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Effect of Irrigation Numbers and Plant Density on Growth, Yield of Garlic Cultivar Eggaseed [-1]

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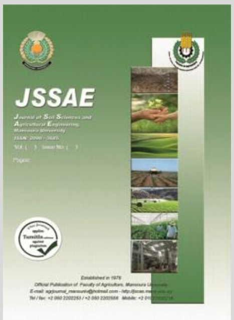

ABSTRACT

Two field trials were carried out during the two successive winter seasons of 2015/2016 and 2016/2017 at the Experimental Farm of Sids Horticulture Research Station, Agriculture Research Center, Egypt. The objective of this study is to investigate the effect of both irrigation frequency, i.e., irrigation once every 14 days (the plant received 10 irrigations),21days (the plant received 7 irrigations) and 28 days (the plant received 5 irrigations) and plant density. The cloves number was 30 cloves/ m^2 (D_1) in low plant density 45 (D_2) and 60 cloves/ m^2 (D_3) in the higher plant density was used Egaseed-1 garlic cultivar. The obtained results indicated that effect of irrigation numbers and plant densities were significantly affected all vegetative growth parameters (plant height,, leave numbers, vegetative growth weight and bulbing ratio) and all bulb quality parameters (bulb dry matter %, clove weight (g), bulb fresh weight (g) and cured bulb diameter (cm) of Eggaseed-1garlic cultivar where the highest values of various vegetative growth and bulb quality parameters were recorded with plants that received 10 irrigations addition to low plant population (30 cloves / m2). The highest marketable yield were recorded when plants received 10 irrigations in addition to low populations 30 cloves /m^2. However, the lowest values of all yield parameters were recorded when plants received 5 irrigations in addition to high population 60 plants/m^2. in both seasons. Irrigation plants every 28 days with high population (60 plants/m2) significantly decreased weight loss % after two, four and six months under storage in both seasons.

Keywords: garlic, irrigation numbers, growth, yield, water relationships

INTERODUCTION

Garlic (*Allium sativum* L.) is belongs to family Alliaceae. It is an herbaceous annual and the second most important bulb crop after onion. Original abode of garlic is said to be Central Asia and Southern Europe, especially Mediterranean sea region (Simon, 2001). The economic yield is obtained from its underground developed part known as bulb. Its pungent flavour makes it used mainly as a spice, seasoning and flavoring for foodstuff involving both green tops and bulbs. Its medicinal value is also well recognized in the control and treatment of hypertension, worms, germs, bacterial and fungal diseases, diabetes, cancer, ulcer, rheumatism etc. (Kilgori *et al*. 2007).

Optimum water application is a pre-requisite to successful garlic production in relation to bulb size, weight and quality. Garlic requires adequate moisture for good establishment, growth, development bulb yield and bulb quality (Karaye and Yakubu, 2007). Doro (2012) reported that garlic not tolerates neither excess water nor water stress as both could decrease bulb yield of up to 60 percent. Garlic crop is sensitive to water limitation and drought stress, and optimum yield of this bulb crop depends on well managed irrigation. Soil moisture is an important factor that influences the growth, development and yield of garlic. Growing period of garlic is mainly dry and soil moisture is dependent on the irrigation and its frequency. Thus frequency of irrigation influences growth of bulb and its yield. (Bhuiya *et al.* 2003).

The yield and quality of garlic bulbs largely depend upon the genetic characters of the variety, climate and management practices such as time of planting, nutrients, irrigation, plant density, plant protection, size of cloves … etc. A lot of work has been undertaken in Egypt and abroad to investigate the optimum conditions for better plant growth and development of garlic crop. Among various factors, irrigation number and plant density have been reported to exert a great influence on vegetative growth, total yield and quality of garlic crop. Miko *et al.* (2000) reported that garlic is sensitive to moisture stress and high temperature and about 60% reduction in yield has been associated with water stress. The number of irrigation required for garlic depends upon the moisture retention capacity of soil and climatic conditions. Hanson *et al.* (2003) reported that the highest garlic yield was obtained by irrigating once a week. For constant growth and marketable yield the moisture content of soil should be maintained at optimum level. Delay in moisture supply during the vegetative stage causes stunted growth while no water supply during bulbing may cause splitting or cracking of bulbs and reduced yield. Sula (1990) observed that more frequent irrigation prolonged the growth period by 10-12 days increased photosynthetic activity thus increased yield and reduced cost per unit of product. He added that achieved yield varied from 5.28 to 6.16 t/ha by irrigating the crops 3-4 times. Mohammed and Rokon (2017) reported that irrigation interval significantly influenced yield and morphological characteristics (plant height, individual bulb weight/plant, number of clove/bulb, clove weight and bulb yield), Where irrigation frequency of 10 days interval resulted with the highest bulb yield of 10.48 t/ha with 372 mm of seasonal water used. It was followed by 15 days interval (9.81 t/ha) where 275 mm of seasonal water was

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used. They added that minimum weight loss was obtained at 10 and 15 days intervals. They concluded that from an economic point of view, farmers can take irrigation schedules of 10 or 15 days interval for maximum return where irrigation water is available. At water stress conditions garlic might be irrigated at 20 days interval but consequently bulb yield will be reduced. Many researchers found a direct relationship between yield and yield components of bulb crops with available moisture and time of irrigation (Ahmed *et al.,* 2007; Singh *et al,* 2007; Ahmed *et al.,* 2009).

Also, the productivity of unit area greatly influenced by the number of plants in units area. However, total yield is associated strongly by the number of growing plants in unit area, on the other side, the yield quality response negatively. Effect to different plant density treatments on the garlic bulb yield are stated by (Gautam *et al.* (2007, Kilgori *et al.* (2007), Rekowska and Skupien (2009); Temperini *et al.* (2010); El -Shal *et al* (2011) and Ahmed (2013).Abd El-Latif and Abdelshafy (2017).Found that seasonal values of applied irrigation water (AIW) for the surface irrigation system, were 3326 and 3297 m^3 fed-1 for the 100% ETP treatment and were 2525 and 2506 m^3 fed^{-1} for the 75% ETP treatment in 2015/16 and 2016/17 seasons, respectively (1 fed = 0.42 ha), meanwhile the mean water use efficiency (WUE) and water productivity (WP) values were the surface system (2.12 and 2.23 kg/m^{-3}) in the two respective seasons for garlic plant.

The objectives of this work are to study the response of growth, yield and quality of garlic to the different irrigation number and plant densities.

MATERILS AND MOTHODS

The present investigation was conducted at Sids Horticultural Research Station, A.R.C., Beni-Suef Governorate (Middle Egypt, Lat. 29º 04' N, Long. 31º 06' E and 30.40 m above the mean sea level), Egypt, during the two winter successive growth seasons of 2015 /2016 and 2016/2017. to study the effect of irrigation intervals and plant density of garlic cultivar Eggaseed-1 on growth, yield quality, storagability and some water relations. Monthly average agrometeorological data at the experimental site and class A pan (E_{pan}) values for the two growing seasons are presented in Table 1. Soil moisture constants, and some physical (according to Klute 1986) and chemical(a ccording to Page *et al.* 1982) specifications of the soil at the trail site were determined and listed in Tables 2 and 3.

Table 1. Some meteorological data of the trail site which were recorded during two growth seasons.

Month	Temp. Mean max. (°C)	Temp. Mean min. (°C)	Relative humidity (%)	Wind speed (m/sec)	Rain fall (mm)	Possible sunshine duration (hr)	E pan (mm /day)
			First season				
October	29.9	19.8	57.0	2.0	0.0	11.3	6.11
November	23.7	15.5	47.0	1.9	1.0	10.5	4.10
December	18.3	13.7	62.7	1.8	3.1	10.1	2.28
January	17.4	10.3	60	1.7	4.6	10.3	2.12
February	20.9	11.0	53	1.6	1.8	11.0	2.89
March	26.9	12.0	43	2.5	0.0	11.9	4.82
April	29.7	17.8	40	1.9	0.0	12.8	5.30
			Second season				
October	32.7	20.7	56	2.0	0.0	11.4	6.32
November	26.9	15.7	59	1.8	0.0	10.6	3.87
December	21.6	9.9	58	1.7	1.0	10.1	2.32
January	19.6	8.3	59.5	2.6	2.0	10.5	2.71
February	24.4	10.4	61.7	2.0	3.3	11.0	3.08
March	27.3	13.1	50.0	2.3	0.0	11.9	4.53
April	33.5	16.5	41.0	2.4	1.1	12.7	5.52

Table 2. Some soil water constants and bulk density of the experimental site.

Season	Soil depth (cm)	Field capacity (%, w/w)	Wilting point (%, w/w)	Available water (%, w/w)	Bulk density (gcm^{-3})
2015/16	00 – 15	46.70	20.23	26.47	1.17
	15 – 30	44.01	19.70	24.31	1.18
	30 – 45	35.55	18.92	16.58	1.22
	45 – 60	34.20	17.43	16.77	1.31
Mean		40.12	19.07	21.03	1.22
2016/17	00 – 15	47.31	20.98	26.33	1.18
	15 – 30	43.38	20.65	22.73	1.21
	30 – 45	35.10	19.01	16.09	1..23
	45 – 60	33.78	18.21	15.57	1.41
Mean		39.89	19.71	20.18	1.26

Table 3. Particle size distribution and some chemical properties of the experimental soil at 2015/2016 and 2016/2017.

Seasons	Particle size distribution*			Textural Class	Chemical properties**					
	Clay %	Silt %	Sand %		OM %	EC, dSm^{-1} (at 25°C)	Available (ppm) N	P	K	pH
2015/2016	48.78	33.11	18.11	Clay	1.18	1.12	41.00	11.11	200.3	7.8
2016/2017	48.10	33.61	18.29	Clay	1.30	1.03	36.00	10.73	204.6	7.9

The experimental design used in the two growing seasons was a split plot in randomized complete block design with three replicates.

Main plots (Irrigation numbers, I):

I_1= Irrigation every 14 days (the plant received 10 irrigations).
I_2 = Irrigation every 21 days (the plant received 7 irrigations).
I_3 = Irrigation every 28 days (the plant received 5 irrigations)

Sub plots (plant densities, D):

Three plant densities were used in these experiments. Garlic plant spaced about five, seven and ten cm apart between plants within ridge on both sides of the rows (northern and southern ridge side). The cloves number, per ridge, was 30 cloves/m^2 (D_1) in low plant density to 45 (D_2) and 60 cloves/m^2 (D_3) in the higher plant density. The depth of planting was about 3-5 cm and cloves should be set with tip up. Garlic was planted by planting individual cloves per hill. plant density were arranged at random in sub plots. Each experimental plot area was 42 m² consisted of ten ridges; each was 0.7 m in width and 6 m in length.

Crop - water relationships:

The irrigation treatments were start after 30 days from planting. All treatments received equal amounts of water at the first irrigation. Submerged flow orifice with fixed dimension was used to measure the amount of water applied according to the following equation (Michael, 1978).

$$Q = CA\sqrt{2gh}$$

Where:

Q=discharge through orifice, (L/sec.).
C=coefficient of discharge, (0.61).
A=cross-sectional area of the orifice, (cm^2).
g=acceleration of gravity, (981 cm/sec^2).
h=pressure head, causing discharge through the orifice (cm).

1. Water consumptive use (C.u.) :

Water consumptive use was determined via soil samples from the sub plots just before each irrigation and 48 hrs later besides at harvest, in 15 cm increment system to 60 cm depth of the soil profile. The Cu was calculated according to Israelsen and Hansen (1962) as follows:

$$C.u = \frac{(Q_2 - Q_1) \times D \times Bd}{100} \ldots\ldots$$

Where :

Cu = Water consumptive use , mm
D = Soil layer depth , mm
Bd = Bulk density of soil layer , g cm^{-3}
Q_2 = Soil layer moisture content , wt/wt %, 48 hrs post irrigation …. and
Q_1 = Soil layer moisture content , wt/wt %, Just before irrigation .

2. Water use efficiency (WUE):

Water use efficiency (WUE, kg m^{-3}) reported here as the ratio of garlic total yield (Y) to actual consumptive use according to Stanhill (1986):

$$WUE = \frac{Y\ (kg\ fed^{-1})}{C.U\ (m^3 fed^{-1})}$$

Where:

Y = Marketable yield (kg fed^{-1}).
C.U. = Seasonal consumptive use (m^{3}fed^{-1}).

3. Water productivity (WP):

Water productivity is an efficiency term calculated as a ratio of product output over water input. The output could be biological goods such as garlic yield, fodder, bulbs….etc. So, water productivity, in the present study, is expressed as kilogram of marketable bulbs yield (kg) obtained per the unit of applied irrigation water. The water productivity values (kilograms of garlic yield m^{-3} of applied water) were calculated as follows:

WP (kg m^{-3}) = Marketable yield (kgfed^{-1}) / applied water (m^{3}fed^{-1}), FAO (2003).

The common culture practices were done as follows: Nitrogen 400 kg fed^{-1}.as ammonium sulphate (20.6 %) at three equal quantities at 30, 60 and 105 days from planting. Phosphorus 300 kg /fed. as calcium superphosphate (15.5 % P2O5)was applied at once time duration of preparing the soil for planting, and potassium100 kg /fed. as potassium sulphate (48 % K_2O) were used after 70 days from planting,. The Eggseed -1 cv. of garlic cloves was planted on the 10 and 16th October in the seasons of 2015/2016 and 2016/2017, respectively. Also, other treatments practices normal cultural of growing garlic plant were followed. Two weeks before harvest, ten plants were taken randomly from each experimental plot to determine the following characters:

1- Plant height (cm)
2- Leaves number /plant
3- Vegetative fresh weight (g /plant)
4- Bulbing ratio at harvesting time: neck diameter / bulb diameter (cm),

Garlic was harvest on the 14 and 20th of April, in the 2015/2016 and 2016/2017seasons, respectively. Fresh bulb yield (kg/plot) and yield/fed. were calculated (ton/ fed.). The harvested garlic plants were left in the field to be cured for 21 days and the cured plants were weighed. Loss weight percentage as a result of curing were calculated. Marketable yield > 3.5 cm for bulb diameter were weighed. After curing, ten plants from each trail plot were taken randomly to determine the following characters:

1-Bulb dry matter %
2- Clove weight (g)
3- Cured bulb weight (g/plant)
4- Cured bulb diameter (cm)

Storage ability:

The cured yield of Eggaseed-1 cultivar was used in this study to determine percentage of loss weight during storage period. On the 11th of May, five Kilogram of whole cured plants was taken randomly from each experimental plot in both seasons and placed in net bags and stored in room with common storage condition. Samples were weighed three times during storage on the 11 July., 11 Sep., 11 Dec., in both seasons and loss weight percentages were calculated.

Statistical Analysis:

Data from both years were combined in a single analysis. Analysis of variance and Duncan's Multiple Range test at 0.05 level means separation tests using MSTST(1985). Software C were used to compare the collected data.

RESULTS AND DISCUSSION

Crop - water relationships:

Applied Irrigation Water (A.I.W.):

Data offered in Table (4) clearly show that the values of water applied were increased under I_1 irrigation treatment in comparison with the other two irrigation treatments. The highest values were 2882.7 and 2983.7 m^{3}fed.$^{-1}$ due to I_1 treatment. While, the lowest values were recorded under I3 irrigation treatment as 2423.4 and 2519.0 m^{3}fed^{-1} due to in the two growing seasons, respectively. This might be due to increasing number of irrigations accompanied with reducing irrigation period and hence increasing amount of water applied. These results are in agreement with those obtained by Ahmed *et al*., (2009) and Mohammed and Rokon (2017).

Table 4. Used irrigation water under different irrigation numbers and plant densities in 2015/2016 and 2016/2017 seasons.

Irrigation numbers (I)	Plant density (D)	A.I.W. (m^3 fed^{-1}) First season	Second season	Mean
	D_1	2619	2692	2655.5
I_1	D_2	2866	2908	2887.0
	D_3	3163	3350	3256.5
Mean		2882.7	2983.3	2933.0
	D_1	2377	2430	2403.5
I_2	D_2	2598	2684	2641.0
	D_3	2937	3046	2991.5
Mean		2637.3	2720.0	2678.7
	D_1	2250	2305	2277.5
I_3	D_2	2385	2506	2445.5
	D_3	2635	2746	2690.5
Mean		2423.3	2519.0	2471.2
Mean of plant densities	D_1	2415.3	2475.7	2445.5
	D_2	2616.3	2699.3	2657.8
	D_3	2911.7	3047.3	2979.5

I_1, I_2 and I_3 irrigation every 14 , 21and 28 days which produce irrigation numbers 10,7 and 5 irrigations respectively ; (D_1, D_2 and D_3) plant densities: 30, 45 and 60 cloves/ m^2 , respectively.

Water consumptive use (C.U.) :

Water consumptive use is defined as the water lost from the plant organs, specially leaves surface and namely transpiration besides that evaporated from the soil surface during the entire growing season. Data in Table (5) indicated that the amounts of seasonal water consumptive use increased in case of frequent irrigation as in irrigation every 14 days than the two irrigation treatments. This trend showed that the increment in water consumptive use depends on the availability of soil moisture in root zone.The relative increases of C.U. caused by irrigation every 14 days treatment reached to 17.3 and 34.5% and17 and 33% in comparison with irrigation every 21 and 28 days treatments in the two seasons, respectively. Doorenbos and Pruitt (1977) gave an extensive explanation of the effect of available soil water on evapotranspiration, they stated that after irrigation or rain the water content will be reduced primarily by evapotranspiration. They added that as the soil was dried, the rate of water transmitted through the soil will reduce. The effect of soil water content on evapotranspiration varies with crop and soil type, as well as water holding characteristics. These results were supported by the data obtained by, El-Akram (2012) who found that onion actual evapotranspiration (ETc) was higher with more frequent irrigation, i.e. irrigating as 40% of available soil moisture was depleted, in comparison with irrigation at 60 and 80% depletion treatments. The obtained results were in harmony with those obtained by Sankara *et al.* (2008).

Table 5. Water consumptive use (m^3 fed^{-1}) as affected by irrigation numbers and plant densities in 2015/2016 and 2016/2017 growing seasons.

Irrigation numbers (I)	Plant density (D)	C.U. (m^{-3} fed^{-1}) First season	Second season	Mean
I_1	D_1	1966.2	1986.5	1976.4
	D_2	2121.8	2218.3	2170.1
	D_3	2376.7	2417.7	2397.2
Mean		2154.9	2207.5	2181.2
I_2	D_1	1603.8	1675.8	1639.8
	D_2	1774.3	1801.4	1787.5
	D_3	2135.2	2182.8	2159.0
Mean		1837.8	1886.7	1862.2
I_3	D_1	1402.8	1479.3	1441.1
	D_2	1613.3	1694.4	1653.9
	D_3	1791.1	1806.5	1798.8
Mean		1602.4	1660.1	1631.3
Mean of plant densities	D_1	1657.6	1713.9	1685.8
	D_2	1836.5	1904.7	1870.6
	D_3	2101.0	2135.7	2118.4

I_1, I_2 and I_3 irrigation every 14,21and28 days which produce irrigation numbers 10,7 and 5 irrigations respectively ; (D_1, D_2 and D_3) plant densities: 30, 45 and 60 cloves/ m^2 , respectively.

With regard to plant densities, the results indicate that plant densities had a positive effect on water consumptive use in both seasons. Increasing plant density up to 60 cloves/ m^2. increased C.U. The increasing percentage in C.U. all over the two seasons due to 60 cloves/ m^2 were 25.7 and 13.2 % as compared with 30 and 45 cloves/ m^2, respectively. The increment of C.U. caused by increasing plant density is mainly due to the high yielding of cured yield and marketable cured yield for Garlic as well as increased the root system which need excess of water, besides the increase of water transpiration from the succulent leaves caused by high plant densities.

Water use efficiency (W.U.E.):

Water use efficiency by garlic plant expressed as kg marketable bulb produced/m^3 of water consumed as affected by irrigation intervals and plant density is presented in Table (6).

The results reveal that irrigating garlic crop at 21 days interval improved the water use efficiency and such findings were true in 2015/16 and 2016/17 seasons. Water use efficiency were increased under 21 days interval by (16.23 and 17.76%) and (12.35 and 32.64%) in 2015/16 and 2016/17, respectively, comparable with irrigating at 14 and 28 days intervals. Higher WUE with 21 days interval, comparing with that under 14 days interval is mainly attributable to both higher garlic yield and less water consumed under the former. In spite of water consumed under 28 days interval was lower than that with 21 days interval, WUE was improved under the later which is attributable to higher garlic yield. It has been frequently reported that lack of water availability can reduce the amount and efficiency of water use (Maman *et al.* 2003). In connection, Zabawi and Dennet (2010) reported higher WUE with the lower plant available water level and tended to reduce as plant available water level increased.

Table 6. Water use efficiency (kg marketable bulb/m^3) as affected by irrigation numbers and plant densities in 2015/2016 and 2016/2017 growing seasons.

Irrigation numbers (I)	Plant density (D)	W.U.E. (kg marketable bulb/m^3) First season	Second season	Mean
I_1	D_1	1.98	2.11	2.05
	D_2	1.54	1.58	1.56
	D_3	1.11	1.41	1.26
Mean		1.54	1.70	1.62
I_2	D_1	2.41	2.40	2.41
	D_2	1.79	1.94	1.87
	D_3	1.16	1.39	1.28
Mean		1.79	1.91	1.85
I_3	D_1	1.92	1.96	1.94
	D_2	1.55	1.30	1.43
	D_3	1.10	1.07	1.09
Mean		1.52	1.44	1.48
Mean of plant densities	D_1	2.10	2.16	2.13
	D_2	1.63	1.61	1.62
	D_3	1.12	1.29	1.21

I_1, I_2 and I_3 irrigation every 14,21and28 days which produce irrigation numbers 10,7 and 5 irrigations respectively ; (D_1, D_2 and D_3) plant densities: 30, 45 and 60 cloves/ m^2 , respectively.

Decreasing plant density resulted in gradual WUE increases, where the values due to 30 cloves/ m^2 plant density were higher by 28.83 and 87.5% and 34.16 and 67.44% in 2015/16 and 2016/17seasons respectively, comparable with 45 and 60 cloves/ m^2. Such findings indicating that with decreasing plant density, the increase in marketable cured total yield was proportionally higher than the increase in water consumptive use.

Interaction data clear out that the highest WUE (1.41and1.40kgm^{-3}) were attained due to irrigating at 21 days interval and 30 cloves/m^2 respectively, in 2015/16 and 2016/17.

Water productivity (W.P.):

Water productivity (WP), calculated by dividing the bulb yield by the total amount of water applied for different treatments and presented in Table (7) . Results indicate that the mean values of WP, as a function of all irrigation interval treatments and plant density were 1.13 and 1.17 kg marketable bulb m^{-3} water applied in the two successive seasons. Irrigating garlic every 21 days gave the highest WUE averages, i.e. 1.23 and 1.30 kg marketable bulb m^{-3} water applied in first and second seasons, respectively. However, the lowest values, i.e. 1.00 and 0.95 kg marketable bulb m^{-3} water applied in the two successive seasons were detected from 28 days irrigation intervals. Irrigation plant respectively every 14 days decreased WP values by 6.50% and 3.08 % in both seasons, respectively, than irrigation every 21 days.

Plant density of 30 cloves/ m^2 gave the highest WP values, i.e. 1.44 and 1.48 kg marketable bulb m^{-3} water applied in first and second seasons, respectively. The lowest WP values, i.e. 0.81 and 0.90 kg marketable bulb m^{-3} water applied in the two successive seasons were observed from plant density of 60 cloves/ m^2. These results may be due to that plant density of 30 cloves/ m^2 gave the highest marketable yield, but plant density of 60 cloves/ m^2 exhibited the lowest one (Table 10).

The results in Table (7) reveal that irrigation every 21 days and plant density of 30 cloves/ m^2 gave the highest productivity of water unit, i.e. 1.63 and 1.62 kg marketable bulb m^{-3} water applied in both seasons, respectively.

Whereas, irrigation every 28 days and plant density of 30 cloves/ m^2 gave the lowest values of water unit productivity, i.e. 0.75 and 0.70 kg marketable bulb m^{-3} water applied in the two successive seasons, respectively.

Table 7. Water productivity (kg marketable bulb/m^3) as affected by irrigation numbers and plant densities in 2015/2016 and 2016/2017 growing seasons.

Irrigation numbers (I)	Plant density (D)	W.P. (kg marketable bulb/m^3) First season	Second season	Mean
	D_1	1.49	1.56	1.53
I_1	D_2	1.14	1.20	1.17
	D_3	0.83	1.01	0.92
Mean		1.15	1.26	1.21
	D_1	1.63	1.62	1.63
I_2	D_2	1.22	1.29	1.26
	D_3	0.84	0.98	0.91
Mean		1.23	1.30	1.27
	D_1	1.20	1.26	1.23
I_3	D_2	1.05	0.88	0.97
	D_3	0.75	0.70	0.73
Mean		1.00	0.95	0.98
Mean of	D_1	1.44	1.48	1.46
Plant	D_2	1.14	1.12	1.13
densities	D_3	0.81	0.90	0.85

I_1, I_2 and I_3 irrigation every 14,21and28 days which produce irrigation numbers 10,7 and 5 irrigations respectively ; (D_1, D_2 and D_3) plant densities: 30, 45 and 60 cloves/ m^2 , respectively.

Vegetative growth:

Main effect of irrigation numbers:

Results in Table (8) show the effect of irrigation numbers on garlic growth parameters i.e. plant height, leave numbers, vegetative growth weight and bulbing ratio. Data clear that these parameters were significantly increased with increasing irrigation numbers from 5 up10 irrigations. where the higher values were obtained when the plant received 10 irrigations. These results were true in both growing seasons. It might be due to the availability of water at the root zone, with 14 days irrigation interval treatment increased the mobility of nutrients in the soil that consequently increased the mineral uptake by plant and this increased carbohydrate assimilation, photosynthetic and other physiological activity (Sula 1990). These results are in harmony with those reported by Mohammed and Rokon (2017) on garlic.

Main effect of plant densities:

Data in Table 8 show that all vegetative growth parameters were significantly affected by plant densities. Results show that low population 30 plants/m^{2}gave the highest values from vegetative growth characters (leave numbers, vegetative growth weight and bulbing ratio) except plant height. Highest values of plant height were observed with increasing plant population. High population (60 plants/ m^2) gave the tallest plants in the two years than that of wider plant densities (30 and 45 plants/m^2). The wider plant density seems to have helped the individual plant to utilize more soil water, nutrition, air and light to help it to put up better growth Dhakulkar *et al* (2009). The results of the present investigation are in agreement with the finding of Rekowska and Skupien (2009) Temperini *et al*. (2010); El –Shal *et al* (2011) and Ahmed (2013) on garlic.

Effects of interaction treatments:

Data in Table (8) show the effect of the interaction treatments among irrigation numbers and plant densities on vegetative growth of garlic plants. Results clear that all vegetative growth parameters (plant height,, leave numbers, vegetative growth weight and bulbing ratio) were significantly affected by the interaction treatments in both seasons. The higher values of various vegetative growth parameters were recorded with plants that received 10 irrigations addition to low plant population (30 plants/m^2), except plant height. The higher values of plant height were recorded with plants that received 10 irrigations with interaction of high plant population (60 plants/m^2). However, the lowest values of other vegetative growth were recorded with garlic plant received 5 irrigations and low plant populations. These results may be due to the efficiency of irrigations numbers on promotion of vegetative growth of garlic plants as discussed in Table 8 and the role of plant populations in increasing the availability of soil nutrients which in turn on increasing the vegetative growth of garlic plants.

Table 8. Plant height (cm), leave number/plant, vegetative growth weight (g) and bulbing ratio of cultivar Eggaseed-1 as affected by irrigation numbers, plant densities and their interactions in the two successive winter seasons.

Irrigation numbers (I)	Plant Density (D)	Plant height (cm)	Leave Number /plant	Vegetative growth Weight(g)	Balbing Ratio
First season					
	D_1	66.0 BCD	12.43 A	53.33 A	0.33 A
I_1	D_2	70.60AB	11.87 AB	49.33 AB	0.21 BC
	D_3	75.33 A	11.77 BC	43.67 C	0.14 DEF
Mean		70.64 A	11.99 A	48.78 A	0.23 A
	D_1	63.37 CD	11.53 BCD	52.00 AB	0.24 B
I_2	D_2	69.67 AB	11.43 BCDE	48.30 B	0.17 CDE
	D_3	71.23 AB	11.10 CDEF	39.23 D	0.12 EF
Mean		68.09 B	11.30 B	46.51 B	0.18 B
	D_1	55.00 E	10.83 DEF	37.07 D	0.18 BCD
I_3	D_2	60.43 D	10.73 EF	28.00 E	0.13 DEF
	D_3	67.100 BC	10.67 F	25.57 E	0.10 F
Mean		60.84 C	10.74 C	30.21 C	0.14 C
Mean	D_1	61.46 C	11.60 A	47.74 A	0.25 A
of plant	D_2	66.90 B	11.34 B	41.88 B	0.17 B
density	D_3	71.22 A	11.14 C	36.16 C	0.12 C
Second season					
	D_1	70.90 D	12.67 A	56.00 A	0.31 A
I_1	D_2	75.80 C	11.97 B	52.87 B	0.21 BCD
	D_3	82.30 A	11.23 C	48.30 C	0.15 DEF
Mean		76.33 A	11.96 A	52.39 A	0.22 A
	D_1	68.63 E	11.97 B	54.33AB	0.25 B
I_2	D_2	74.90 C	11.7 B	50.10 C	0.19 BCDE
	D_3	77.87 B	11.30 C	49.17 C	0.17 CDE
Mean		73.80 B	11.64 B	51.20 B	0.20 B
	D_1	62.40 F	11.33 C	41.37 D	0.22 BC
I_3	D_2	68.0 E	10.87 D	33.80 E	0.13 EF
	D_3	75.6 C	10.80 D	29.17 F	0.11 F
Mean		68.67 C	11.00 C	34.78 C	0.15 C
Mean	D_1	67.31 C	11.99 A	50.57 A	0..26 A
of plant	D_2	72.90 B	11.50 B	45.59 B	0.18 B
density	D_3	78.59 A	11.11 C	42.21 C	0.14 C

Means within each column followed by the same letter are not statistically different at 0.05 level (Duncan's range test).

Bulb quality and yield component:

Main effect of irrigation intervals on bulb quality and yield component:

Results in Table 9 show the effect of irrigation numbers on garlic bulb parameters i.e. bulb dry matter %, clove weight (g), bulb fresh weight (g) and cured bulb diameter (cm). Data clear that all bulb characteristics were significantly increased with increasing irrigation numbers from 5 up10 irrigations in both seasons. The highest values were obtained when the plant received 10 irrigations followed by the plant received 7 irrigations. This increase may be due to the role of water when absorbed in large amount by plants to build many compounds essential for plant growth and development such as proteins, and chlorophyll that lead to increased bulb quality and yield component Mohammed and Rokon (2017). Similar findings were reported by Singh *et al*, 2007; Ahmed *et al*., 2009; and Mohamed 2009).

Main effect of plant densities on bulb quality:

Data in Table 9 show that all bulb quality and yield component parameters were significantly affected by plant densities. Using low population 30 plants/m^2 gave the highest values of quality and yield component characters , while the lowest values recorded with the using high population 60 plants /m^2 in both seasons. The lower plant densities were subjected to low degree of competition for space, nutrients and for all other resources of environments and hence, instead of vertical growth plant have grown horizontally producing more number of leaves resulted into increased, absorption and utilization of radiant energy resulting in higher amount of photosynthates, and showed positive effect on quantity parameters Dhakulkar *et al* (2009).This results of the present investigation are in line with Ahmed (2013) on garlic.

Table 9. Bulb dry matter%, clove weight(g), bulb fresh weight (g) and cured bulb diameter of cultivar Eggaseed-1 as affected by irrigation numbers, plant densities and their interactions in the two successive winter seasons .

Irrigation numbers (I)	Plant density (D)	Bulb dry matter %	Clove weight (g)	Bulb fresh weight (g)	Cured bulb diameter (cm)
		First season			
	D_1	26.5 A	5.70 A	70.00 A	6.70 A
I_1	D_2	25.27 B	4.77 B	58.33 B	5.50 C
	D_3	23.38 D	3.80 C	47.67 CD	4.87 DE
Mean		25.00 A	4.76 A	58.67 A	5.69 A
	D_1	25.70 B	5.10 B	62.67 B	6.30 B
I_2	D_2	24.33 C	4.67 B	52.67 C	5.13 D
	D_3	22.93 D	3.17 D	46.00 D	4.80 E
Mean		24.30 B	4.31 B	53.78 B	5.41 B
	D_1	21.90 E	4.03 C	49.00 CD	4.93 DE
I_3	D_2	20.30 F	3.07 D	39.33 E	4.37F
	D_3	19.60 F	2.57 E	35.00 E	3.80 G
Mean		20.60 C	3.22 C	41.11 C	4.37 C
Mean	D_1	24.70 A	4.94 A	60.56 A	5.98 A
of plant	D_2	23.30 B	4.17 B	50.11 B	5.00 B
density	D_3	21.97 C	3.18 C	42.89 C	4.49 C
		Second season			
	D_1	26.90 A	6.43A	77.33 A	6.40 A
I_1	D_2	25.93 B	5.20 B	62.67 C	5.43 B
	D_3	24.43 C	4.17 D	54.33 E	4.50 CD
Mean		25.76 A	5.27 A	64.78 A	5.44 A
	D_1	26.13 B	5.47 B	71.67 B	5.67 B
I_2	D_2	25.50 B	4.87 C	58.67 D	4.93 C
	D_3	24.83 C	3.63 E	54.33 E	7.17 DE
Mean		25.49 B	4.66 B	61.56 B	4.92 B
	D_1	23.13 D	4.40 D	50.33 E	4.50 CD
I_3	D_2	22.37 F	3.43 E	43.00 F	4.10 DE
	D_3	20.67 F	2.97 F	30.67 G	3.67 E
Mean		22.06 C	3.60 C	41.33 C	4.09 C
Mean	D_1	25.39 A	5.43 A	66.44 A	5.52 A
of plant	D_2	24.60 B	4.50 B	54.78 B	4.82 B
density	D_3	23.31 C	3.59 C	46.44 C	4.11 C

Means within each column followed by the same letter are not statistically different at 0.05 level (Duncan's range test).

Effects of Interaction between irrigation numbers and plant densities on quality and yield component of garlic plants:

Data in Table 9 show the effect of the interaction treatments among irrigation numbers and plant densities on yield component of garlic plants. Results showed that all bulb quality parameters i.e. (bulb dry matter %, clove weight (g), bulb fresh weight (g) and cured bulb diameter (cm) were significantly affected by the interaction treatments as shown in two seasons. The highest values were recorded with plants received 10 irrigations in addition to low populations (30 plants /m^2). Whereas the lowest values were recorded with plants received 5 irrigations in addition to high populations (60 plants /m^2).

Yield parameters:

Main effect of irrigation numbers on fresh, cured and marketable yield (ton/fed.):

Results in Table 10 show the efficiency of irrigation numbers on increasing garlic yield parameters, i.e., [fresh ,cured and marketable yield (ton/fed.). Data show that yield parameters were significantly increased with increasing irrigation numbers from 5 up to 10 irrigations. The highest values from yield were obtained when plant received 10 irrigations. in two growing seasons. The effect of water on increasing fresh , cured and marketable yield ton /fed. could be due to the effect of water on increasing vegetative growth as mentioned before (Table ,8). The important of water in cell division process and the biosynthesis of protein could explain the beneficial effect of the proper rate of water which enhance the uptake of nutrients to meet the superior in growth and development of bulb These results are quite similar with those obtained by(Sula 1990, Ahmed *et al.*, 2007; Singh *et al*, 2007 and Ahmed *et al.*, 2009).

Effect of Plant densities on fresh ,cured and marketable cured yield (ton/fed.):

Data in Table 10 show that both fresh and cured yield were significantly affected by using plant density. However, using high population 60 plants /m^2 gave the highest values from fresh and cured yield (ton/fed.) followed by using 45 plants/m^2. The higher bulb yield under high population was attributed due to significantly more number of plants per unit area. While, the lowest values were recorded with 30 plants/m^2 in two seasons. However, marketable cured yield was significant affected by using plant densities, which using low population 30 plants /m2 gave the highest values from marketable cured yield (ton/fed.)followed by using 45 plants/m2 but the lowest values were recorded with 60 plants/m2 in both seasons. Higher planting densities produced significantly greater yields, while lower marketable cured yield was recorded under lower plant density. These results are in harmony with those stated by Temperini*et al.* (2010); El –Shal *et al* (2011) and Ahmed (2013).

Main effects of interaction between irrigation numbers and plant densities on yield:

Data in Table 10 show the effect of the interaction treatments between irrigation numbers and plant densities on yield of garlic plants. Results indicate that fresh and cured yield ton/fed. were significantly affected by the interaction treatments in both seasons. The highest yield values were recorded when plants received 10 irrigations in addition to high populations 60 plants /m^2 . However, the lowest values of yield were recorded when plants received 5 irrigations in addition to low population 30 plants/m^2. Moreover, the highest marketable yield values were recorded when plants received 10 irrigations in addition to low populations (30 plants /m^2). Whereas plant received irrigation in addition to 45 plants/ m^2 showed intermediate response. However, the lowest values of all yield parameters were recorded when plants received 5 irrigations in addition to high population 60 plants/m^2. in both seasons.

Table 10. Total fresh yield (ton/fed.), cured yield (ton /fed.) and marketable cured yield (ton /fed.) of cultivar Eggaseed-1 as affected by irrigation numbers, plant densities and their interactions in the two successive winter seasons

Irrigation numbers (I)	Plant Density (D)	Total fresh yield (ton/fed.)	Cured yield (ton /fed.)	Marketable cured yield (ton/fed.)
		First season		
	D_1	7.30 E	4.37 D	3.90 A
I_1	D_2	9.37 C	5.27 BC	3.27 B
	D_3	11.83 A	6.43 A	2.63 C
Mean		9.50 A	5.36 A	3.27 A
	D_1	6.70 F	4.10 DE	3.87 A
I_2	D_2	8.80 D	4.93 C	3.17 B
	D_3	10.23 B	5.80 B	2.47 C
Mean		8.58 B	4.94 B	3.17 B
	D_1	5.00 H	3.03 F	2.70 C
I_3	D_2	5.97 G	3.60 E	2.50 C
	D_3	6.93 F	3.90 DE	1.97 D
Mean		5.97 C	3.51 C	2.39 C
Mean	D_1	6.33 C	3.83 C	3.49 A
of plant	D_2	8.04 B	4.60 B	2.98 B
density	D_3	9.67 A	5.38 A	2.36 C
		Second season		
	D_1	7.73 D	4.63 D	4.20 A
I_1	D_2	9.93 C	5.70 C	3.50 B
	D_3	12.20 A	6.70 A	3.40 B
Mean		9.96 A	5.68 A	3.70 A
	D_1	7.03 E	4.23 E	3.93 A
I_2	D_2	9.63 C	5.43 C	3.47 B
	D_3	11.27 B	6.20 B	3.00 C
Mean		9.31 B	5.29 B	3.47 B
	D_1	5.33 F	3.10 G	2.90 C
I_3	D_2	6.70 E	3.80 F	2.20 D
	D_3	7.07 E	3.97 EF	1.93 D
Mean		6.37 C	3.62 C	2.34 C
Mean	D_1	6.70 C	3.99 C	3.68 A
of plant	D_2	8.76 B	4.98 B	3.06 B
density	D_3	10.18 A	5.62 A	2.78 C

Means within each column followed by the same letter are not statistically different at 0.05 level (Duncan's range test).

Storage ability

Main effect of irrigation numbers on the storage ability:

For the effect of irrigation numbers on the weight loss % after two, four and six months, the obtained results in Table 11 reveal that weight loss % after two, four and six months were significantly affected by irrigation treatment in two seasons. The highest values for weight loss % was obtained from bulbs that produced from plants received 10 irrigations, the lowest values for weight loss percentage was obtained from bulbs that produced from plants which received (5 irrigations) in both seasons. Bulb weight loss percentage variation occurred during storage in different by irrigation interval treatments. These results are in agreement with those stated Mohammed and Rokon (2017) on garlic.

Main effect of plant densities on the storage ability:

Regarding to the effect of plant densities, the obtained results in Table 11 indicate that weight loss % were significantly affected by the plant densities after two, four and six months in both seasons. High populations 60 plants /m2 significantly decreased the weight loss % after two, four and six months followed by plant densities 45 plants /m^2 , in both seasons.

Effects Interaction between irrigation numbers and plant densities on the storage ability

Results in Table 11 indicate that the interaction effects among irrigation numbers and plant densities had significant effect on weight loss % after two, four and six months in two seasons, The highest values of weight loss % after two, four and six months were obtained from plants that received 10 irrigations with plant densities of 30 plants /m^2 in two seasons. Also, the results indicate that plant supplied with 5 irrigation with high population 60 plants/m2 significantly decreased weight loss % after two, four and six months under storage in both seasons.

Table 11. Loss weight percentage after 2,4 and 6 months from storage of cultivar Eggaseed-1 as affected by irrigation numbers, plant densities and their interactions in the two successive winter seasons

Irrigation numbers (I)	Plant density (D)	Loss weight % after 2 months	Loss weight % after 4 months	Loss Weight % after 6 months
		First season		
	D1	13.23 A	19.00 A	24.97 A
I1	D2	11.80 B	17.50 B	22.90 B
	D3	10.40 C	15.43 C	21.17 C
Mean		11.81 A	17.31 A	23.01 A
	D1	10.10 CD	17.30 B	22.67 B
I2	D2	9.70 D	15.43 C	21.00 C
	D3	8.93 E	14.33 D	19.83 D
Mean		9.58 B	15.69 B	21.17 B
	D1	8.80 EF	15.03 C	20.83 C
I3	D2	8.30 F	13.63 E	19.50 D
	D3	7.70 G	12.93 F	18.77 E
Mean		8.27 C	13.87 C	19.70 C
Mean of	D1	10.71 A	17.11 A	22.82 A
plant	D2	9.93 B	15.52 B	21.13 B
density	D3	9.01 C	14.23 C	19.92 C
		Second season		
	D1	4.20 A	13.60 A	19.43 A
I1	D2	3.50 B	11.93 B	17.80 B
	D3	3.40 B	10.83 C	16.13 C
Mean		3.70 A	12.12 A	17.79 A
	D1	3.93 A	10.47 D	17.67 B
I2	D2	3.47 B	9.80 E	16.00 CD
	D3	3.00 C	9.23 F	14.90 E
Mean		3.47 B	9.83 B	16.19 B
	D1	2.90 C	9.00 F	15.67 D
I3	D2	2.20 D	8.50 G	14.13 F
	D3	1.93 D	7.90 H	13.37 G
Mean		2.34 C	8.47 C	14.39 C
Mean of	D1	3.68 A	11.02 A	17.11 A
plant	D2	3.06 B	10.08 B	15.52 B
density	D3	2.78 C	9.32 C	14.23 C

Means within each column followed by the same letter are not statistically different at 0.05 level (Duncan's range test).

CONCLUSION

Finally, cv. Eggaseed -1 from the previous mentioned results it can be could concluded that irrigation garlic, plant ten or seven irrigations with low populations 30 plants /m2 were recommended to obtain the highest total marketable cured yield (ton/fed.) with the best quality in garlic bulbs although this treatment had negative affect on storability.

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تأثير عدد الريات والكثافة النباتية على النمو والمحصول لصنف الثوم ايجاسيد - 1

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خلال عامين متتاليين فى الموسم الشتوي 2016/2015 و 2017/2016 نفذت تجربتان حقليتان بمحطة بحوث البساتين بسدس –مركز البحوث الزراعية – مصر بهدف دراسة تأثير عدد الريات (الرى كل 14 ، 21 ،28 يوم) وتعطى عدد ريات (10 ، 7، 5 ريات) على الترتيب وكثافة زراعية (30 ،45،60 فص / م2) على النمو والإنتاجية والقدرة التخزينية لصنف الثوم ايجاسيد -1 وأظهرت النتائج ما يلى : أظهرت معاملة رى نباتات الثوم كل 14 يوم ما يقدر ب(10 ريات) خلال عمر النيات والكثافة النباتية المنخفضة 30 نيات لكل م2 أعلى القيم فى صفات النمو الخضرى (طول النيات – عدد الأوراق – وزن النمو الخضرى – دليل التبكير او معدل التبصيل) وكذا فى صفات المحصول (نسبة المادة الجافة للأبصال –وزن الفص- وزن البصلة الطازج –قطر البصلة الجاف) وكذلك المحصول القابل للتسويق بينما سجلت معاملة الرى كل 28 يوم ما يقدر ب 5 ريات خلال عمر النبات والكثافة النباتية العالية 60 نبات لكل م2 اقل القيم لقياسات النمو والمحصول القابل للتسويق ومكونات المحصول. أدت معاملة الرى كل 28 يوم + الكثافة النباتية المرتفعة الى التقليل فى الفقد أثناء التخزين بالرغم من تأثيرها السلبى على صفات النمو والمحصول القابل للتسويق ومكوناته.من نتائج الدراسة يمكن التوصية برى محصول الثوم من 7 -10 ريات مع كثافة نباتية منخفضة (30 فص لكل م2) للحصول على افضل محصول كما ونوعا على الرغم من تأثيرها السلبى على التخزين.