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GROWTH RESPONSE OF GARLIC (*ALLIUM SATIVUM* L.) TO SALINE WATER IRRIGATION AND NITROGEN FERTIGATION

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ABSTRACT

A field study was executed to assess the impacts of saline irrigation and nitrogen fertigation on the growth, yield, and quality of garlic variety HG-17 at the Research Farm of the Soil Science Department, CCSHAU, Hisar during the Rabi seasons of 2021-22 and 2022-23. The experimental framework was established in a split-plot design with three replications. The treatments incorporated three levels of saline water (canal water, ECiw=2.5 dS/m, and ECiw=5.0 dS/m) as primary treatments and three levels of nitrogen fertilizer (75%, 100%, and 125% of recommended dose of nitrogen) as secondary treatments. The results presented that all the growth parameters *viz*., plant height at 90 days after planting (DAP), number of leaves per plant, leaf length and breadth, shoot weight per plant as well as and total plant biomass were recorded significantly maximum under irrigation with canal water as compared to saline water levels. Among nitrogen levels, all the growth characteristics were increased with increasing nitrogen levels and recorded maximum with 125% RDN applied through drip as compared to lower levels (75% and 100% RDN) of nitrogen during both the years of study, as well as pooled data of two years.
Keywords**:** Garlic, bulb yield, Fertigation, Nitrogen levels, Saline Water levels.

Introduction

Garlic (*Allium sativum* L.), the second most significant cultivated species in the Allium genus after onion, is predominantly employed as a flavoring agent while attracting pharmaceutical interest for its therapeutic benefits, attributed to its distinctive organic sulfur compounds such as alliin, allicin, and various sulfur-containing amino acids (Rizk *et al.,* 2021; Salata *et al.,* 2021). Garlic is enriched with essential vitamins such as riboflavin, thiamine, nicotinic acid, and vitamin C, which enhance its nutritional value and establish its status as a medicinal plant with notable antimicrobial efficacy, as well as beneficial effects on blood pressure, digestion, and immune function (Salata *et al.,* 2021; Kazemi *et al.,* 2010). According to the FAO 2023 report around 28.67 million tonnes of garlic are full grown globally yearly. It is assessed that production in India is continued at a level of about 3213.93 thousand tonnes and is supported out on an area of about 382.61 thousand hectares, second worldwide in terms of land area and production, behind China (Anonymous, 2023-2024). The detrimental impact of environmental stress on garlic growth arises from a disruption in the balance of reactive oxygen species and antioxidant mechanisms, necessitating effective irrigation management, while optimal fertilization and irrigation are crucial for economic viability, particularly given the significance of water availability in humid temperate regions for crop yield (Rizk *et al.,* 2021).

Soil salinity poses a critical threat to global agriculture, impacting around 6% of the world's land and severely diminishing crop yield, particularly in vegetables, affecting 20% of cultivated and half of irrigated lands worldwide (Ahmad *et al.,* 2021; El-Saber, 2021). Salinity adversely impacts garlic (*Allium sativum* L.), a salt-sensitive species, by disrupting ionic balance through excessive Na^+ and Cl^- accumulation, inducing oxidative stress via heightened reactive oxygen species production, and diminishing water uptake capacity, thereby inducing osmotic stress analogous to drought conditions (El-Saber, 2021; Zelm *et al.,* 2020; Munns, 2002). The morphological effects of salinity on garlic are pronounced, as saline irrigation notably diminishes leaf count and plant height due to factors such as water stress, ion toxicity, nutrient imbalances, and deficiencies, leading to stunted growth from direct salt toxicity and hindered nutrient absorption (Ahmad *et al.,* 2021).

Salinity adversely affects garlic's reproductive development and yield parameters, including bulb dimensions and biomass, leading to diminished marketable yield and quality, thus posing a significant economic challenge for producers (Elkhatib *et al.,* 2021; Ahmad *et al.,* 2021). Nitrogen is a vital macronutrient for garlic (*Allium sativum* L.) production, integral to various physiological processes that directly impact growth, development, and yield, as it enhances photosynthetic efficiency through chlorophyll composition, thus influencing biomass and bulb formation (Taha *et al.,* 2024), and its adequate availability is crucial for synthesizing essential organic compounds like amino acids, proteins, and nucleic acids, which are fundamental for optimal plant functioning (Taha *et al.,* 2024). Research indicates a direct correlation between nitrogen application rates and vegetative growth metrics in garlic, where increased nitrogen enhances leaf number, length, and dry matter accumulation, thereby expanding photosynthetic capacity for carbohydrate production essential for bulb development, while also being crucial for protein synthesis that impacts both growth dynamics and the nutritional quality of garlic bulbs (Metwally *et al.,* 2024).

Effective nitrogen management in garlic cultivation is crucial, as over-application may lead to negative consequences; while elevated nitrogen fosters vegetative growth and increases protein content, it can concurrently inhibit the production of certain secondary metabolites such as anthocyanins, and excessive soil nitrogen may promote leaf growth to the detriment of bulb development, thereby potentially diminishing economic yield, underscoring the necessity for a balanced nitrogen strategy that optimizes growth without jeopardizing bulb quality or development (Taha *et al.,* 2024). The interaction of nitrogen fertilization with potassium is crucial for garlic growth, as potassium not only enhances carbon and nitrogen assimilation but also aids in the nutrient translocation from leaves to bulbs, leading to improved photosynthesis, stomatal conductance, transpiration, and biomass accumulation when combined with a consistent nitrogen supply (Metwally *et al.,* 2024; Xu *et al.,* 2023; Guo *et al.,* 2019). In conclusion, nitrogen fertilization is vital for garlic production, affecting growth, yield and quality; thus, a balanced fertilization strategy that considers nutrient interactions and prevents over-application is essential for optimizing both productivity and quality in garlic cultivation. In this study, systematically investigated the Effect of saline water and nitrogen fertigation on growth of garlic.

Materials and Methods

The experiment was conducted during the year 2021-22 and 2022-23 at Research Farm of Soil Science Department, CCSHAU, Hisar, Haryana situated at an altitude of 215 m above mean sea level, lying between $29^0$09'03.5" N latitude and $75^0$41'20.8" E longitude with a climate characterized by semi-arid conditions. This region is characterized by hot and dry winds during the summer and severe dry weather during the winter. Planting of cloves of garlic variety Hisar Garlic17 (HG-17) was done during the *Rabi* seasons of 2021-22 and 2022-23 was done on the raised beds of with three rows planted on each bed with spacing at 15 cm × 10 cm. The experiment was laid out in a split-plot design with tree replications. The treatment consists of three saline water levels (canal water, EC_{iw}=2.5 dS/m and EC_{iw}=5.0 dS/m) as main treatments and three N fertilizer levels (75%, 100% and 125% RDN) as sub-main treatments. The results showed that all the growth parameters viz., plant height, number of leaves per plant, leaf length and breadth, shoot weight per plant and total plant biomass, were recorded significantly maximum under irrigation with canal water as compared to saline water levels during both the years of study, as well as pooled data of two years. The data analysis statistical method described by Panse and Sukhatme (1967) was followed for the analysis and interpretation of experimental results was done using OPSTAT software, developed by CCS HAU, Hisar.

Results

Plant height at 90 days after planting (DAP)

The data on garlic plant height recorded at 90 DAP (Table-1) indicated that different levels of saline water irrigation had significant impacts on plant height, which decreased significantly with increasing saline water levels throughout the both years of research. When compared to saline levels of irrigation water, the maximum mean plant height (49.1 and 50.5 cm) was observed under irrigation with canal water, while the minimum mean plant height (37.7 and 40.5 cm) was observed under saline water (EC_{iw}= 5.0 dS/m) during 2021-22 and 2022-23 years, respectively. Likewise, two-year pooled mean plant height data at 90 DAP also followed the same trend and significantly higher mean plant height (54.9 cm) at 90 DAP was recorded in canal water irrigation and lowest mean in saline water at 5.0 dS/m (44.0 cm).

Fertigation-based nitrogen application also had significant effects on plant height at 90 DAP during both years and it increased as fertigation level increased from 75 to 125% RDN. Among the various fertigation levels, the maximum mean plant height (47.5 and 50.3 cm) was recorded with 125% RDN fertigation, while the shortest mean plant height (37.9 and 38.4 cm) was recorded with 75% RDN fertigation during 2021-22 and 2022-23 years, respectively. Furthermore, two-year pooled plant height data at 90 DAP also followed the same trend and significantly higher mean plant height (48.9 cm) at 90 DAP was recorded in nitrogen at 125% RDN and lowest mean in 75% RDN (38.1 cm). However, the interaction between saline water and nitrogen fertigation was found to be non-significant. Similar trends in plant height at 90 DAP were observed in the years 2021-22 and 2022-23, as well as in pooled data of both years.

Number of leaves per plant

In Table-2, the data with regard to the number of leaves per plant is demonstrated. The significantly highest mean number of leaves per plant (10.24 and 11.43) was obtained under irrigation with canal water in comparison to other treatments. The lowest mean number of leaves per plant (8.15 and 9.11) was recorded under irrigation with saline water 5.0 dS/m during 2021-22 and 2022-23 years, respectively and two years pooled data of mean number of leaves per plant also followed the same trend and significantly higher mean number of leaves per plant (10.84) was recorded with canal water irrigation and lowest mean (8.63) in saline water 5.0 dS/m.

The number of leaves per plant was significantly impacted by the various nitrogen fertigation levels. In comparison to other treatments, nitrogen fertigation at 125% RDN resulted in significantly higher mean number of leaves per plant (9.81 and 10.95) but at 75% RDN fertigation, the lowest mean number of leaves per plant (8.57 and 9.71) were observed during the years 2021-22 and 2022-23, respectively. Similarly, two years pooled data on the mean number of leaves per plant also followed the same trend and significantly highest mean number of leaves per plant (10.38) was recorded in nitrogen at 125% RDN and lowest mean (9.14) in 75% RDN. The data in Table-2. also demonstrated that there was no significant interaction between the different levels of saline water and nitrogen fertigation. For number of leaves per plant were seen during both the years as well as in pooled data.

Leaf length (cm)

The data of leaf length (Table-3) revealed that when saline water levels were raised from canal water to saline water 5.0 dS/m, leaf length decreased significantly and the maximum mean leaf length (35.5 and 36.5 cm) was recorded in canal water whereas the minimum mean leaf length (27.5 and 29.0 cm) was attained when irrigation was applied with saline water 5.0 dS/m during 2021-22 and 2022-23, respectively. Similarly, two years pooled data of mean leaf length also followed the same trend and significantly higher mean leaf length (36.0 cm) was recorded in canal water and lowest mean (28.3 cm) in saline water EC_{iw}= 5.0 dS/m.

Nitrogen fertigation also had a significant impact on leaf length, which increased as the nitrogen level increased. Longer mean leaf length (35.1 and 35.8 cm) were obtained through the use of 125% RDN with fertigation. However, smaller mean leaf length (27.5 and 28.9 cm) was obtained by 75% RDN during 2021-22 and 2022-23 years, respectively. Furthermore, leaf length pooled data across two years also followed the same trend and significantly higher mean leaf length (35.4 cm) was recorded in nitrogen at 125% RDN and lowest mean in 75% RDN (28.2 cm). Although the interaction between saline water and nitrogen fertigation was found to be non-significant for leaf length in 2021-22 and 2022-23 as well as pooled data of both years.

Table 1 : Effect of saline water and nitrogen fertigation on plant height (cm) at 90 DAP in garlic

Saline water levels	2021-22				2022-23				Pooled			
	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean
Canal water	45.3	48.5	53.5	49.1	43.5	51.7	56.3	50.5	44.4	50.4	54.9	49.9
Saline water 2.5 dS/m	37.1	43.2	47.1	42.5	39.1	44.3	48.3	43.9	38.1	43.7	47.7	43.2
Saline water 5.0 dS/m	31.2	40.2	41.8	37.7	32.5	43.0	46.2	40.5	31.8	41.6	44.0	39.1
Mean	37.9	44.0	47.5		38.4	46.3	50.3		38.1	45.2	48.9	
CD at 5%	Irrigation Water (I): 1.8 Nitrogen levels (N): 1.5 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 2.8 Nitrogen levels (N): 1.6 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 3.2 Nitrogen levels (N): 1.4 N at same level of I: NS I at same level of N: NS			

Table 2 : Effect of saline water and nitrogen fertigation on number of leaves per plant in garlic

Saline water levels	2021-22				2022-23				Pooled			
	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean
Canal water	9.65	10.35	10.73	10.24	10.90	11.57	11.83	11.43	10.28	10.96	11.28	10.84
Saline water 2.5 dS/m	8.75	9.60	9.88	9.41	10.00	10.83	11.23	10.69	9.38	10.22	10.56	10.05
Saline water 5.0 dS/m	7.31	8.32	8.83	8.15	8.23	9.30	9.80	9.11	7.77	8.81	9.32	8.63
Mean	8.57	9.42	9.81		9.71	10.57	10.95		9.14	10.00	10.38	
CD at 5%	Irrigation Water (I): 0.30 Nitrogen levels (N): 0.34 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 0.34 Nitrogen levels (N): 0.31 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 0.70 Nitrogen levels (N): 0.26 N at same level of I: NS I at same level of N: NS			

Leaf breadth (mm)

Leaf breadth decreased considerably when saline water levels were increased from canal water to saline water 5.0 dS/m (Table-4) When irrigation was given with canal water compared to saline water levels, the maximum mean leaf breadth (13.91 and 14.51 mm) was recorded, while the minimum mean leaf breadth (10.18 and 10.87 mm) was achieved when irrigation was applied with saline water 5.0 dS/m during 2021-22 and 2022-23, respectively. Similarly, two years of pooled data on mean leaf breadth also followed the same trend and significantly higher mean leaf breadth (14.32 mm) was recorded with canal water and lowest mean (10.53 mm) in saline water at 5.0 dS/m.

The effect of nitrogen fertigation significantly affected the leaf breath and it increased as the level of nitrogen increased. Using 125% RDN with fertigation produced longer mean leaf breadth (13.09 and 14.81mm), while 75% RDN produced smaller mean leaf breadth (10.83 and 10.89 mm) during 2021-22 and 2022-23, respectively and two years pooled data of mean leaf breadth also followed the same trend and significantly higher mean leaf breadth (13.95 mm) was recorded with 125% RDN and lowest mean (10.86 mm) in 75% RDN. Although the interaction between saline water and nitrogen fertigation was observed to be non-significant for leaf breath during both the years as well as in the pooled data of two years.

Shoot weight per plant at 15 days before harvest (g)

The data on garlic shoot weight per plant recorded 15 days before harvest under various treatments (Table-5) revealed that different levels of saline water irrigation had a significant impact on garlic shoot weight per plant decreased with increasing saline water levels. The maximum mean shoot weight per plant (29.78 and 30.66 g) was observed with canal water, while the minimum mean (23.18 and 24.17 g) was achieved at saline water 5.0 dS/m during 2021-22 and 2022-23, respectively. Similarly, pooled data of two years regarding mean shoot weight per plant recorded at 15 days before harvest also followed the same trend and significantly higher mean shoot weight per plant (30.33 g) was recorded in irrigation with canal water and lowest mean (23.68 g) in saline water at 5.0 dS/m.

Similarly, garlic shoot weight per plant, recorded 15 days before harvest increased with increasing nitrogen fertigation from 75% to 125% RDN. The highest mean shoot weight per plant (29.66 and 30.54 g) at 15 days before harvest was recorded at 125% RDN fertigation, while the lowest mean shoot weight per plant (22.00 and 22.88 g) was recorded when 75% RDN was supplied using fertigation during the years 2021-22 and 2022-23, respectively. Similarly, two years pooled data of mean shoot weight per plant at 15 days before harvest also followed the same trend and significantly higher mean shoot weight per plant (30.10 g) at 15 days before harvest was recorded with application of nitrogen at 125% RDN and lowest mean (22.44 g) in 75% RDN. Although, the interaction between saline water and nitrogen fertigation was observed to be non-significant for shoot weight per plant at 15 days before harvest during both the years as well as in pooled data.

Table 3 : Effect of saline water and nitrogen fertigation on leaf length (cm) in garlic

Saline water levels	2021-22				2022-23				Pooled			
	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean
Canal water	33.1	35.3	38.2	35.5	31.6	38.2	39.8	36.5	32.4	36.8	39.0	36.0
Saline water 2.5 dS/m	26.6	31.3	34.8	30.9	29.3	34.2	35.7	33.1	27.9	32.7	35.3	32.0
Saline water 5.0 dS/m	22.8	27.4	32.3	27.5	25.7	29.5	31.9	29.0	24.2	28.5	32.1	28.3
Mean	27.5	31.3	35.1		28.9	34.0	35.8		28.2	32.6	35.4	
CD at 5%	Irrigation Water (I): 2.6 Nitrogen levels (N): 1.3 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 1.6 Nitrogen levels (N): 1.4 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 1.1 Nitrogen levels (N): 0.9 N at same level of I: NS I at same level of N: NS			

Table 4 : Effect of saline water and nitrogen fertigation on leaf breadth (mm) in garlic

Saline water levels	2021-22				2022-23				Pooled			
	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean
Canal water	12.93	13.77	15.03	13.91	12.95	14.02	16.57	14.51	12.94	14.23	15.80	14.32
Saline water 2.5 dS/m	10.66	11.40	12.77	11.61	10.80	13.02	14.91	12.91	10.73	12.21	13.84	12.26
Saline water 5.0 dS/m	8.90	10.17	11.46	10.18	8.92	10.75	12.95	10.87	8.91	10.46	12.21	10.53
Mean	10.83	11.78	13.09		10.89	12.60	14.81		10.86	12.30	13.95	
CD at 5%	Irrigation Water (I): 1.90 Nitrogen levels (N): 1.30 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 1.44 Nitrogen levels (N): 0.77 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 1.85 Nitrogen levels (N): 1.14 N at same level of I: NS I at same level of N: NS			

Total plant biomass (g)

The data on total plant biomass of garlic under various treatments (Table-6) depicted those different levels of saline water irrigation had a significant impact on garlic total plant biomass of garlic, which decreased with increasing saline water levels. The significant highest mean total plant biomass (41.8 and 44.7 g) was observed at canal water and the lowest mean (31.2 and 34.7 g) was achieved at saline water 5.0 dS/m during 2021-22 and 2022-23, respectively. Additionally, pooled data of two years on the mean of total plant biomass also followed the same trend and significantly higher mean total plant biomass (43.3 g) was recorded with canal water and lowest mean (32.9 g) in saline water at 5.0 dS/m.

Similarly, garlic total plant biomass increased with increased nitrogen fertigation (75 to 125% RDN). When a lesser dosage of nitrogen 75% RDN was fed by fertigation, the lowest mean total plant biomass (30.6 and 34.0 g) was reported. The maximum mean total plant biomass (41.5 and 43.3 g) was recorded at 125% RDN fertigation during 2021-22 and 2022-23, respectively and two years pooled data of mean of total plant biomass also followed the same trend and significantly highest mean total plant biomass (42.4 g) was recorded in nitrogen at 125% RDN and lowest mean (32.3 g) in 75% RDN. While it was also found that there was no substantial interaction between saline water and nitrogen fertigation for total plant biomass was observed in the years 2021-22 and 2022-23, as well as in pooled data.

Table 5 : Effect of saline water and nitrogen fertigation on shoot weight per plant (g) at 15 days before harvest in garlic

Saline water levels	2021-22				2022-23				Pooled			
	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean
Canal water	24.46	31.56	33.31	29.78	25.56	32.66	33.75	30.66	25.01	32.44	33.53	30.33
Saline water 2.5 dS/m	22.51	27.22	28.51	26.08	22.94	29.32	30.61	27.62	22.73	28.27	29.56	26.85
Saline water 5.0 dS/m	19.02	23.36	27.17	23.18	20.12	25.13	27.27	24.17	19.57	24.25	27.22	23.68
Mean	22.00	27.38	29.66		22.88	29.04	30.54		22.44	28.32	30.10	
CD at 5%	Irrigation Water (I): 1.79 Nitrogen levels (N): 1.33 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 2.11 Nitrogen levels (N): 0.82 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 1.71 Nitrogen levels (N): 1.10 N at same level of I: NS I at same level of N: NS			

Table 6 : Effect of saline water and nitrogen fertigation on total plant biomass (g) in garlic

Saline water levels	2021-22				2022-23				Pooled			
	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean
Canal water	37.5	42.2	45.8	41.8	39.0	45.5	49.8	44.7	38.2	43.8	47.8	43.3
Saline water 2.5 dS/m	29.9	39.5	43.0	37.5	32.9	39.3	41.7	37.9	31.4	39.4	42.3	37.7
Saline water 5.0 dS/m	24.4	33.5	35.8	31.2	30.1	35.4	38.6	34.7	27.2	34.4	37.2	32.9
Mean	30.6	38.4	41.5		34.0	40.0	43.3		32.3	39.2	42.4	
CD at 5%	Irrigation Water (I): 2.2 Nitrogen levels (N): 1.9 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 2.3 Nitrogen levels (N): 1.0 N at same level of I: NS I at same level of N: NS				Irrigation Water (I): 1.2 Nitrogen levels (N): 0.7 N at same level of I: NS I at same level of N: NS			

Discussion

The results of the experiment demonstrate that nitrogen fertigation and quality of irrigation water strongly and positively impacted most of the parameters that were determined, *i.e.* plant height, number of leaves per plant, leaf length and breadth, shoot weight per plant, total plant biomass. In this research two-year pooled data is discussed among with the different treatments.

The results of two years pooled data indicated that the plant height of garlic at 90 DAP were significantly affected by the application of saline water and nitrogen levels through the (Table-1). The plant height was maximum under canal water irrigation than saline water level 5.0 dS/m. An average plant height at 90 DAP the garlic plant height under canal water was 54.9 cm which was 24.8% higher than the plant height of 44.0 cm under saline water level 5.0 dS/m. Salinity concentration of irrigation water affected plant height negatively. It was observed that onion plant height at highest salt levels more than 4 dS/m gradually decreased and final plants height was severely stunted (Regessa *et al.,* 2022). The plant height may be restricted or totally inhibited on saline soils due to the three reasons *i.e.,* the toxic effect of accumulated ions in the plant tissues, osmotic effect on plant root, the specific effect of the constituent ions or the combination of all these factors. Razzaque *et al.,* (2021), Ghassemi and Raei (2021), Anjum *et al.,* (2021), Patel *et al.,* (2020) or Hussein and Faham (2018) also reported increased plant height of onion with the decreasing levels of saline water irrigation.

Plant height was significantly affected by the nitrogen fertilizer doses at all the saline water levels applied through fertigation (Table-1). The plant height was recorded highest at 125% RDN in all the irrigation water treatments for all the plant growth stages. The plant height increased by 18.9% (90 DAP) at 100% RDN and 28.3% (90 DAP) with the application of 125% RDN over 75% RDN applied through fertigation. This could be due to the adequate supply of nitrogen, which in turn, contributes to better vegetative development, resulting in increased plant height. Additionally, nitrogen plays an integral function in the leaves, synthesizing chlorophyll for photosynthesis and improves cell division and growth. The obtained results were similar to the findings of Abera and Adinew (2023), Sisay *et al.,* (2023), Kevlani *et al.,* (2023), Gashaw (2021) and Singh *et al.,* (2020) in garlic.

The number of leaves per plant, leaf length and breadth were significantly affected by the salinity levels of irrigation water (Tables-2,3 and 4) during both the years of investigation. Application of saline water reduces the number of leaves per plant (7.5% and 20.4%), leaf length (11.1% and 21.4%) and leaf breadth (14.4% and 26.5%) in plots of irrigation with saline water 2.5 dS/m and 5.0 dS/m to over canal water irrigation. Number of leaves per plant, leaf length and leaf breadth also followed similar pattern with significant maximum value in canal water and reduced as salt level increased. This might be due to salinity affecting the growth by increasing soil pH and directly creating nutrient deficiencies or imbalances and toxicity. Salinity stress was reported to affect different metabolic processes such as CO_2 assimilation, protein synthesis, osmotic adjustment, nutrient uptake, photosynthesis, organic soluble accumulation, alteration in respiration rates and soil water potential. The present results are in conformity with the findings of Regessa *et al.,* (2022), Razzaque *et al.,* (2021), Anjum *et al.,* (2021) and Yohannes *et al.,* (2020) in onion.

Number of leaves per plant, leaf length and breadth increased with the increasing nitrogen application from 75% to 125% RDN (Tables-2,3 and 4) during both the years of investigation. The number of leaves per plant, leaf length and breadth increased by 13.6%, 25.5% and 28.5 % with the application of 125% RDN over 75% RDN. The increased nitrogen fertilizer rates could be attributed to the photosynthetic area, which has been linked to the formation of additional leaves by nitrogen that resulted in a high number of leaf, leaf length and breadth which have the physiological capacity to mobilize and translocate photosynthesis to economically valuable organs, thereby increasing N content which enhanced the leaf length and breadth by a stimulative effect on cell division and cell enlargement leading to increased plant growth. Abera and Adinew (2023), Tena and Desta (2023) and Kevlani *et al.* (2023), reported that growth parameters of garlic increased with the increasing level of nitrogen upto 150 kg/ha in garlic. Similar results were also reported by Sisay *et al.* (2023), Gashaw (2021), Tilahun *et al.* (2021), Amare and Mamo (2020) and Kumar *et al.* (2018).

The two years pooled data indicated that shoot weight per plant and total plant biomass were significantly affected by the salinity levels of irrigation water and nitrogen fertigation (Tables-5 & 6). Application of saline water reduced the shoot weight per plant (11.5% and 21.9%), total plant biomass (12.9% and 24.0%) and in plots of EC_{iw}=2.5 dS/m and 5.0 dS/m over canal water. This reduction in shoot weight per plant and total plant biomass might be due to salt stress that significantly reduced growth parameters and photosynthetic attributes which finally reduced photo-assimilate production and translocation. The present results are in close agreement with the finding of Regessa *et al.* (2022) in onion and Astaneh *et al.* (2019), Ghassemi and Raei (2021) in garlic crop.

Shoot weight per plant and total plant biomass increased with the increasing nitrogen application from 75% RDN to 125% RDN (Tables-5 & 6). According to pooled data of two years, the shoot weight per plant and total plant biomass increased by 34.1% and 31.3% with the application of 125% RDN over 75% RDN. The increased in shoot weight per plant and total plant biomass due to the higher nitrogen fertilizer application that could be as a result of the positive effect of nitrogen which might cause a luxurious vegetative growth which leads to enhanced assimilates production that in turn resulted in a higher shoot weight and total plant biomass. Similar results were also reported by Tena and Desta, (2023), Abera and Adinew (2023) in garlic and they reported that delayed in maturity of garlic crop due to increasing level of nitrogen fertilizer. Tilahun *et al.,* (2021), Amare and Mamo (2020), Yitayih *et al.* (2017), Gererufael *et al.* (2020), Gashaw *et al.* (2020). Kilgori *et al.* (2007) observed significant increase of fresh biomass yield of garlic with increasing levels of N from 0 to 120 kg/ha. Similar results were also reported by Tadila and Nigusie (2018) and Kumar *et al.* (2018).

Conclusions

The growth characters, like plant height at 90 days after planting (49.1 and 50.5 cm), number of leaves per plant (10.24 and 11.43) and leaf length (35.5 and 36.5 cm) were recorded significantly higher under irrigation with canal water as compared to other saline water levels, whereas among nitrogen levels, the plant height at 90 days after planting (47.5 and 50.3 cm), number of leaves per plant (10.24 and 11.43) and leaf length (35.1 and 35.8 cm) were recorded significantly higher under 125% RDN level as compared to other nitrogen fertigation levels during both the years 2021-22 and 2022-23, respectively. Similarly, two years pooled data of also followed the same trend and significantly highest plant height, number of leaves per plant and leaf length was recorded under application of canal water along with 125% RDN.

The leaf breadth (13.91 and 14.51 mm), shoot weight per plant at 15 days before harvest (29.78 and 30.66 g) and total plant biomass (41.8 and 44.7 g), were recorded significantly maximum under irrigation with canal water as compared to other saline water levels (EC_{IW} = 2.5 dS/m and 5.0 dS/m). Among nitrogen levels, the leaf breadth (13.09 and 14.81 mm), shoot weight per plant at 15 days before harvest (29.66 and 30.54 g) and total plant biomass (41.5 and 43.3 g) were significantly maximum under 125% RDN level as compared to other nitrogen fertigation levels during both the years 2021-22 and 2022-23. Similarly, two years pooled data of leaf breadth and shoot weight per plant at 15 days before harvest also followed the same trend and significantly highest was recorded under application of canal water along with 125% RDN.

Based on two years study, it can be concluded that different levels of saline water irrigation and nitrogen application through drip significantly influenced the growth of garlic. For achieving the higher plant growth and morphological characteristics, garlic crop can be irrigated with canal water along with 125 % RDN through fertigation besides the basal application of recommended dose of phosphorus and potash in the soils.

References

Abera, T. and Adinew, A. (2023). Effect of nitrogen fertilizer rates on yield components yield and quality of garlic (*Allium Sativum* L.) varieties at Kedidagamela district, Southern Ethiopia. *International Journal of Agricultural and Natural Sciences*, **16**(2), 195-206.

Ahmad, J., Wang, H., Song, J., Nuerawuti, M., Zhang, X., Yang, W., Ma, L. and Li, X.X. (2021). The tolerance of an extensive collection of garlic (*Allium sativum* L.) germplasms to salt stress a sustainable solution to salt stress. *Applied Ecology and Environmental Research*, **19**(3), 2281-2303.

Amare, G. and Mamo, T. (2020). Effects of nitrogen and NPS fertilizer rates on fresh yield of garlic (*Allium sativum* L.) at Debre Berhan, Ethiopia. *Journal of Agriculture and Crops*, **6**(8), 113-118.

Anjum, N.N., Anjum, A.M., Feroze, R.M., Saeed, H.M., Shah, R., Rafique, B., Zulfiqar, T., Ashraf, M., Asim, T., Rafique, R., Rafique and S. Ali (2021). Assessment of morphological and biochemical response of different onion cultivars under salt stress conditions. *Pakistan Journal of Science*, **73**(2), 306-312.

Anonymous, (2023-24). Spices Statistics at spice wise area and production. Spices Board (Ministry of Commerce and Industry, Government of India). Available online: www.indianspices.com.

Astaneh, K.R., Bolandnazar, S., Nahandi, Z.F. and Oustan, S. (2019). Effects of selenium on enzymatic changes and productivity of garlic under salinity stress. *South African Journal of Botany*, **121**(4), 447-455.

Christa. Zelm EV, Zhang Y, Testerink C, (2020). Salt Tolerance Mechanisms of Plants. *Annual Review of Plant Biology*, **71**(1), 403-433.

Elkhatib A.H, Gabr, M.S. and Elazomy, AA. (2021). Salt stress relief and growth-promoting effect of sweet pepper plants (*Capsicum annuum* L.) by glutathione, selenium, and humic acid application. *Alexandria Science Exchange Journal*, **42**(3), 583-608.

El-Saber, M.M. (2021). Effect of biosynthesized Zn and Se nanoparticles on the productivity and active constituents of garlic subjected to saline stress. *Egyptian Journal of Desert Research*, **71**(1), 99-128.

Gashaw, B. (2021.). Evaluation of different rates of NPS on growth and yield performances of garlic (*Allium sativum* L.) in Cheha district, Gurage zone, Ethiopia. *International Journal of Agronomy*, **2021**(2), 1-5.

Gashaw, B., Woldetsadik, K. and Belete, K. (2020). Growth and yield performance of garlic (*Allium sativum* L.) varieties to application of vermicompost at Koga Irrigation Site, Northwestern Ethiopia. *Journal of Biology, Agriculture and Healthcare*, **10**(23), 1-7.

Gererufael, A.L., Abraham, T.N. and Reda, B.T. (2020). Growth and yield of onion (*Allium cepa* L.) as affected by farmyard manure and nitrogen fertilizer application in Tahtay Koraro district, Northwestern Zone of Tigray, Ethiopia. *Journal of Vegetos*, **33**(4), 617-627.

Ghassemi, S. and Raei, Y. (2021). Evaluation of ion content, productivity and essential oil quality of garlic under saline conditions and biochar and polyamine treatments. *Journal of Food Composition and Analysis*, **96**(1), 1-8.

Guo, J., Jia, Y., Chen, H., Zhang, L., Yang, J., Zhang, J., Hu, X., Ye, X., Li, Y. and Zhou, Y. (2019). Growth, photosynthesis, and nutrient uptake in wheat are affected by differences in nitrogen levels and forms and potassium supply. *Scientific Reports*, **9**(1), 1-12.

Hussein, M.M. and Faham, E.Y.S. (2018). Chlorophyll, carotenoids pigments and growth of three onion cultivars as affected by saline water irrigation. *Egyptian Journal of Agronomy*, **40**(3), 285-296.

Kazemi, S., Asgary, S., Moshtaghian, J., Rafieian, M., Adelnia, A. and Shamsi, F. (2010). Liver protective effects of hydroalcoholic extract of *Allium hirtifolium* boiss. in rats with alloxan-induced diabetes Mellitus. *Arya Atherosclerosis Journal*, **6**(1), 11-15.

Kevlani, L., Leghari, Z., Wahocho, A.N., Memon, N.U.N., Talpur, H.K., Ahmed, W., Jamali, F.M., Kubar, A. A. and Wahocho, A.S. (2023). Nitrogen nutrition affect the growth and bulb yield of garlic (*Allium Sativum* L.). *Journal of Applied Research in Plant Sciences*, **4**(1), 485-493.

Kilgori, J.M., Magaji, M.D. and Yakudu, A.I. (2007). Productivity of two garlic (*Allium sativum* L.) cultivars as affected by different levels of nitrogenous and phosphorous fertilizers in Sokoto, Nigeria. *American Eurasian Journal Agriculture and Environment Science*, **2**(2), 158- 162.

Kumar, P., Kumar, S. and Aulakh, S.S. (2018). Effect of spacing and nitrogenous fertilizer on growth and yield parameters of garlic (*Allium sativum* L.). *International Journal of Chemical Studies*, **6**(4), 356-359.

Metwally, A.K.B., Yousef, A.F., El-Raheem, A.A.S.A. and El-Raheem, G.H.A. (2024). Exploring the influence of supplemental potassium fertilizer types and rates on garlic quality and yield. *Archives of Agriculture Sciences Journal*, **7**(1), 47-63.

Panse, V.G. and Sukhatme, P.V. (1967). Statistical methods for agricultural research workers. 2nd Edition, Indian Council of Agricultural Research, New Delhi.

Patel, A.J., Vekaria, C.L., Sakarvadia H.L., Parmar K.B. and Ponkia H.P. (2020). Effect of saline irrigation water on growth and yields of onion (*Allium cepa* L.) varieties. *International Journal of Chemical Studies*, **8**(4), 966-969.

R. Munns. (2002). Comparative physiology of salt and water stress. *Plant, Cell and Environment,* **25**(2), 239-250.

Razzaque, A.M., Zamil, S.S., Hasan, M.M. and Siddika, M. (2021). Effects of salinity on growth, yield and nutrients content of two onion cultivars. *Journal of Sher-e-Bangla Agricultural*

University, **12**(2), 24-29.
Regessa, D.M., Gemechis, O.A. and Chala, E.E. (2022). Growth, physiology and yield of onion (*Allium cepa* L.) under salt stress. *In Greener Journal of Agricultural Sciences*, **12**(2), 154-167.
Rizk, S.M. and Deshesh T. (2021). Effect of different irrigation levels and methods of humic acid addition on growth, yield and storability of garlic. *Journal of Plant Production*, **12**(9), 987-997.
Sałata, A., Buczkowska, H., Paplinsk, R. and Rutkowska, A. (2021). The effects of using sulfur and organic bedding on the content of macro and micronutrients and biologically active substances in winter garlic bulbs. *Agriculture*, **11**(399), 1-23.
Singh, H., Batra, K.V., Singh, S. and Bhatia, K.A. (2020). Effect of drip irrigation and nitrogen fertigation on growth characters of garlic. *Indian Journal of Pure and Applied Biosciences*, **8**(3), 123-129.
Sisay, T.B., Agerchu, K.J. and Nuraga, W.G. (2023). Effects of bended NPSB fertilizer rates and varieties on growth and yield of garlic (*Allium sativum* L.) in Gummer district, Central Ethiopia. *The Scientific Temper*, **14**(4), 17-25.
Tadila, G. and Nigusie, D. (2018). Effect of manure and nitrogen rates on growth and yield of garlic (*Allium sativum* L.) at Haramaya, Eastern Ethiopia. *Journal of Horticulture and Forestry*, **10**(9), 135-142.
Taha, M.N., Bukhari, A.N., Hatamleh, A.A., Górnik, K., Sabah, S.S., Hashem, F.A., El-Gabry, Y.A.E., Shahin, M.G.E., Lamlom, S.F., Ahmed, Y.N., Abou-Hadid, A.F. and Abd-Elrahman, S.H. (2024). An attempt to reduce nitrogen fertilization levels and their impact on the growth and productivity of garlic (*Allium sativum* L.) under different planting dates. *Horticulturae*, **10**(12), 1-17.
Tena, N. and Desta, B. (2023). Influence of nitrogen rates on garlic (*Allium sativum* L.) growth, bulb yield and quality in debre berhan, central highland of ethiopia. *Berhan International Research Journal of Science and Humanities,* **7**(1), 51-79.
Tilahun, M., Tena, W. and Desta, B. (2021). Effects of different nitrogen and sulfur fertilizer rates on growth, yield, quality and nutrient uptake of onion (*Allium cepa* L.) at Shewa Robit, North Shewa, Ethiopia. *The Open Biotechnology Journal*, **15**(1), 59-67.
Xu, X., Zhang, X., Ni, W., Liu, C., Qin, H., Guan, Y., Liu, J., Feng, Z., Xing, Y. and Tian, G. (2023). Nitrogen potassium balance improves leaf photosynthetic capacity by regulating leaf nitrogen allocation in apple. *Horticulture Research*, **11**(1), 1-11.
Yitayih, M., Buke, T. and Woelore, W. (2017). The role of nitrogen fertilizer on the growth performance of garlic (*Alliums sativum* L.) at wolaita sodo university. *In International Journal of Agriculture Innovations and Research*, **6**(3), 556-558.
Yohannes, F.D., Ritsema, J.C., Habtu, S., Dam, V.C.J. and Froebrich, J. (2020). Effect of cyclic irrigation using moderately saline and non-saline water on onion (*Allium cepa* L.) yield and soil salinization in semi-arid areas of Northern Ethiopia. *International Commission on Irrigation & Drainage*, **69**(5), 1-13.