amorim *et al.* (2002) and Shama *et al.*, (2016)** who found that increasing salinity significantly reduced garlic yield components. The reduction in garlic yield and its components under saline conditions could be attributed to the reduction in vegetative growth characteristics **(Al-Zohiri, 2009).** Furthermore, **Pessarakli (1994)** mentioned that salinity stress retards plant growth through its influence on several plant physiological processes e.g., osmotic adjustment, nutrient uptake, photosynthesis, organic soluble accumulation, alteration in respiration rates and soil water potential.

The results of yield chemical characteristics (N, P, K, Na, K^+/Na^+ ratio and Protein %) were in harmony with those found by **Siddiqui *et al.* (1996) and AI-Safadi and Faoury (2004).** that bulb content of Na increased significantly with the increase of saline level while the potassium content significantly reduced. In the same time **Al-Zohiri (2009)** stated that the control level gave the lowest values in case of sodium followed by1500 ppm compared with other tested treatments during both seasons of study. The results also in agreement with those found by **Abo El-Fadel and Mohamed (2013)** who mentioned that the highest values of N, P and K uptake were recorded by cultivar Baladi followed by cultivar Sids-40, furthermore the same trend recorded with the protein % content. This might be due to the genetic differences among cultivars and their ability for utilizing the environmental sources especially light, CO_2, water and nutrients. The same trend observed by **Shama *et al.* (2016)** who stated that the highest significant K content was recorded with the saline water level of 1500 ppm whereas highest Na level showed with the highest saline level 4500 ppm but in otherwise the highest significant K^+/Na^+ ratio with the control. **Shabala and Cuin (2008)** mention that the cytosolic K^+/Na^+ ratio determines cell metabolic competence and, ultimately, the ability of a plant to survive in saline environments. Different strategies commonly used by plants to improve salt stress tolerance; maintain desirable K^+/Na^+ ratio in the cytosol, regulation of K^+ uptake and prevention of Na^+ entry, efflux of Na+ from cell or compartmentalize Na^+ into vacuole **(Munis *et al.*, 2010).** Many researchers reported that K^+/Na^+ ratio might be considered as useful indicator for plant salinity tolerance **(Khan *et al.*, 2009) and Saleh, (2011).** One of the key features of plant salt tolerance is the ability of plant cells to maintain optimal K^+/Na^+ ratio in the cytosol **(Tester and Davenport, 2003).**

According the obtained results of enhancement of growth and yield characteristics by Sodium nitroprusside (SNP) foliar application it could be explained by its role as nitric oxide (NO) donor in plant and protection against oxidative stress because under SNP treatment, lipid peroxidation decrease and pigment lose was ameliorated **(Molassiotis *et al.*, 2010).** Furthermore, salinity imposes both osmotic stress and ionic toxicity to plants disturbing the activities of cytosolic enzymes thereby causing nutritional disorders and oxidative damage **(Xiong and Zhu 2002) and (Valderrama *et al.*, 2006) .** NO is involved in the regulation of various physiological and biochemical processes in plants such as plant growth **(Arasimowicz and Floryszak, 2007).** Also, **Gracia-Mata and Lamattina (2001)** mentioned that the application of SNP enhances plant tolerance to drought stress by reducing water stress, ion leakage and transpiration rate and reducing stomatal closure. Furthermore, **Uchide *et al.* (2002)** reported that NO is an important signal molecule involved in plant response to biotic and abiotic stresses. It has been shown that some phytohormones play roles in regulating plant growth and response to stresses by inducing NO formation. **Graziano *et al.* (2002)** reported that the increase of chlorophyll content may be attributed to the role of NO in maintaining the availability of metabolically active nutrient elements, which are necessary in chlorophyll biosynthesis and chloroplast within the plant. futhermore **Fan *et al.* (2012)** on cucumber concluded that proline metabolism was significantly altered during the exogenously applied NO under stress and that promoted the accumulation of higher levels of free proline. The results of plant growth characters, chlorophyll content, proline content and physical and chemical of yield characteristics are in agree with those obtained by **Tan *et al.* (2008)** on wheat plan, **Jelonek *et al.* (2009)** on cucumber and **Fazelian *et al.* (2012)** on chamomile.

The ameliorative effects of foliar application of GB could be clarified by its role as compatible solute in osmotic adjustment **(Hoque *et al.*, 2007a; Chen and Murata, 2008; Wani *et al.*, 2013).**

Exogenous application of GB to non-accumulator plants may be a possible alternative, approach for tolerance against multiple abiotic stresses **(Yang and Lu, 2005).** Also, exogenous application of GB increased growth characters of salt-stressed tomato plants **(Heuer, 2003),** improved abiotic stress tolerance of barley **(Tasuku *et al.*, 2009)** and counteracted the salt-induced adverse effects on eggplant growth and yield **(Abbas *et al.*, 2010).** Furthermore, GB reported to have an ameliorative effect in drought stress increasing dry weight and leaf area of soybean **(Agboma *et al.*, 1997a),** enhanced chlorophyll contents of wheat **(Zhao *et al.*, 2007)** and increased significantly garlic growth characteristics, free Proline content and yield characteristics **(Ahmed, 2020).** Also, **Gadallah (1999)** found that application of glycine betaine improved vegetative growth improved K^+ uptake and increased chlorophyll contents increased bean plants growth characteristics **(Xing and Rajashekar, 1999),** barley shoot fresh weight **(Wahid and Shabbir, 2005)** and increased the proline and chlorophylls content in garlic leaves **(Osman, 2009).**

5. Conclusion

The study concluded that irrigation water with saline levels above 1000 ppm have an adverse effect on garlic growth and yield. However, irrigation of garlic with moderately saline water at 1000 ppm can enhance vegetative growth, chemical content, and yield of garlic cultivars, particularly the Balady cultivar, which showed greater salt tolerance compared to Sids-40. Higher salinity levels above 1000 ppm negatively impacted growth and yield could be mitigated by foliar applications of glycine betaine (GB) and sodium nitroprusside (SNP). Glycine betaine was especially effective in improving growth parameters, yield components, and biochemical characteristics such as chlorophyll and proline content under salinity stress. Therefore, combining moderate saline irrigation with foliar GB application offers a practical approach to alleviate salt stress in garlic, supporting sustainable cultivation under saline conditions.

References

Abbas, W.; Ashraf, M. and Akram, N.A. (2010). Alleviation of salt-induced adverse effects in eggplant (*Solanum melongena* L.) by glycine betaine and sugarbeet extracts. Scientia Horticulturae, 125: 188 – 195.

Abbott, C.L. and El-Quosy, D.E.D. (1998). Drainage water reuse studies in the Nile delta and development of guide lines. International, workshop Drainage water Reuse in Irrigation. Sharm El-Sheikh, Egypt, 1 (5): 3-5.

Abd El Aal, A.M.H. (2010). The effect of irrigation with drainage water on some Potato varieties. Ph.D., thesis Fac. Agric., Al-Azhar Univ.

Abd El-Razik, A.H. (1996). Potato crop under semi-arid conditions with special references to irrigation and potassium fertilization in sandy soil. Alex. J. Agric. Res., 41:329-341.

Abel, G.H. and Mackenzie, A.J. (1964). Salt tolerance of soybean varieties (*Glycine max L.*) during germination and later growth Crop Sci., 4: 157-161.

Abo El Fadel, N.I. and Mohamed W.H. (2013). Response of two garlic cultivars to foliar nutrition under irrigation with saline water. Egypt. J. Soil Sci., 53 (2): 207-220.

Agboma, P.C.; Peltonen-Sainio, P.; Sinclair, T.R.; Jokinen, K. and Pehu, E. (1997a). An evaluation of the effect of exogenous glycine betaine on the growth and yield of soybean; timing of application, watering regimes and cultivars. Field Crops Research. 54: 51-64.

Ahmed, W.M.S. (2020), Improvement of production and quality of garlic under water stress conditions Ph.D., thesis Fac. Agric., Ain Shams Univ.

Al-Harbi, H.H.; Hegazi, A.A.; Alsadon, A.A. and El-Adgham, F. (2002): Growth and yield of onion (*Allium cepa* L.) cultivars under different levels of irrigation water salinity. J. King Saud Univ., 14, *Agric. Sci.*, (1): 23-32.

Al-Safadi, B. and Faoury, H. (2004). Evaluation of salt tolerance in Garlic (*Allium sativum* L.) cultivars using in vitro techniques. Advan. Horti. Sci., 18(3):115-120.

Al-Zohiri, S.S.M. (2009). Amelioration the adverse effect of irrigation water salinity on growth, yield and its quality of garlic plants by application of some antioxidants. The Fifth Inter. Conf. of Sustain. Agric. Develop., Fac. of Agric., Fayoum Univ., 21-23 Dec., p. 41-55.

Amorim, J.R.; Fernandez, P.D.; Gheyi H.R. and Azevedo N.C. (2002). Effect of irrigation water salinity and its mode of application on garlic growth and production (in French). Pesq. Agropec. Bras. Brasilia 37: 167-76.

Analytical software (2008): Statistix Version 9, Analytical software, Tallahassee, Florida, USA.

Arasimowicz M; Floryszak-Wieczorek, J. (2007) Nitric oxide as a bioactive signalling molecule in plant stress responses. Plant Science 172:876–887.

Ayers, A. D. (1952). Seed germination as affected by soil moisture and salinity. Agron. J., 44:82-84.

Bates, L.S.; Waldren, J.R.P. and Teare, I.D. (1973). Rapid determination of free proline for water-stress studies. Plant and Soil, 39: 205-207.

Bernstein, L. (1975). Effect of salinity and sodicity on plant growth. Ann. Rev. Phytopathol., 13: 295-312. (CAB Abst., 1973-1985).

Bernstein, L. (1981). Effect of salinity and soil water regime on crop yields. Salinity in irrigation and water resources. Civil engineering. J., 4:47-64. (CAB Abst. 1973-1985).

Bower, G.A. (1976). The effect of soluble salts on soil water availability. North Dekota Ag. Ex. Sta. Rep. No. 874, Farm Res., 33: 9-14. (CAB Abst. 1973-1985).

Chapman, H.D.; and Pratt, P.F. (1961). Methods of Analysis for Soils, Plants and Waters. Priced Publication 4034. Division of Agric. Sci., Univ. of California, Berkeley.

Cheeseman, J. (1988). Mechanism of salinity tolerance in plants. Plant Physiol., 87:104-108.

Chen, T.H. and Murata, N. (2008). Glycine betaine: an effective protectant against abiotic stress in plants. Trends Plant Sci. 13(9):499-505.

Cushman, J. C.; Derocher, E. and Bohnert, H.J. (1990). Gene expression during adaptations to salt stress. PP. 173-203. In: Katterman (ed.) Environmental injury to plant. Academic press, New York.

Dogras, C.; Siomos, A. and Pasomakelis, C. (1991). Sugar and dry matter changes in potatoes stored in clamp in mountainous region of northern Greece. Potato Res., 34: 211-214.

Dong, Y.; Jinc, S.; Liu, S.; Xu, L. and Kong, J. (2014). Effects of exogenous nitric oxide on growth of cotton seedlings under NaCl stress. Journal of Soil Science and Plant Nutrition. 14(1), 1-13.

El-Hifny, M.I. (2010). Response of garlic (*Allium sativum* L.) to some sources of organic fertilizers under North Sinai conditions. Res. J. Agric. Biol. Sci., 6(6): 928-936.

Fan, H.F.; Du, C.X. and Guo, S.R. (2012). Effect of nitric oxide on proline metabolism in cucumber seed-lings under salinity stress. J Amer Soc Hort Sci 137:127–133.

FAO (1994) Irrigation and drainage, water quality for agriculture. Paper no. 29.

FAO (2025) FAOSTAT, Agricultural Statistical Database. http://faostat.org.

Fazelian, N.; Nasibi, F. and Rezazadeh, R. (2012). Comparative the effects of nitric oxide and spermidin pretreatment on alleviation of salt stress in chamomile plant (*Matricaria recutita* L.). J. of stress physiol. and biochem., 8 (3): 214-223.

Gadallah, M.A.A. (1999). Effects of proline and glycine betaine on *Vicia faba* responses to salt stress. Biologia Plantarum. 42(2): 249-257.

Garcia-Mata, C. and Lamattina, L. (2001). Nitric oxide induces stomatal closure and enhances the adaptive plant responses against drought stress. Plant Physiol 126:1196–1204.

Graziano, M.; Beligni, M.V. and Lamattina, L. (2002). Nitric oxide improves internal iron availability in plants. Plant Physiol., 130:1852-1859.

Gupta, I.C. (1990). Use of saline water in agriculture in arid and semi-arid zones of India. Oxford and IBH Publishing Co, New Delhi, pp 225-252.

Hayat, S.; Hasan, S. A.; Fariduddin, Q. and Ahmad, A. (2008). Growth of tomato (*Lycopersicon esculentum*) in response to salicylic acid under water stress. J. Pl. Interact., 3(4): 297- 304.

Heuer, B. (2003). Influence of exogenous application of proline and glycine betaine on growth of salt-stressed tomato plants. Plant Science. 165: 693-699.

Hewitt, E.J. (1952). Sand and water culture methods used in the study of plant. Commonw. Bureau of Hort. East Mailing, 22: 241.

Hoagland, D.R. and Arnon, D.I. (1950). The water culture method for growing plants without soil. Cal. Agric. Expt. Sta. Circular, 347: 1-32.

Hoque, M.A.; Banu, M.N.A.; Okuma, E.; Amakob, K.; Nakamura, Y.; Shimoishia, Y. and Murata, Y. (2007a). Exogenous proline and glycine betaine increase NaCl-induced ascorbate–glutathione cycle enzyme activities, and proline improves salt tolerance more than glycine betaine in tobacco Bright Yellow-2 suspension-cultured cells. Journal of Plant Physiology 164: 1457-1468.

Hoque, M.A.; Banua, M.N.A; Nakamura, Y.; Shimoishia, Y. and Murata, Y. (2007b). Proline and glycine betaine enhance antioxidant defense and methylglyoxal detoxification systems and reduce NaCl-induced damage in cultured tobacco cells Journal of Plant Physiology 164: 1469-1478.

Israelson, O.W. and Hanson, V. E. (1962). Irrigation principles and practices. 3rd ed. John Wiley and Sons, New York, 207-230.

Jackson, M.L. (1973). Soil chemical analysis. Prentice-Hall, Inc., India.

Jelonek, A. M.; Floryszak, W. J. and Kubis, J. (2009). Interaction between polyamine and nitric oxide signaling in adaptive responses to drought in cucumber. J. Plant Growth regul.,28: 177-186.

Kaya, C.; Kirnak, H.; Higgs, D. and Saltati, K. (2002). Supplementary calcium enhances plant growth and fruit yield in strawberry cultivars grown at high (NaCl) salinity. Sci. Hortic., 26: 807-820.

Khan, M.A.; Shirazi, M.U.; Muhammad, A.K.; Mujtaba, S.M.; Islam, E.; Mumtaz, S.; Shereen, A.; Ansari, R.U. and Ashraf, Y. (2009). Role of proline, K/Na ratio and chlorophyll content in salt tolerance of wheat (*Triticum aestivum* L.). Pak. J. Bot., 41: 633-638.

Mahmoudi, H.; Huan, G.J.; Gruber, M.Y.; Kaddour, R.; laChaal, M.; Ouerghi, Z., and Hannouf, A. A. (2010). The impact of genotype and salinity on physiological function, secondary metabolite accumulation, and anti-oxidative responses in lettuce. J. Agric. Food Chem. 58, 5122-5130.

Martinez, C.A.; Maestri, M. and Lani, E.G. (1996). In vitro salt tolerance and proline accumulation in Andean potato (*Solano spp.*) differing in frost resistance. Plant Sci., 116: 177-184.

MALR (2025). Bulletin of the agricultural statistical (I) Winter field, Vegetable crops, greenhouses year 2023/2024. The Economic Affairs Sector of the Ministry of Agriculture and Land reclamation, Egypt, 154.

Molassiotis, A.; Tanou, G. and Diamantidis, G. (2010). NO says more than "yes" to salt tolerance – salt priming and systemic nitric oxide signalling in plants. Plant Signal Behav 5:209–212.

Munis, M.F.H.; Tu, L.; Ziaf, K.; Tan, J.; Deng, F. and Zhang, X. (2010). Critical osmotic, ionic and physiological indicators of salinity tolerance in cotton (*Gossypium hirsutum* L.) for cultivar selection. Pak. J. Bot., 42: 1685-1694.

Munns, R. (2005). Genes and salt tolerance: bringing them together. New Phytologist, v.167, p.645-663.

Munns, R. and Termatt, A. (1986). Whole plant responses to salinity. Aust. J. Pl. Physiol., 13: 143-160.

Osman, H.S.M. (2009). Rationing water requirments of rice plant using some osmoregulating compounds. Ph.D. Thesis, Faculty of Agriculture, Ain Shams University, Cairo, Egypt. p. 126.

Parida, A.K. and Das, A.B. (2005). Salt tolerance and salinity effects on plants: a review. Ecotoxicology and Environmental Safety, v.60, p.324-349, 2005.

Pascale, S. and Barbieri, G. (1995). Effect of soil salinity from long term irrigation with saline-sodic water on yield and quality of winter vegetables crops. Sci. Hort., 64: 145-157.

Pasternak, D. (1987). Salt tolerance and crop production a comprehensive approach. Ann. Rev. Phytopath., 25:271-29.

Pessarakli, M. (1994). Physiological responses of cotton (*Gossypium hirsutum* L.) to salt stress. In: Handbook of Plant and Crop Physiology (*M. Pessarakli*, Ed.), pp. 679-693, Marcel Dekker, Inc., New York.

Plummer, D.T. (1971). An introduction to practical biochem. Published by Mc Graw Hill Book Company (U.K.) Limited**.**

Pregl, E. (1945). Quantitative organic micro-analysis 4th Ed. J. Chundril. London. pp 385-387.

Ramadan, H.M.; EL-Sayed, S.F.; Khereba, A.H.A. and Hamed, A.M. (2003). Effect of irrigation frequency with different saline water levels on potato plants. (b) - Chemical composition. Minufiya J. Agric. Res. Vol. 28 No. 1: 247-265.

Ruskin, F. R.; John, H. and Michael, M. D. (1990). Saline agriculture. National Academy press. Washington D. C. library of Congress catalog card No. 89-64265. **(**CAB Abst. 1988-2000).

Saleh, B. (2011). Effect of salt stress (NaCl) on biomass and K+/Na+ ratio in cotton. J. Stress Physiol. & Biochem., 7 (4): 5-14.

Shabala, S. and Cuin, T.A. (2008). Potassium transport and plant salt tolerance. Physiol. Plant., 133(4): 651–669.

Shama, M.A.; Mousa, S.A.M. and Abo El Fadel, N.I. (2016). Salicylic acid efficacy on resistance of garlic plants (*Allium sativum*, L.) to water salinity stress on growth, yield and its quality. Alex. Sci. Exchan. J. Vol., 37 No. 2. 165-175.

Siddiqui, S.; Gupta, K.; Yadav A. and Managal, J. L. (1996). Soil salinity effect on soluble saccharides phenol, fatty acids and mineral contents and respiration rate of garlic cultivars. Biologia plantarum. 38: 611-615.

Tan, J.F.; Zhao, H.J.; Hong, J.P.; Han, Y.L.; Li, H. and Zhao, W.C. (2008). Effect of exogenous nitric oxide on photosynthesis, antioxidant capacity and proline accumulation in wheat seedling subjected to osmotic stress. World J. Agric. Sci., 4: 307-313.

Tasuku, H.; Mitsuya, S.; Fujiwara, T.; Jagendorf, A.T. and Takabe, T. (2009). Tissue specificity of glycine betaine synthesis in barley**.** Plant Science. 176: 112–118**.**

Tester, M. and Davenport, R. (2003). Na^+ tolerance and Na^+ transport in higher plants. Ann. Bot., 91: 503–527.

Tisdale, S. and Nelson, W. (1975). Soil fertility and fertilizers Macmillan publishing Co. Inc, New York, Third ed., pp 98-99.

Uchida, A.; Jagendorf, A.T.; Hibino, T.; Takabe, T. and Takabe, T. (2002) Effects of hydrogen peroxide and nitric oxide on both salt and heat stress tolerance in rice. Plant Sci., 163:515–523.

Valderrama, R.; Corpas, F.J.; Carreras, A.; Fernandez-Ocana, A.; Chaki, M.; Luque, F.; Gómez-Rodríguez, M.V.; Lmenero-Varea, P.; Del Río, L.A. and Barroso, J.B. (2007). Nitrosative stress in plants. FEBS Lett 581:453–461.

Velmurugan, A.; Swarnam, P.; Subramani, T.; Meena, B. and Kaledhonkar, M.J. (2020). Water demand and salinity. Desalination challenges and opportunities. Intech open. PP.96.

Wahid and Shabbir. (2005). Induction of heat stress tolerance in barley seedlings by pre-sowing seed treatment with glycine betaine. Plant Growth Regulation. 46:133–14.

Wang, B.; Liu, H.; Li, C.; Zhu, Y.; Tain, X.; Ma, G. and Zou, H. (2011). Effects of nitric oxide on some physiological characteristics of maize seedlings under waterlogging. Afr. J. of Agric. Res., 6 (19): 4501-4504.

Wani, S. H.; Singh, N.B.; Haribhushan, A. and Mir, J.I. (2013). Compatible Solute Engineering in Plants for Abiotic Stress Tolerance Role of glycine betaine. Current Genomics, 14 (3): 157-165.

Xing, W. and Rajashekar, C.B. (1999). Alleviation of water stress in beans by exogenous glycine betaine. Plant Science, 148: 185–195.

Xiong, L. M. and Zhu, J. K. (2002). Salt tolerance. In: Somerville CR, Meyerowitz EM (eds) The Arabidopsis book. American Society of Plant Biologists, Rockville.

Yang, X. and Lu, C. (2005). Photosynthesis is improved by exogenous glycinebetaine in salt-stressed maize plants. Physiol. Plant, 124:343-352.

Zaki, M.F; Abou-Hussein, S.D.; Abou El-Magd, M.M. and El-Abagy, M.M. (2009). Evaluation of some sweet fennel cultivars under saline irrigation water. European Journal of Scientific Research, 30 (1): 67-78.

Zhao, X.X.; Ma, Q.Q.; Liang, C.; Fang, Y.; Wang, Y.Q. and Wang, W. (2007). Effect of glycinebetaine on function of thylakoid membranes in wheat flag leaves under drought stress. Biologia Plantarum, 51 (3): 584-588.