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Raising of Water Use Efficiency, Mineral Fertilization and Their Effects on Productivity and Chemical Constituents of Garlic under Micro Drip Irrigation Systems

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Abstract: The objective of this experiment was to investigate the effect of drip irrigation systems and mineral NPK fertilization on growth, yield and chemical constituents of garlic. This experiment was carried out during two successive seasons 2020-2021 and 2021-2022 in sandy soil at Baloza Research Station, North Sinai Governorate, Egypt. The experiment was laid out in a split plot design with three replicates, keeping drip irrigation system [emitters conventional emitters (surface irrigation 4.0 L h^{-1}, subsurface irrigation 4.0 L h-^{1}) and low flow emitters subsurface irrigation (4.0, 3.0, 2.0 L h^{-1})] in the main plots and mineral NPK fertilization (100%, 75% and 50% recommended doses) in the sub-plots. The result showed that the highest values of plant growth parameters, *i.e.*, plant height, number of leaves per plant, leaf fresh, as well as dry weight and bulb diameter, bulb weight, clove number per bulb, and total yield, were recorded when plants irrigated with conventional emitters surface (4 L h^{-1}) as compared with plants irrigated with others drip irrigation systems. On the other hand, plants irrigated with low flow emitters (2 L h^{-1}) recorded the highest values of all chemical constituents, i.e., vitamin A, vitamin C, total phenolic, total flavonoids and antioxidant activity. All mineral NPK fertilization levels significantly enhanced plant growth parameters, yield and its components. The 100% NPK treatment is the superior in its effect on all the aforementioned characteristics. The best results were recorded when plants were irrigated with conventional emitters surface (4 L h^{-1}) and fertilized with 100% NPK recommended doses of mineral fertilization followed by conventional emitters surface (4 L h^{-1}) and fertilized with 75% NPK. The highest values of WUE is obtained by LEF 2 L h^{-1} and 100% of doses. But, the best results in chemical constituents were obtained by irrigated with low flow emitters (2 L h^{-1}) and addition of 75% NPK.

Key words: Garlic, Drip irrigation, Mineral fertilization, Growth, Yield.

1. Introduction

Garlic (*Allium sativum* L.) is Egypt's most important vegetable crop and belongs to the Liliaceae family. It is one of the most ancient spices having pungent characteristics of the Allium genus **(Bose and**

Som 1990). Garlic is a member of the family Liliaceae. The second most widely used spice crop of Allium after onion **(Purseglove, 1985)**. It is a well-known spice with many health benefits due to its several bioactive components, including organic sulfides, saponins, phenolic compounds, and polysaccharides **(Szychowski *et al*., 2018)**. Many studies reported that garlic has amazing biological qualities, including antibacterial, anti-inflammatory, anticancer, anti-inflammatory, immunomodulatory, anti-diabetic, and antioxidant effects, **(Boonpeng *et al*., 2014 and Yun *et al*., 2014)**. Furthermore, raising the temperature and lowering the humidity in garlic increases its polyphenol content and total flavonoid content, **(Kim, 2013 & Sun and Wang, 2018)**. One of the most significant and aromatic herbs that have been utilized in traditional medicine since ancient times is garlic **(Ayaz and Alposy 2007; Badal *et al*. 2019)**. According to **Barnes *et al*. (2002)** and **Badal *et al*. (2019)**, it is regarded as the second species that is used alongside onions, which are used as a medicine against several common ailments, including the common cold, the flu, snake bites, hypertension, lung disorders, whooping cough, stomach disorders, cold, earache and assists in preventing cardiovascular disease.

Garlic is a cool-season vegetable crop with a long growing season of approximately seven months. The potential nutrient and water needs are, therefore, high. Garlic growers worldwide are continually under increasing pressure to optimize irrigation and nutrient management **(Fan *et al*., 2020; Gallardo *et al*., 2020)**. To significantly improve irrigation and nutrient management, many technologies were required. One of these technologies is water-drip irrigation fertilization technology, which has the advantages of saving water, fertilizer, labor, reducing pests and diseases, increasing crop yield, protecting the environment, etc. It can increase yield. **(Fan *et al*., 2020)**, and use low-flow drip irrigation that enhances water lateral movement and plant yield and quality **(Elnesr *et al*., 2016)**.

Drip irrigation involves placing tubing with emitters on the ground alongside the plants. The emitters slowly drip water into the soil at the root zone **(Hadiutomo, 2012)**. The drip irrigation system irrigation technique helps meet plants' water needs so that it will increase the utilization of soil nutrients, reduce pressure or accelerate seedlings' adaptability, and increase plant growth success **(Surata, 2007)**. It reduces water requirements and checks unwanted weed growth. Drip irrigation is a high-frequency irrigation method with an efficiency of about 98-99% **(Ertek *et al*., 2007)**. Drip irrigation is beneficial for plants in terms of yield, better plant morphological characteristics, viz. plant height number of branches, root finesses and root length **(Antony and Sigandhupe, 2004)**. This study aimed to investigate the effects of drip irrigation systems and mineral NPK fertilization on growth, yield, and chemical constituents of garlic grown in sandy soil under North Sinai Governorate conditions.

2. Material and Methods

2.1. Experimental site

This study was conducted at Baloza Research Station in North Sinai Governorate, Egypt, located at latitude 31°3′N and longitude 32°36′E during two successive growing seasons (2020/2021 and 2021/2022) to evaluate the effect of drip irrigation systems and mineral NPK fertilization on growth, yield, and chemical constituents of garlic cv. Sids 40. The soil was sand texture according to the USDA Soil Taxonomy (2014). The soil analyses indicated that the soil was very slightly alkaline (pH = 8.04-8.23), and slightly fertile [organic matter = 0.74-0.83% with low available phosphorous (1.25-1.92 mg kg^1) and potassium (21-27 mg kg^1) concentrations]. Irrigation water was pumped from As-Salam conduit water, with (on average) pH 7.45 and EC 1.98 dS m^1.

2.2. Plant material and experimental treatments

Garlic (*Allium sativum* L. cv. Sids 40) was planted on October 1st in both seasons on both sides of ridges, 10 cm apart. The experiment was arranged in a split-plot design with three replications. The main plots were assigned to the drip irrigation systems; the systems include two types of emitters: conventional emitters (surface irrigation 4.0 L h^{-1} and subsurface irrigation 4.0 L h^{-1}) and low flow emitters subsurface irrigation (4.0, 3.0 and 2.0 L h^{-1}), while the subplots were occupied by the three levels of mineral NPK fertilization (100, 75 and 50% from recommended doses). The recommended doses of mineral fertilization according to the Egyptian Ministry of Agriculture were calcium super-phosphate (15% P_2O_5) at the rate of 960 kg ha^{-1}, Ammonium sulphate (20.5% N) at the rate of 720 kg

ha^{-1}, and potassium sulphate (48% K_2O) at the rate of 480 kg ha^{-1}. The experimental plot area was 10.5 m^2; each experimental plot consisted of 3 ridges, 5 m length and 0.7 m width. The farmyard manure (48 m^3 ha^{-1}) was added at soil preparation, whereas the mineral fertilizers were added in doses (one-third of the amount when preparing the soil for cultivation and the other two-thirds in doses during the growing seasons with irrigation water.

2.3. Water irrigation requirements

Garlic irrigation water requirements were calculated with Baloza weather station (Table 1). Irrigation operating was according to tensiometer reading. Irrigation scheduling was done according to **Doorenbos and Pruitt (1977)**.

$$IR = \left[\frac{S_p \times S_L \times K_c \times Et_o \times A \times I_{INTERVAL} \times K_r}{1000 \times Ea} \right] + LR$$

Where :
IR = Irrigation water requirements (m^3ha^{-1} day^{-1})
Sp = Distance between plants in the same drip line =0.07 m
Sl = Distance between drip lines = 0.5 m
Kc = Crop factor of garlic, according to **FAO, 1984**
Et0= Potential evapotranspiration (mm day^{-1})
A = Area irrigated (m^2)
Interval= Irrigation interval (3 days under experimental conditions)
Kr = Reduction factor that depends on ground cover (%)
LR= Leaching requirements (%)
Ea = Application efficiency (%) where 90% drip irrigation

Table (1). Seasonal water requirements of garlic plants

Growth stage		Months	ET_o	K_c	Et_c	I_r m^3ha^{-1}
			mm day^{-1}		mm day^{-1}	
Initial (71)		31 days of October	4.30	0.70	3.01	559.86
		30 days of November	3.10	0.70	2.17	403.62
		11days of December	2.30	0.70	1.61	299.46
Development (40)		20 days of December	2.30	0.95	2.19	406.41
		20 days of January	2.37	0.95	2.25	418.78
Mid (60)		11 days of January	2.37	1.00	2.37	440.82
		28 days of February	2.60	1.00	2.60	483.60
		20 days of March	4.57	1.00	4.57	850.02
Late (20)		11 days of March	4.57	0.70	3.20	595.01
		10 days of April	5.50	0.70	3.85	716.10
Total (Ir) + 10%	Emitter (4 l/h)	5173.68 m^3 ha^{-1}				
	Emitter (3 l/h)	3880.26 m^3 ha^{-1}				
	Emitter (2 l/h)	2586.84 m^3 ha^{-1}				

2.4. Data recorded for the studied traits

2.4.1. Plant growth parameters

Growth parameters were evaluated after 140 days of planting. Plant height, leaf number per plant, leaf fresh and dry weight was determined, with ten plants in each experimental plot.

2.4.2. Yield and its components

The harvest started at the full maturity stage of bulbs (190 days from planting). Bulb diameter, bulb weight, clove number per bulb, and total yield were determined with ten plants from each experimental plot.

2.4.3. Water use efficiency (kg/m^3)

Field water use efficiency (WUE) is calculated according to **(Vietes, 1962 and Michael, 1978)**:

$$\text{WUE}= \frac{\text{Total yield (t/ha)}}{\text{Applied water amounts (m}^3\text{/ha)}}$$

2.4.4. Chemical components

The fresh cloves of garlic were taken from the garlic plants in this study and washed thoroughly using distilled water to remove dust or any other unwanted particles adhering to the surface of the cloves to determine their chemical components.

2.4.4.1. Determination of vitamin A in garlic cloves by HPLC according to (Dionex, 2010)

HPLC condition for analysis of vitamin A

The system Thermo (Ultimate 3000) consisted of: pump, automatic sample injector, and associated DELL-compatible computer supported with Cromelion7 interpretation program. A diode array detector DAD-3000 was used. Samples and standards solutions as well as the mobile phase were degassed and filtered through 0.45 µm membrane filter (Millipore). Identification of the compounds was done by comparison of their retention's time and UV absorption spectrum with those of the standards. Solvent preparation: 20 mM Hexane dissolved in HPLC deionized water. Sample preparation: 5 ml of sample are mixed with 5 ml of mobile phase. The mixture is centrifuged at 5000 rpm for 5m and filtered through 0.45 µm membrane. Mobile phase: Acetonitrile: Methanol (75:25). Flow rate: 1.0 ml/min. Injection Vol: 20 µl. Column: RP- C18. Column size: SVEA -RP- C18 gold 5µm 250×4.6mm- NANOLOGICA-Sweden. Temperature: 30°C. Wavelength: 325 nm.

2.4.4.2. Determination of vitamin C in garlic cloves by HPLC according to (Nollet, 2000)

HPLC condition for analysis of vitamin C

The system Thermo (Ultimate 3000) consisted of: pump, automatic sample injector, and associated DELL-compatible computer supported with Cromelion7 interpretation program. A diode array detector DAD-3000 was used. Samples and standards solutions as well as the mobile phase were degassed and filtered through 0.45 µm membrane filter (Millipore). Identification of the compounds was done by comparison of their retention's time and UV absorption spectrum with those of the standards. Solvent preparation: 20 mM KH2PO4 dissolved in HPLC deionized water to adjust pH to 2.5, 3.0, 3.5 and 4.0. Sample preparation: 5 ml of sample are mixed with 5 ml of mobile phase. The mixture is centrifuged at 5000 rpm for 5m and filtered through 0.45 µm membrane. Mobile phase: 20% methanol – 80% potassium buffer at pH 3.0 at WL 300 nm. Flow rate: 1 mm/ min. Injection vol.: 10µg. Column: C18. Column size: SVEA -RP- C18 gold 5µm 250×4.6mm- NANOLOGICA-Sweden. Temperature: 40° C. Wavelength: 240 nm.

2.4.4.3. Determination of total phenolic components

200 µL of 70% methanolic extract (1 mg/mL) were made up to 3 mL with distilled water. Mixed thoroughly with 0.5 mL of Folin–Ciocalteu reagent for 3 min, followed by the addition of 2 mL of 20% (w/v) sodium carbonate. The mixture was allowed to stand for a further 60 min in the dark, and absorbance was measured at 650 nm. The total phenolic content was calculated from the calibration curve, and the results were expressed as mg of gallic acid equivalent per g dry weight **(Kaur and Kapoor, 2002)**.

2.4.4.4. Determination of total flavonoids

Different aliquots of the solution of quercetin equivalent to 5-300 µg were separately introduced into test tube, evaporated to dryness on a hot water bath (40- 50°C). Two grams of each defatted powder were extracted with petroleum ether, then ethanol (95 %) was added and the volume of the extract was adjusted to 50 ml. Five ml of the extract were transferred to a test tube, then 5 ml aliquots of 0.1 M $AICl_3$ reagent were added. The solution was evaporated to dryness in water bath. The absorbance of the color developed was measured using UV at 445 nm for quercetin, **(Karawaya and Aboutabl, 1982)**.

2.4.4.5. In vitro antioxidant activity by DPPH assay

The hydrogen atom or electron donation abilities of the corresponding extracts were measured from the bleaching of the purple- colored methanol solution of 2,2 -diphenyl -1-picryl hydrazyl (DPPH). This spectrophotometric assay was done using the stable radical DPPH as a reagent according to the method of Burits and Bucar (2000). Briefly, 50 µl of the extracts (various concentrations) were added to 5 ml of the DPPH solution (0.004 % methanol solution). After 30 min incubation at room temperature, the absorbance was read against pure methanol at 517 nm. The radical- scavenging activities of the samples were calculated as percentage of inhibition according to the following equation:

$$I\% = \frac{A\ blank - A\ sample}{A\ blank} \times 100$$

Where A blank is the absorbance of the control (containing all reagents except the test compound), and A sample is the absorbance of the test compound. Extract concentration providing 50% inhibition (IC50) was calculated from the plot of inhibition percentage against extract concentration using PHARM/PCS-version 4. All tests were done in triplicate.

2.5. Statistical Analysis

The obtained data were then statistically analyzed using COSTAT software package. The means that were significant were separated using Duncan's multiple range tests at $P \leq 0.05$ **(Gomez and Gomez, 1984)**.

3. Results and Dissection

3.1. Plant growth parameters

Data presented in Table 2 show the growth parameters of garlic plants in response to drip irrigation systems (conventional emitters and low flow emitters subsurface irrigation) in the two seasons of the study. The results show that growth parameters like plant height, number of leaves per plant, leaf fresh, and dry weight

differed significantly due to drip irrigation systems. Plants irrigated with conventional emitters surface (4 L h^{-1}) significantly recorded the highest values of all the aforementioned characteristics, followed by conventional emitters sub-surface (4 L h^{-1}), and followed by low flow emitters (4 L h^{-1}) in both growing seasons. The low flow emitter’s treatment (2 L h^{-1}) recorded the lowest values of all plant growth in both seasons. Similar findings were reported by **Antony and Singandhupe (2004)**, **Bhasker *et al*. (2018)** and **Jata *et al*. (2018)**.

Table (2). Effect of drip irrigation methods and mineral fertilization on plant growth parameters of garlic during 2020/2021 and 2021/2022 seasons

Treatments	Plant height (cm)		Number of leaves/plant		Leaf fresh weight (g)		Leaf dry weight (g)	
	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022
Irrigation methods								
CES 4 L h^{-1}	51.78a	47.65a	10.89a	10.44a	37.01a	38.66a	5.14a	5.41a
CES-S 4 L h^{-1}	47.56b	45.19b	10.56a	9.89a	36.90a	37.46b	5.13a	5.24b
LFE 4 L h^{-1}	46.89b	42.78c	10.22a	9.56a	34.57b	36.98b	4.80b	5.18b
LFE 3 L h^{-1}	42.33c	34.89d	8.56b	8.22b	30.22c	32.97c	4.20c	4.62c
LFE 2 L h^{-1}	37.89d	28.67e	6.89c	7.33b	26.69d	26.61d	3.71d	3.73d
Fertilization								
100% FRD	47.67a	42.88a	9.87a	9.47a	34.40a	36.16a	4.78a	5.06a
75% FRD	46.27a	39.82b	9.53ab	9.13ab	33.20b	35.22b	4.61b	4.93b
50% FRD	41.93b	36.80c	8.87b	8.67b	31.64c	32.23c	4.40c	4.51c
Irrigation methods x Fertilization								
CES 4 L h^{-1} x 100% FRD	51.00ab	49.17a	11.00a	10.33a	37.46a	39.16ab	5.21a	5.48ab
CES 4 L h^{-1} x 75% FRD	54.33a	48.45a	11.33a	10.67a	37.77a	39.68a	5.25a	5.55a
CES 4 L h^{-1} x 50% FRD	50.00abc	45.33ab	10.33abc	10.33a	35.80bc	37.16d	4.98bc	5.20d
CES-S 4 L h^{-1} x 100% FRD	49.67abc	47.92a	11.00a	10.33a	37.59a	38.58abc	5.23a	5.40abc
CES-S 4 L h^{-1} x 75% FRD	47.67bcd	45.00ab	10.67ab	10.00ab	36.99ab	38.03bcd	5.14ab	5.32bcd
CES-S 4 L h^{-1} x 50% FRD	45.33bcd	42.67bc	10.00abc	9.33abcd	36.13abc	35.78e	5.02abc	5.01e
LFE 4 L h^{-1} x 100% FRD	48.67bcd	45.00ab	10.67ab	10.00ab	36.47abc	39.00ab	5.07abc	5.46ab
LFE 4 L h^{-1} x 75% FRD	47.67bcd	43.00bc	10.33abc	9.67abc	35.19c	37.81cd	4.89c	5.29cd
LFE 4 L h^{-1} x 50% FRD	44.33cd	40.33c	9.67abc	9.00abcde	32.04d	34.13f	4.45d	4.78f
LFE 3 L h^{-1} x 100% FRD	46.00bcd	39.67c	9.33abcd	9.00abcde	32.27d	34.27f	4.49d	4.80f
LFE 3 L h^{-1} x 75% FRD	43.33d	34.33d	8.33bcde	8.00bcde	29.88e	33.72f	4.15e	4.72f
LFE 3 L h^{-1} x 50% FRD	37.67e	30.67de	8.00cde	7.67cde	28.51f	30.92g	3.96f	4.33g
LFE 2 L h^{-1} x 100% FRD	43.00d	32.67d	7.33de	7.67cde	28.22f	29.77h	3.92f	4.17h
LFE 2 L h^{-1} x 75% FRD	38.33e	28.33e	7.00e	7.33de	26.16g	26.87i	3.64g	3.76i
LFE 2 L h^{-1} x 50% FRD	32.33f	25.00f	6.33e	7.00e	25.70g	23.18j	3.57g	3.25j

FRD: fertilization recommendation doses, CES: conventional emitters surface, CES-S: conventional emitters sub-surface, LFE: low flow emitters

The results in Table 2 show that all recommended doses of mineral NPK fertilization treatments significantly enhanced plant growth parameters in both seasons. Application of 100% NPK gave the highest values of plant height, number of leaves per plant, and leaf fresh and dry weight, while application of 50% NPK gave the lowest values in both seasons. These results were in agreement with **Salim and Abou El-Yazied (2015)**, **Jilani *et al*. (2019)** and **Obiadalla-Ali *et al*. (2021)**. The stimulating effect of NPK fertilization on plant growth may be attributed to its effective role in many biochemical processes within plants as it is necessary for cell protoplasm formation, photosynthesis activity in all plants and necessary for division and merestimic activity in plant organs **(Russel, 1973)**. Furthermore, nitrogen is essential for the synthesis of chlorophyll, enzymes and proteins, phosphorus is essential for root growth, phospho-proteins, phospholipids and ATP, ADP formation, and potassium play an important role in the promotion of enzymes activity and enhancing the translocation of assimilates and protein synthesis **(Devlin and Witham, 1986)**. Phosphorus is a component of high-energy substances such as ATP, ADP, and AMP; it is also important for nucleic acids and phospholipids **(Salim and Abou El-Yazied, 2015)**.

The effect of the interaction between the two studied factors on plant growth parameters differed significantly in the two growing seasons. The highest values were obtained by irrigated with conventional emitters surface (4 L h^{-1}) and addition of 100% NPK or 75% NPK, while the lowest values were obtained by irrigated with low flow emitters (2 L h^{-1}) and addition of 50% NPK in both seasons.

3.2. Yield and its components

Data presented in Table 3 show the impact of different drip irrigation systems on yield and its components (bulb diameter, bulb weight, clove number per bulb, and total yield) of garlic grown in two consecutive years. The drip irrigation systems significantly affect garlic yield and its components. The highest values of these traits were recorded with plants irrigated with conventional emitters surface (4 L h^{-1}), followed by conventional emitters sub-surface (4 L h^{-1}), and followed by low flow emitters (4 L h^{-1}) in both growing seasons. On the other hand, the conventional emitters sub-surface (2 L h^{-1}) treatment gave the lowest values of bulb diameter, bulb weight, clove number per bulb, and total yield in both seasons. Similar results were found by **Antony and Singandhupe (2004)** and **Jata *et al*. (2018)**.

As shown in Table 3 garlic yield and its components were significantly affected by application of mineral NPK fertilization treatments in both seasons. The results reflected clearly that the mean values of bulb diameter, bulb weight, clove number per bulb, and total yield increased generally by increasing the NPK level up to 100% level. Most of the detected increments were found significant in all characters of garlic yield and its components, in both growing seasons. However, the application of the highest level (100% NPK) did result in a further significant increase in the mean values of the four previously mentioned characters. These results reflected a general correspondence with those obtained by **Arisha and Bardisi (1999)**, **Doss *et al*. (2015)**. The obtained increase in tuber yield of garlic due to application of NPK fertilizer may be attributed to the solubility and the availability of N, P and K and their supply to plant **(Dawa and Bazeed, 2009)**. The enhancer plant growth may be due to increased nitrogen application rates, which play a significant role in building blocks of amino acids, enhancing cell division, cell elongation, chlorophyll synthesis, and protein synthesis, which promote the growth of plants **(Obiadalla-Ali *et al*., 2021)**.

Table (3). Effect of drip irrigation methods and mineral fertilization on yield and its components of garlic during 2020/2021 and 2021/2022 seasons

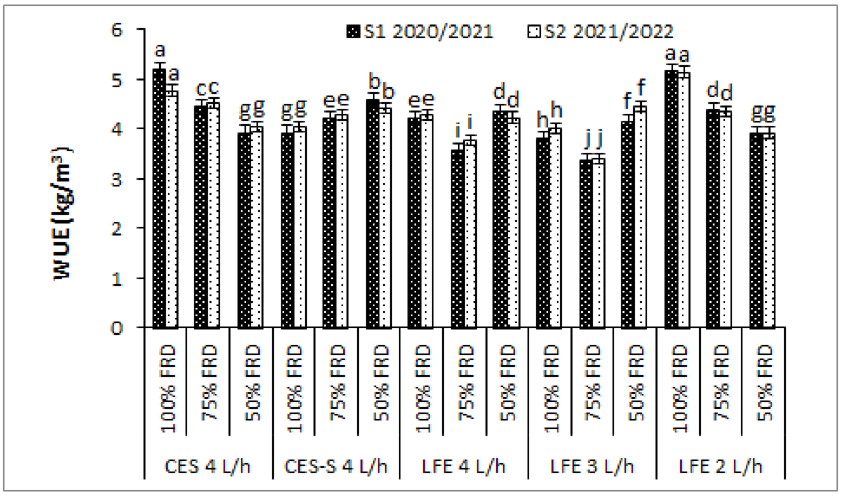
Treatments	Blub diameter (cm)		Blub weight (g)		Cloves number/bulb		Total yield (t ha^{-1})	
	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022
Irrigation methods								
CES 4 L h^{-1}	6.79a	6.34a	96.81a	94.99a	23.56a	20.11a	23.42a	22.98a
CES-S 4 L h^{-1}	6.31b	6.02b	88.18b	88.97b	19.33b	18.33b	21.33b	21.52b
LFE 4 L h^{-1}	6.16b	5.78c	82.24c	83.04c	17.44c	17.56b	19.89c	20.09c
LFE 3 L h^{-1}	4.82c	4.58d	59.71d	65.36d	15.44d	13.56c	14.45d	15.81d
LFE 2 L h^{-1}	3.73d	4.03e	48.05e	53.22e	11.33e	10.56d	11.62e	12.87e
Fertilization								
100% FRD	5.87a	5.60a	84.91a	83.39a	19.20a	18.33a	20.54a	20.17a
75% FRD	5.67a	5.38b	74.62b	78.47b	17.33b	15.67b	18.05b	18.98b
50% FRD	5.14b	5.06c	65.46c	69.49c	15.73c	14.07c	15.84c	16.81c
Irrigation methods x Fertilization								
CES 4 L h^{-1} x 100% FRD	7.00a	6.52a	111.06a	102.10a	24.33a	22.33a	26.87a	24.70a
CES 4 L h^{-1} x 75% FRD	6.93a	6.38a	95.29abc	96.47b	23.33ab	19.67b	23.05abc	23.34b
CES 4 L h^{-1} x 50% FRD	6.43ab	6.11ab	84.08bcde	86.41cd	23.00ab	18.33c	20.34bcde	20.91cd
CES-S 4 L h^{-1} x 100% FRD	6.50ab	6.16ab	98.35ab	94.43b	21.33abc	21.00b	23.79ab	22.84b
CES-S 4 L h^{-1} x 75% FRD	6.47ab	6.05ab	90.12bcd	91.56bc	19.33bcde	17.67cd	21.80bcd	22.15bc
CES-S 4 L h^{-1} x 50% FRD	5.97abc	5.85b	76.05cdef	80.92d	17.33cdef	16.33de	18.40cdef	19.58d
LFE 4 L h^{-1} x 100% FRD	6.53ab	6.15ab	93.27bc	90.38bc	20.33abcd	20.00b	22.56bc	21.86bc
LFE 4 L h^{-1} x 75% FRD	6.27ab	5.80b	81.57bcde	85.76cd	17.00cdef	17.67cd	19.73bcde	20.75cd
LFE 4 L h^{-1} x 50% FRD	5.67bcd	5.39c	71.88defg	72.97e	15.00efg	15.00e	17.39defg	17.65e
LFE 3 L h^{-1} x 100% FRD	5.23cd	4.95d	66.48efg	71.58e	17.00cdef	16.00de	16.08efg	17.32e
LFE 3 L h^{-1} x 75% FRD	4.93de	4.63d	59.23fgh	64.78f	15.67defg	13.33f	14.33fgh	15.67f
LFE 3 L h^{-1} x 50% FRD	4.30ef	4.15e	53.44gh	59.74g	13.67fgh	11.33g	12.93gh	14.45g
LFE 2 L h^{-1} x 100% FRD	4.10ef	4.22e	55.39gh	58.48gh	13.00fgh	12.33fg	13.40gh	14.15gh
LFE 2 L h^{-1} x 75% FRD	3.75f	4.05e	46.90h	53.80h	11.33gh	10.00h	11.35h	13.01h
LFE 2 L h^{-1} x 50% FRD	3.33f	3.82e	41.85h	47.38i	9.67h	9.33h	10.13h	11.46i

FRD: fertilization recommendation doses, CES: conventional emitters surface, CES-S: conventional emitters sub-surface, LFE: low flow emitters

Data in Table 3 show that bulb diameter, bulb weight, clove number per bulb, and total yield are significantly affected by the interaction between drip irrigation systems and mineral NPK fertilization in the two growing seasons. The higher values of all the characters above were recorded by plants irrigated with conventional emitters surface (4 L h^{-1}) and fertilized with 100% NPK treatment. On the other hand, the lower values were recorded when plants irrigated with conventional emitters sub-surface (2 L h^{-1}) and fertilized with 50% NPK treatment in the two growing seasons.

3.3. Water use efficiency (WUE)

Data illustrated in Figure 1 show the significant differences between treatments. For irrigation system treatment, the average highest significant value of water use efficiency, WUE was 4.98, 4.73, 4.14, 3.89, and 3.98 kg/m^3 for CES 4 L h^{-1}, LEF 2 L h^{-1}, CES-S 4 L h^{-1}, LEF 4 L h^{-1} and LEF 3 L h^{-1}, respectively. The significant differences for the 100% doses of fertilizers, for fertilizer treatments, the average highest significant value of water use efficiency, WUE was 4.45, 4.18, and 3.98 kg/m3 for 100% NPK, 75% NPK and 50% NPK, respectively.



FRD: fertilization recommendation doses, CES: conventional emitters surface, CES-S: conventional emitters sub-surface, LFE: low flow emitters

Figure (1). Effect of drip irrigation methods and mineral fertilization on water use efficiency (WUE)

For the interaction of irrigation methods and NPK fertilization doses (Figure 1), the highest significant value of water use efficiency was 5.16 kg/m^3 (LEF 2 Lh^{-1} x 100%FRD) and 4.98 kg/m3 (CES 4 L h^{-1} x 100% FRD), the value of water use efficiency is so high for LEF 2 L h^{-1}, it can be approved in case the yield is equal or more than the economic yield, not less, other important notes need to clear, It can accept that the crop decreases in the water or fertilizer application according to the surrounding conditions and the laws of the country. For example, in France, the state compensates the farmer for the decrease in the crop due to the reduction of nitrates to maintain the non-pollution of groundwater, reuse it again keep it pure, and support the ecosystems. Likewise, in Spain, the reduction in the crop and the amount of water can be accepted due to the water and energy crisis, and this decrease can be economically acceptable due to the high energy costs of pumping water and also the scarcity and high price of water. Therefore, the factor LEF 3 L h^{-1} is considered acceptable due to the saving of a quarter of applied water and it is also possible to accept the additions of fertilizers for the rest of the factors. These results agree with **(Oktem *et al*., 2003, Wan and Kang, 2006, Howell *et al*. 1997 and Camp *et al*. 1989).**

3.4. Chemical components of cloves

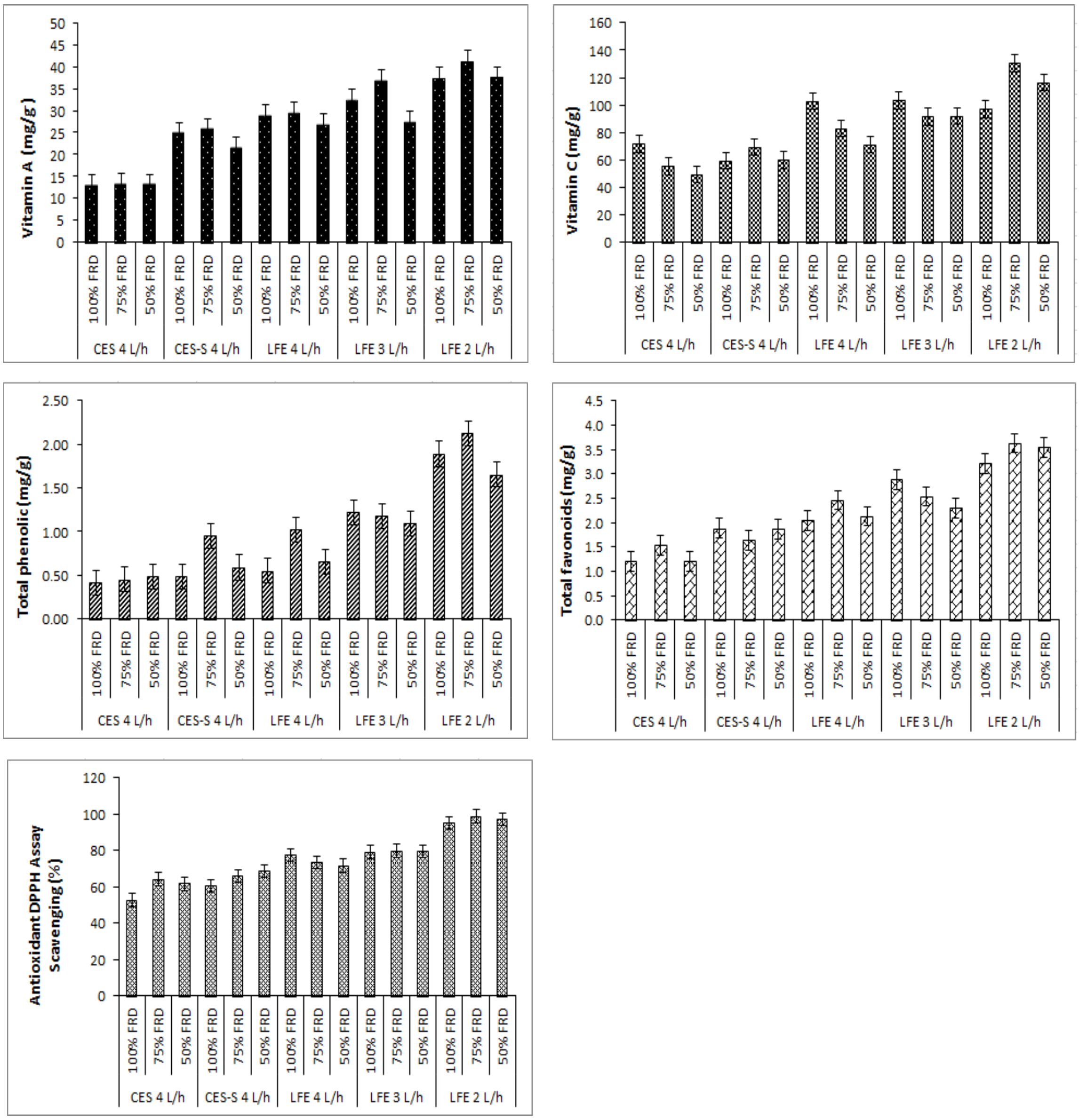
Data presented in Figure 2 show the chemical components of garlic cloves in response to drip irrigation systems (conventional emitters and low flow emitters subsurface irrigation) in this study. The results showed that chemical components such as vitamin A, vitamin C, total phenolic, total flavonoids and antioxidant activity different affects due to drip irrigation systems. Plants irrigated with low flow emitters treatment (2 L h^{-1}) recorded the highest values of all the aforementioned characteristics, followed by low flow emitters treatment (3 L h^{-1}). The conventional emitters surface (4 L h^{-1}) recorded the lowest values of vitamin A, vitamin C, total phenolic, total flavonoids and antioxidant activity. The increment in all chemical components with decreasing water of irrigation, it may be due to concentration effect which increases osmotic potential inside plant cells to face the stress **(Taha *et al*., 2019)**.

The results in Figure 2 reveal that all recommended doses of mineral NPK fertilization treatments enhanced chemical parameters in second season. Application of 75 % NPK gave the highest values of vitamin A, vitamin C, total phenolic, total flavonoids and antioxidant activity (29.40, 86.01, 1.14, 2.36 mg/g and 79.43%) respectively, while application of 50% NPK gave the lowest values of this regared except antioxidant activity the lowest value (93.07%) recorded at 100% NPK treatment. Because NPK is essential for the formation of cell protoplasm, photosynthesis in all plants, division, and merestimic activity in plant organs, NPK fertilization has a stimulating effect on chemical components. This effect can be attributed to its effective role in many biochemical processes within plants **(Russel, 1973)**. Furthermore, Potassium plays a significant role in promoting enzymes activity and enhancing the translocation of assimilates and protein synthesis, while nitrogen is necessary for the synthesis of chlorophyll, enzymes, and proteins. Phosphorus is necessary for phospho-proteins, phospholipids, and ATP, and ADP formation **(Devlin and Witham, 1986)**. Phosphorus is necessary for nucleic acids and phospholipids, as well as high-energy compounds like ATP, ADP, and AMP **(Salim and Abou El-Yazied, 2015)**.

The effect of the interaction between the irrigation methods and minerals fertilizers doses on chemical parameters showed different affects. The highest values of vitamin A, vitamin C, total phenolic, total flavonoids and antioxidant activity were obtained by irrigated with low flow emitters (2 L h^{-1}) and addition of 75% NPK (41.39, 130.29, 2.12, 3.63 mg/g and 98.96%) respectively, followed by irrigated with low flow emitters (2 L h^{-1}) and addition of 50 % NPK (37.64, 116.29, 1.65, 3.54 mg/g and 79.01%), respectively in comparison with other interaction treatments under this study. Meanwhile the lowest value of this respect obtained from plants irrigated with conventional emitters surface (4 L h^{-1}) and addition of 100% NPK (12.94, 71.67, 0.41, 1.21 mg/g and 52.82%), respectively.

4. Conclusion

The present study investigated the effects of drip irrigation systems and mineral NPK fertilization on garlic plants. The results were examined regarding different growth parameters, yield, and chemical components. The result showed that the highest values of plant growth parameters and total yield were obtained by irrigated plants with conventional emitters surface (4 L h^{-1}) and fertilized with 100% NPK recommended doses of mineral fertilization followed by conventional emitters surface (4 L h^{-1}) and fertilized with 75% NPK. Still, the highest values of WUE is obtained by LEF 2 L h^{-1} and 100% of doses. On the other hand, the highest values of all chemical constituents were obtained by irrigated plants with low flow emitters (2 L h^{-1}) and the addition of 75% NPK. The balance between yield, water, and fertilizers must consider the economic, ecosystem, and Country legislation.



FRD: fertilization recommendation doses, CES: conventional emitters surface, CES-S: conventional emitters sub-surface, LFE: low flow emitters

Figure (2). Effect of drip irrigation methods and mineral fertilization on chemical components of garlic cloves

Conflicts of Interest: The authors declare no conflict of interest.

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