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RESEARCH ARTICLE

Effect of the Culture System; Planting Density and Spraying with Potassium Sillicate in Growth and Yield of Tomato

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ABSTRACT

Factorial experiment was carred out to study of the agricultural irrigation system, planting density and sprying with potassium silicate in growth and quality of tomato yield. This experiment included three factors, the first factor reprecented type of drip irrigation systems (S) as follows: S1 (single row drip irrigation (S1) and duble row drip irrigation (S2). Second factor reprecented of tomato planting densities, these densities resulted from planting of tomato in three spaces as follows: D1 (40 cm) (planting density: 12 plants per experimental unit); D2 (50 cm) (planting density: 10 plants per experimental unit) and D3 (60 cm) (planting density: 8 plants per experimental unit). Third factor was reprecented sprying of tomato plants with potassium silicate with three consitrations as follows: K0 (without sprying); K1(treated of plant with 1 m l-1) and K3 (treated of plant with 2 m l-1). These experiment carried out by using Factorial experiment within split plot design, the main plots were allocated for agricultural irrigation systems (S1 and S2) and they were randomly distributed within each replicate, within main plots, a factorial experiment was carried out by using RCBD design that included 9 treatments (3D× 3K). The results showed asignificant superiority when used single irrigation system (S_1) in the most of growth vegetative characteristics as well superiority in the yield characteristics sach as number of fruits per plant (29.76); plants yield (2.67 kg plant^{-1}) and the productivity (60.016 ton h^{-1}), compared with duble irrigation system (S_2). Planting of tomato at the destance 60 cm (8 plant experimental unit^{-1}) had highest values in fruit number (32.43); yield of plant (2.94kg), while planting of tomato at adestance 40cm had significantly superiority in the productivity (62.75 ton h^{-1}). The results showed that spraying potassium silicate at a concentration of 1 ml per liter (K_1)was better than from the other concentrations in most indicators of the tomato yield sach as yield of the plant (2.67kg) and the productivity (60.135ton h-1).

INTRODUCTION

Tomato (Solanum lycopersicum L) belongs to the Solanaceae family (R. Alaa El-Den H et al, 2022; Alwan K. A., et al, 2016) from 100 gener and 2500 species (Salman, A. K and Ayad W.A., 2019) and producers cultivate tomato in the open field, with a small number producing under protection farming (T,Bozo, T. et al,2019). The production of tomato in opened fields is one of the most widespread methods in iraq, as the production of this method constituted the largest percentage of the crop in the local markets in the central and northern regions from Iraq. We noted that the areas cultivated with this method decreased in conjunction with the beginning of the spread of early spring

agriculture by using low tunnels, This may be due to many reasons, including the deterioration of prices, or due to the decrease in the quantity and quality of the exposed crop as a result of the early rise in temperatures and the increase in their rates (Amarasinghe et al., 2022). There is a scarcity of irrigation water resources as a result of the decline in the amount of rain in central and northern iraq (Qasim et al., 2021). The contemporary farmer must using modern materials and methods that enable him to confront the emerging problems that determine tomato crop production , such as climate changing and scarcity of irrigation water (Gudmundsson L. et al.2017; Jawad T. K et al, 2018). Water resources constitute the basic lifeline for the environment of arid and semi-arid areas. Water resources in Iraq have faced many threats, especially in the second half of the last century, as large areas dried up and water resources shrank due to the establishment of irrigation projects in Syria, Turkey, and Iran (Al-Lami A. A. et al, 2023; Al-Lami and Al-Rawi,2023) therefore, the irrigation systems that regulates of irrigation water consumption such as drip irrigation, is one of the important modern irrigation methods that which reducing water losses (Acar and Fariz, 2009; Al-Dulaimy and Al-Mhmdy, 2018). There are previous studies that have attempted to reducing the damage that which resulted from higher than normal temperatures on horticultural crops in general by protective methods and materials that reduces thermal stress and water stress on the plant, in addition, using of methods to protecting of plants from thermal stress contributes to achieving the plant's water balance by reducing heat and reducing the rate of transpiration (Obaid et al., 2021). Importance of these methods lies in reducing water loss from the plant by controlling on the rate of plant transpiration sach as using anti-transpirants (Amarasinghe et al., 2022; Zeboon and Baqir, 2022). Potassium silicate is one of the compounds that has been applied in foliar spraying operations on the plants because it has a positive effect in regulating the water content of the plant by reducing the transpiration process during hot seasons, as well importance of silica in supportes the cell walls and improving the quality of the fruits (Mohammed and Majeed,2024; Al- waili and Al-Sahaf, 2022) in addition, importance of potassium in the process of regulating the osmosis potential as well water potential and increase the abilityof plant to save water by controlling the process of opening and closing stomata (Alrawi and Aljumail, 2018). Plant density is the number of plants per unit area (Xiaotao ea al,2022) and this planting density will be affected by many factors such as type of plant, naturing of plant growth and environmental conditions (Feng et al., 2010), in adition the studies have shown that increasing planting density of tomato plants produced a decrease in plant yield (Maboko & Du Plooy, 2013), but at the same time caused increases in tomato production per unit area and improves the quality of the fruits (Maboko et al. 2017; Madavi and et al, 2017; Madavi et al, 2017). the method of intensive agriculture has been used to inhansment of vegetable crops production , or it is a method where a large number of crops are grown with other input strategies to achieve a higher output. This techniqu that helps increase the higher production from a specific land. (Kumar, T et al, 2022), where the number of plants for unit area with an appropriate management method for the vegetable shoots (Hasab O. S and M. A. Al-Naqeeb,2019; Obaid et al,2022).

From the above, the study aimed to demonstrate the effect of the agricultural irrigation system, plant density, and spraying with potassium silicate on the growth, yield and quality of tomato fruits in the opened farming.

MATERIALS AND METHODS

The experiment carried out in the college of Agriculture to study effect of irrigation system (single row & duble row system) and planting spaces (plants density) as well sprying with putacium sillicate in production of tomato plants (S_{25}). The experiment included three factors, the first factor reprecented irrigation systems (S) as follows: S_1 (single row system (S1) and duble row system (S_2). The second factor it was planting of tomato by using three spaces of tomato planting (40 cm: that produced a plant density of 12 plants per experimental unit; (50 cm: that produced a plant density of 10 plants per experimental unit and 60 cm: that produced a plant density of 8 plants per experimental unit, while third factor was sprying with putacium sillicates (BARRICADE) by using three levels from consitration as follows: K_0(without sprying); K_1(sprying with 1 m l^{-1}) and K_3(sprying with 2 m l^{-1}).

The experiment design and data analysis:

The experiment carried out by using Factorial experiment within split plot design. The main plots were allocated for agricultural irrigation systems as follow: single irrigation lines (S_1) and double

irrigation lines (S_2), and the main plotes were randomly distributed within each replicate. within each of main plot, a factorial experiment was carried out in an RCBD design that included nine treatments. These nine treatments were included the interaction between three planting density (D_1; D_2 and D_3) with three cases of spraying with potassium silicate (K_0; K_1 and K_2). then we have an experiment consisting of 18 treatments and 48 experimental units. Used SAS program to analyzing of experimental data and determine the significant differences by using LSD test under probability level 0.05 (Al-Rawi and Khalafallah, 2000) .

Measurements of the experiment and field operations:

1- Dimensions of the experimental unit are: 1 m x 2.5 m and area was 2.5 m^2 for both the single irrigation system (S_1) and double irrigation system (S_2).

2- Both systems included two cultivation lines within the experimental units as explained below:

a- Single irrigation line system (S_1) loaded with two tomato planting lines (one line to one side), while the distance between the planting lines was 20 cm.
b- Duble irrigation line system (S_2) loaded with two tomato planting lines (one planting line to one line irrigation), while the distance between the planting lines was 40 cm.

3- Tomato seedlings were planted alternately on both sides of the irrigation line, with planting distances according to the plant density under study (D).

4- Fertilization: Nutrition of the tomato plants there was as a public service by using commercial fertilizer Altrasol (20-20-20) with drip irrigation water (Fertigation (1g $plant^{-1}$), it was done between one irrigation operation and another.

5- Used drip irrigation system with drip spaces of 20 cm and drainage rate of 2.6 l h^{-1}.

6- Pruning of the main tomato stem: it was used to management of the shoots system as a general service for all plants after they exceeded the boundaries of the side experimental units towards the service corridors, it was implemented after the fruit-setting process of the terminal flower clusters stopped that due to high temperatures at the beginning of May.

Table 1. The water measurements according to irrigation system and plant density.

Irrigation system	Water Consumption During the season (L.m2)	The plant's share of irrigation water during the season in litres			
		D1	D2	D3	Consumption average
S1	546 L	113.75 L	136.5 L	170.62 L	140.29 L
S2	1092 L	227.50 L	273.0 L	341.2 L	280.54 L

Experiment indicators:

1- Parameters of vegetative growth:

Total chlorophyll (mg $100g^{-1}$ wet weight); number of the branches; leave area (dcm^2); dry weight of shoot system (g); wet weight of shoot system (kg);

2- Parameters of the yield:

Number of fruits (fruit $plant^{-1}$); fruit weight (g); yield of plant (kg); the productivity (ton h^{-1}).

RESULTS AND DISCUSSION

Effect of experiment factors in the vegetative growth characteristics:

The results of the table showed the significant superiority of the plants when planted with the single irrigation system (S1) in the chlorophyll content (240.003 mg); number of branches (14.52); leave area (135.56 dsm); wet weight (1.75kg) and drt weight of shoot (452.04g), compared with grown by

using double-line irrigation system (S2) which produced the lowest values according to the order (229.300 mg; 12.00 branche; 100.02 dcm; 1.64 kg wet weight and 337.41g dry weight). Also, the plants.

were planted at a distance of 60 cm (8 plants per experimental unit D_3) produced a significant superiority in all vegetative growth indicators, respectively: total chlorophyll (245.22 mg); number of pranches (14.06); leave area (127.09 dcm plant^{-1}); wet weight of shoot (1.71kg) and dry weight (414.17g), compared with the planted at a distance of 40 (12 plants D_1) and a distance of 50 (10 plants D_2). Spraying with Potassium silicate at a concentration of 2 ml L$^-$ recorded highest chlorophyll in leaves (237.127 mg), while the highest a values in other vegetative growth were filled with the treatment K_0 (without sprying with Potassium silicate) respectively: pranches number (14.56); leave area (128.10dcm plant^{-1}); wet weight of shoot (1.71kg) and the dry weight of shoot system (407.44g).

Culturing of tomato by using a single-line irrigation system with planting at distances of 60 cm between the plants (S_1D_3) had asignjficantly superiority in all vegetative growth when recorded 253.50 mg (chlorophyll); 15.89 (branches number); 149.20 dcm (leave area); 1.77kg (wet weight) and 468.33g dry weight. The plants which treated with potassium silicate at a concentration of 2 ml^{-1} and grown on a single irrigation line system (S_1K_2) excelled in concentration of chlorophyll in the leaves (242.67mg), while the plants untreated with potassium silicate (S1K2) had asignificantly superiority in other of the vegetative growth indicators had asignificantly superiority in the most of vegetative growth indicators (branches number(15.56); leave area (149.57dcm); wet weight (1.76 kg) and dry weight (458.89g).

The treatment $S_1D_3K_0$ had asignificant superiority in leave area (181.93dcm); wet weight (1.78kg) and dry weight (480.00g), while the lowest values for these characteristics were recorded for the treatment $S_2D_1K_1$ at secuently:leave area (67.68dcm); wet weight (1.58 kg) and dry weight (286.67g). On the other hand, the results showed that the highest chlorophyll content was in the treatment $S_1D_3K_2$ (258.86mg).

Table 2. Effect of the experiment factores in the vegetative growth charecteristics

Treatments	chlorophyll (mg100g wieght)	branches number per plant	leave area (dcm)	wet weight of shoot (kg)	Dry weight of shoot (g)
S_1	240.00	14.52	135.56	1.75	452.04
S_2	229.30	12.00	100.02	1.64	337.41
LSD	**1.0822**	**1.6423**	**4.8105**	**0.006**	**5.7579**
D_1	223.08	12.50	110.85	1.68	375.56
D_2	235.66	13.22	115.43	1.69	394.44
D_3	245.22	14.06	127.09	1.71	414.17
LSD	**1.3254**	**2.0114**	**5.8917**	**0.0074**	**7.0519**
K_0	232.09	14.56	128.10	1.71	409.44
K_1	234.73	12.17	107.02	1.68	383.33
K_2	237.13	13.06	118.25	1.69	391.39
LSD	**1.3254**	**2.0114**	**5.8917**	**0.0074**	**7.0519**
S_1D_1	228.74	12.67	129.31	1.75	441.11
S_1D_2	237.76	15.00	128.15	1.75	446.67
S_1D_3	253.50	15.89	149.20	1.77	468.33
S_2D_1	217.42	12.33	92.38	1.61	310.00
S_2D_2	233.55	11.44	102.72	1.64	342.22
S_2D_3	236.93	12.22	104.97	1.66	360.00
LSD	**5.9522**	**3.1105**	**24.453**	**0.0161**	**15.906**

S_1K_0	236.55	15.56	149.57	1.76	458.89
S_1K_1	240.78	13.11	132.99	1.75	447.78
S_1K_2	242.67	14.89	124.10	1.75	449.44
S_2K_0	227.64	13.55	106.62	1.66	360.00
S_2K_1	228.68	11.22	81.04	1.62	318.89
S_2K_2	231.58	11.22	112.40	1.63	333.33
LSD	**5.9522**	**3.1105**	**24.453**	**0.0161**	**15.906**
D_1K_0	222.77	13.00	116.26	1.69	390.00
D_1K_1	225.57	11.67	88.71	1.66	360.00
D_1K_2	220.91	12.83	127.57	1.68	376.67
D_2K_0	228.19	16.00	118.29	1.71	408.33
D_2K_1	235.40	12.50	129.98	1.68	383.33
D_2K_2	243.39	11.17	98.03	1.69	391.67
D_3K_0	245.33	14.67	149.75	1.780	430.00
D_3K_1	243.23	12.33	102.36	1.71	406.67
D_3K_2	247.09	15.17	129.14	1.71	405.83
LSD	**9.5583**	**3.9847**	**32.595**	**0.0777**	**26.427**
$S_1D_1K_0$	234.78	12.00	150.61	1.75	446.67
$S_1D_1K_1$	230.54	12.00	109.73	1.74	433.33
$S_1D_1K_2$	220.90	14.00	127.60	1.75	443.33
$S_1D_2K_0$	224.52	19.00	116.18	1.75	450.00
$S_1D_2K_1$	240.50	14.00	173.31	1.743	443.33
$S_1D_2K_2$	248.27	12.00	94.96	1.75	446.67
$S_1D_3K_0$	250.34	15.67	181.93	1.78	480.00
$S_1D_3K_1$	251.30	13.33	115.93	1.77	466.67
$S_1D_3K_2$	258.86	18.67	149.75	1.76	458.33
$S_2D_1K_0$	210.76	14.00	81.90	1.63	333.33
$S_2D_1K_1$	220.59	11.33	67.68	1.58	286.67
$S_2D_1K_2$	220.91	11.66	127.55	1.61	310.00
$S_2D_2K_0$	231.85	13.00	120.39	1.67	366.67
$S_2D_2K_1$	230.30	11.00	86.64	1.62	323.33
$S_2D_2K_2$	238.50	10.33	101.11	1.64	336.67
$S_2D_3K_0$	240.32	13.67	117.57	1.68	380.00
$S_2D_3K_1$	235.15	11.33	88.70	1.65	346.67
$S_2D_3K_2$	235.32	11.67	108.53	1.65	353.33
LSD	**9.6516**	**5.1822**	**34.925**	**0.0781**	**27.459**

Effect of experiment factores in the yield charecteristics:

The results of Table 3 for tomato yield indicators showed that there was a significant superiority for the plants when grown with a single irrigation system (S_1) in all of the yield characteristics when produced the highes values in fruit number (29.7581); fruit wieght (90.752); the yield (2.6729 m^{-2} and 60.0164 ton h^{-1}), compared with the culturing of tomato by using duble row irrigation (S_2). The results show that the factor of planting distances (plant density (D)) produced a significant superiority when planting tomato at a distance of 60 cm (D3) in the number of fruits (32.43) and plant yield (2.94 kg), while the plants that grown at a distance of 40 cm (D_1) had a significant superiority in the weight of the fruit (97.30g) and production per hectare (62.75ton). The results showed that spraying potassium silicate at a concentration of 1 ml per liter (K_1)was better than from the other concentrations in most indicators of the tomato yield (Fruit wieght (101.339g); yield of the plant (2.67kg) and the productivity (60.135ton h^{-1}). The results of the interaction between the studying factors showed that the plants when planted at a distance of 60 cm with single drip

irrigation (S_1D_3) produced the highest values in the number of fruits (35.72), plant yield (3.10 kg), while the highes productivity it was recorded when planted at a distance of 40 cm with a single drip irrigation (S_1D_1) that reached 65.98 ton h^{-1} compared with other combinations. The results of the interaction of study factors showed that treatment combination $S_1D_3K_2$ produced highes values in fruits number (38.83) and plants yield (3.33 kg $plant^{-1}$), but the highest productivity recorded for the treatment $S_1D_1K_1$ when produces 69.73 ton h-1. It is important to note that the treatment combinations S2D1K0 was have lowest values in the plant yield (2.0433kg) and productivity (56.043ton h-1).

Table 3: Effect of the treatments in the yield parameters of Tomato

Treatments of Tomato combination[1)]	Number of fruits	Fruit weight	Yeild of plant	production
	(fruit $plant^{-1}$)	(g fruit-1)	(kg $plant^{-1}$)	(ton h-1)
S_1	29.76	90.752	2.673	60.016
S_2	26.02	96.541	2.502	56.272
LSD	**1.0354**	**2.9649**	**0.0751**	**1.6906**
D_1	23.79	97.300	2.288	62.746
D_2	27.44	92.389	2.534	57.930
D_3	32.43	91.250	2.940	53.757
LSD	**1.2681**	**3.6312**	**0.0919**	**2.0705**
K_0	28.37	91.539	2.569	57.759
K_1	26.56	101.339	2.669	60.135
K_2	28.74	88.061	2.524	56.539
LSD	**1.2681**	**3.6312**	**0.0919**	**2.0705**
S_1D_1	25.48	95.778	2.406	65.975
S_1D_2	28.08	89.056	2.501	57.168
S_1D_3	35.72	87.422	3.112	56,907
S_2D_1	22.11	98.822	2.170	59.518
S_2D_2	26.81	95.722	2.568	58.692
S_2D_3	29.15	95.078	2.768	50.607
LSD	**2.3256**	**8.7243**	**0.1793**	**4.0068**
S_1K_0	29.97	91.967	2.702	60.852
S_1K_1	28.16	95.122	2.662	60.162
S_1K_2	31.14	85.167	2.654	59.036
S_2K_0	26.77	91.111	2.435	54.667
S_2K_1	24.96	107.556	2.677	60.108
S_2K_2	26.33	90.956	2.393	54.042
LSD	**2.3256**	**8.7243**	**0.1793**	**4.0068**
D_1K_0	23.26	97.250	2.233	61.251
D_1K_1	22.13	108.550	2.398	65.780
D_1K_2	25.98	86.100	2.232	61.208
D_2K_0	28.60	91.183	2.613	59.733
D_2K_1	27.78	95.117	2.635	60.228
D_2K_2	25.96	90.867	2.355	53.828
D_3K_0	33.25	86.183	2.860	52.293
D_3K_1	29.77	100.350	2.975	54.397
D_3K_2	34.28	87.217	2.985	54.580
LSD	**3.5209**	**8.0712**	**0.2503**	**5.4512**
$S_1D_1K_0$	25.00	99.600	2.423	66.458

$S_1D_1K_1$	24.13	105.033	2.537	69.573
$S_1D_1K_2$	27.30	82.700	2.257	61.893
$S_1D_2K_0$	28.45	93.533	2.663	60.877
$S_1D_2K_1$	28.49	86.600	2.463	56.303
$S_1D_2K_2$	27.30	87.033	2.377	54.323
$S_1D_3K_0$	36.45	82.767	3.020	55.220
$S_1D_3K_1$	31.87	93.733	2.987	54.610
$S_1D_3K_2$	38.83	85.767	3.330	60.890
$S_2D_1K_0$	21.53	94.900	2.043	56.043
$S_2D_1K_1$	20.13	112.067	2.260	61.987
$S_2D_1K_2$	24.66	89.500	2.206	60.523
$S_2D_2K_0$	28.74	88.833	2.563	58.590
$S_2D_2K_1$	27.07	103.633	2.807	64.153
$S_2D_2K_2$	24.62	94.700	2.333	53.333
$S_2D_3K_0$	30.05	89.600	2.700	49.367
$S_2D_3K_1$	27.68	106.967	2.963	54.183
$S_2D_3K_2$	29.72	88.667	2.640	48.270
LSD	**3.6426**	**8.9435**	**0.2685**	**5.9156**

DISCUSION

The results in Table 2 showed the significant superiority of tomato plants when planting by using single-line irrigation system (S_1) in the all vegetative growth characteristics, as they excelled in the wet weight and dry weight of the shoots, as well the content of chlorophyll in the leaves and total leave area of plant, compared with double-line irrigation system(S_2), This superiority in vegetative growth indicators due to the efficiency of this system in delivering the appropriate amount of irrigation water, as water consumption calculations (Table 1) show that average plant share from irrigation water in this system amounted to 140.29 liters, compared with 280.54 liters when using double-line irrigation system (S_2). this system (S_1) causes increasing the water use efficiency (WUE) with Drip irrigation and its important modern irrigation methods in terms of irrigation efficiency and reducing water losses, or the duble row irrigation system (S_2) was pumping of the water over than excess of the plant's need and washing the nutrients away from the roots system, since there is irrigation without fertilization between each operation. This is consistent with what the IPCC (2001) stated that one of the problems of the deterioration of Iraqi soil production is soil waterlogging, in addition, the amount of water in excess of the plant's need causes waterlogging of the soil, as well as compaction, lack of porosity, difficulty in root penetration, and a decrease in the growth rate of the tomato plant. Because there are different patterns in applying irrigation systems, some of which depend on single irrigation lines and others with double irrigation lines (Hammadi, 1990), it is important to indicate the most efficient method of using irrigation water using the drip irrigation system, therefore, the water consumptions of the two systems were calculated and it was found that the individual irrigation system is the best according to the results that showed in Table1.

The superiority of tomato plants when cultured at a distance of 60 cm (D3: 8 experimental unit plants - 1) in vegetative growth indicators and plant yield may be due to the lack of competition between tomato plants for the nutrients and sunlight (KITILA et al,2012), which resulted in an increase in the plant's share and an improvement in the growth rate and plant yield (BELEMI,2008). The reason for the increasing in productivity of the plants when planted at a distance of 40 cm on the basis of a unit area (hectare) compared with planting distance of 60 it was related to the increase the number of their plants. This result is completely consistent with what Obaid et al. (2022) reached when they planted tomatoes by using soilless culture at a distance of 30 cm and 40 cm. They concluded that planting tomatoes at a distance of 40 contributed to improving the growth and production of the plant, but increasing the number of plants in the experimental unit by planting at a distance of 30. cm led to an increase in productivity per unit area. The effect of potassium silicate resulted in an increased growth of the roots bcause of silicon effect in root stimulation and improved water and

mineral absorption and increased vegetative growth indicators and the yield (Al-Mashhadany and N. J. Al-Amery,2023; Dizayee, A.T.R. and Saleh H. A,2017).

CONCLUSION

Using a single irrigation line in tomato cultivation is more efficient in using water and fertilizers, and that increasing plant density reduces plant yield but increases the amount of production per unit area, in addition to the importance of potassium silicate in enhancing plant resistance to environmental stresses.

Conflicts of interest

The researchers support that this work does not conflict with the interests of others.

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