Integrated Use of Potassium and Soil Mulching on Growth and Productivity of Garlic (*Allium sativum* L.) under Deficit Irrigation

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Abstract. This study was carried out during the winter seasons of 2016 and 2017 at private farm in Beni Suief Governorate, Egypt to investigate the integrative use of potassium levels (24, 48, 72 and 96 kg K_2O fed^{-1}) and soil mulching (rice straw and bare soil) on growth and productivity of garlic under three levels of surface irrigation (60, 80 and 100 % of crop evapotranspiration (ET_C)). The experimental layout was a spit-spilt plot system based on Randomized Complete Blocks Design. Irrigation levels, potassium rates and mulch types were randomly allocated in the main, sub and sub-sub plots, orderly. The obtained results showed that, the amount of irrigation at 80 and/or 100 % ET_C was accompanied increases by plant height, leaves number, leaf area and dry weight plant^{-1}, total bulbs yield, individual bulb weight, cloves weight and number bulb^{-1} compared to irrigation 60 % ET_C. The application of potassium from 24 to 48 and further to 72 and 96 kg K_2O fed^{-1} gave gradual increments in the aforementioned growth and productivity of traits. The rice straw mulch augmented all previous growth, total bulbs yield and its components compared to bare soil. Generally, the 1st order interaction between irrigation percent at 100 and/or 80 % ET_C × potassium rate at 96 and/or 72 kg K_2O fed^{-1}, irrigation percent at 80 and/or 100 % ET_C × rice straw, potassium rate at 96 kg K_2O fed^{-1} × rice straw and the 2nd interaction of irrigation percent at 100 % ET_C × potassium rate at 96 kg K_2O fed^{-1} × rice straw mulch had pronounced effects on morphological characters and bulbs yield and its components compared to other combined treatments.

Introduction

Garlic (*Allium sativum* L.) is one of main vegetable crops and it has been used for flavoring, soup, sausages and salads, in addition to its medical value [1]. Increasing morphological traits and productivity of garlic are essential aims for both growers and consumers. These aims depend on many environmental factors such as irrigation, potassium, mulch and other agricultural practices. The relative amount of water available to agriculture is declining worldwide due to the rapid population growth and the greater incidence of drought in recent years caused by climate change and different human activities [2]. The challenge of irrigated agriculture in our time is how to produce more morphological and productivity of garlic crops from limited water supply. Working on surface irrigation on garlic, [3] they reported that, 75 and 100 % ETp (potential evapotranspiration determined by class A pan) was at par in plant height and cured bulb diameter, in 2nd season, the reverse was true in total bulbs yield, fresh and cured bulb weight. Also, increasing furrow irrigation from 40 % ET_C to 100 % ET_C, significantly, increased onion bulbs yield and bulb diameter whereas, irrigation; 40, 55, 70, 80 and 100 % ET_C did reflect any appreciable effect on bulb weight [4] .

Potassium is assumed to fulfill many tasks in some physiological and biochemical processes for the growth and productivity of plant. [5] displayed that, increasing potassium rate from 0 to 24 and further to 48, 72 and 96 kg fed^{-1} to grown garlic plants correspondingly and intrinsically increased plant height, leaves number and area plant^{-1}, plant dry weight (without roots) and blubbing ratio. [6] reported that, applied potassium rate at 100 and/or 125 K_2O fed^{-1}, significantly, had maximum leaves number and total dry weight plant^{-1} on garlic however, all potassium levels (0, 25, 50, 75, 100 and

125 kg K$_2$O fed^{-1}) did not reflect any, significant, effect on plant height. [7] displayed that, there was a close relationship between applied potassium rates and garlic productivity. In this regard, [8] reteraved that, application 300 K$_2$O fed^{-1} to grown of garlic plants was a pioneer in total bulbs yield, cloves number bulb^{-1} and clove weight relative to the lower levels (control and 100 K$_2$O fed^{-1}).

Numerous investigators have documented the benefit of rice straw mulch on morphological and productivity. Concerning the effect of rice straw mulch on the morphological phenomena, [9] illustrated that, plant height, leaves number plant^{-1}, pseudo stem diameter and root dry matter on onion were, significantly, higher with rice straw compared to bare soil. Regarding the influence of rice straw mulch on the productivity of garlic, [10] showed that, higher total bulbs yield, fresh weight bulb^{-1}, cloves number bulb^{-1} and total bulbs yield plot^{-1} than bare soil.

Therefore, this study was investigated to the influence of furrow irrigation percent, potassium level and mulch type on morphological traits and productivity phenomena.

Materials and Methods

Two similar field experiments at a private farm, Beni Suef Governorate, Egypt during the winter seasons of 2016 and 2017 to recognize the effect of three surface irrigation percent's; 60, 80 and 100 % ET$_C$, four potassium rates; 24, 48, 72 and 96 kg K$_2$O fed^{-1} and two mulch types; rich straw mulch and bare soil on garlic crop cv. Sids 40. The experimental layout was a split-split plot based on a Randomized Complete Blocks Design with three replications. Irrigation percent's, potassium rates and mulch types were randomly allocated in the main, sub- and sub-sub plots, orderly. Each experimental unit including 3 rows; 3.5 m long and 70 cm wide. Each two adjacent main plots were isolated by 2 m and two adjacent sub-plots were separated with 0.5 m. Before the initiation of experimental site, soil samples were collected and analyses according to the published standard [11]. Results of soil analyses have showed, the soil texture; clay, PH; 7.41 and 7.63, N (mg kg^{-1}); 9 and 9.33, P (mg kg^{-1}); 9.52 and 9.70 and K (meg kg^{-1}); 289 and 301 in 2016 and 2017, respectively. Nearly cloves of the same size were soaked in running tap water for 12 hours prior to sowing, then were hand planted singly in both sides of inter-row spacing 10 cm on September 24th and 30th in 2016 and 2017, respectively.

Irrigation percent treatments

The growing garlic plants were started different irrigation treatments after 30 days from planting and after that were irrigated every 15 days interval. Three irrigation water levels; 60, 80 and 100% ET$_C$ were applied where ET$_C$ represents the crop water evapotranspiration. The crop evapotranspiration (ET$_C$) were estimated using the crop coefficient according to the following equation

$$ETC = ETO \times Kc \tag{1}$$

Where:
ET$_C$ = crop water evapotranspiration (mm d^{-1}).
ET$_O$ = reference evapotranspiration of crop; average monthly of Beni Suef, Egypt for 3.25, 2.59, 2.11, 1.96, 2.51 and 3.36 for October, November, December, January, February and March.
K$_C$ = crop coefficient.

The amount of irrigation water applied to each plot during the irrigation treatment was determined by using the following equation

$$IWA = \frac{A \times ETc \times Ii}{Ea \times 1000} + LR \tag{2}$$

Where:
IWA = irrigation water applied (m^3).   A = plot area (m^2).
ET$_C$ = crop evapotranspiration (mm d^{-1}).   Ii = irrigation intervals (d).
Ea = application efficiency (%) (Ea= 60%).   LR=leaching requirements (m^3)

The amount of irrigation water applied (IWA) was controlled through plastic pipe of 50 mm diameter. The amount of water delivered through a plastic pipe was calculated using the following equation according to [12].

$$Q = CA\sqrt{2gh} \times 10^{-3}$$ (3)

Where:
Q = discharge of irrigation water (l. sec^{-1}),   C= coefficient of discharge
A = cross section area of irrigation pipe (cm^2)   G= gravity acceleration (cm. sec^{-2})
H = average effective head of water (cm).

Potassium rate treatments

The form of potassium fertilizer level was potassium sulfate fertilizer (48% K_2O) and was side banded in three equal portions; 60, 90 and 120 days after seed sowing.

Mulch type treatments

Rice straw mulch was done immediately after complete earthing (about 7 days from seed sowing) and bare soil uncovered with rice straw.

All experimental unites received identical doses of N and P_2O_5 at 100 and 60 Kg fed^{-1}, orderly and all other agro-management practices were achieved as recommended in the commercial production of garlic. Harvesting was done after 180 days from planting, in both seasons. In each experimental unit, plants of the middle row were allocated for morphological measurements while, plants of the two outer rows were allocated to measure bulbs yield and its components.

Data Recorded
Morphological characters was done 160 days after planting
1. **Plant height (cm)**; measured from the bulb bottom to the tip of longest leaf.
2. **Leaves number plant^{-1};** estimated by counts.
3. **Leaves area plant^{-1} (cm^2);** calculated using relationship between fresh weight of leaves plant^{-1} and fresh weight and area of 20 disks taken from fresh leaves by a borer known its diameter [13].
4. **Dry weight plant^{-1} without roots (g);** plants sample were placed in a forced-oven at 70 C^o till the weights became constants.

Blubs yield and its components were achieved 180 days after planting
1. **Total bulbs yield fed^{-1}(tones);** bulbs in each treatment were weighed and converted to total bulbs yield fed^{-1}.
2. **Bulb weight (g);** calculated by the following equation
   Bulb weight = $\dfrac{\text{bulbs weight in each experimental unit}}{\text{bulbs number in each experimental unit}}$
3. **Cloves weight bulb^{-1}(g);** ten bulbs from each treatment were separated individually into cloves bulb^{-1} and weighed and the average cloves weight bulb^{-1} was calculated.
4. **Cloves number bulb^{-1};** using ten bulbs, from each treatment, were separated individually into cloves, counted and average cloves number bulb^{-1} was calculated.
5. **Average clove weight (g);** calculated by the following formula

   Average clove weight = $\dfrac{\text{weight cloves bulb}^{-1}}{\text{number of cloves bulb}^{-1}}$

Statistical analysis

Appropriate analysis of variance on obtained data was performed. Comparisons among mean treatments were carried out using Revised Least Significant Difference at P $\leq$ 0.05 [14].

Results

Morphological Characters

Table 1 shows the main effects of three studied factors on morphological phenomena, during the winter seasons of 2016 and 2017. Irrigation at 80 and/or 100 % ET_C produced higher, significantly, than irrigation at 60 % ET_C on plant height, leaves number and leaves area plant[-1] while, increasing irrigation from 60 to 80 and further to 100 % ETC, truly, increased whole plant dry weight, in both seasons. Application potassium 24 up to 96 kg K_2O fed[-1] accompanied, significantly, increased, on plant height, leaves number, leaves area and dry weight plant[-1], in both seasons whilst, difference potassium between 72 and 96 kg K_2O fed[-1] in plant height and 48 and 72 kg K_2O fed[-1] in leaves number plant[-1], in 1st season, was at par. Significant increments of rice straw mulch over bare soil on plant height, leaves number, leaves area and whole dry weight plant[-1], in both investigated seasons.

The statistical comparisons listed in Table 2 show that, the effect of 1st order interaction between irrigation percent's and potassium rates on vegetative traits was, significant, in both seasons nevertheless, leaves number plant[-1] did not appear to be significantly, in 2nd season. The application of irrigation at 80 and/100 % ET_C together with potassium at 72 and/or 96 kg K2O fed[-1] had maximum values of plant height, leaves number, area and dry weight plant[-1]. Also, the results obtained of interaction between irrigation 80 and/or 100 % ET_C × rice straw mulch had, truly, the maximum leaves area plant-1, in both seasons while, the interaction between 100 % ET_C × rice straw mulch was the best on plant height and dry weight plant[-1]. The application of all potassium rates × all mulch types did not reflect any appreciable effect on studied growth characters except dry weight plant[-1], in both seasons. The results indicated that, in both seasons within 96 kg K_2O fed[-1], the application of rice straw mulch resulted in heaviest dry weight plant[-1].

Table 1. The main effect of irrigation percent, potassium rate and mulch type on plant height (cm), leaves number, leaves area (cm^2), leaves dry weight (g) and dry weight plant[-1] (g) during the winter seasons of 2016/2017 and 2017/2018

Treatments	2016				2017			
Irrigation (% ET$_C$)	Plant Height	Leaves Number Plant[-1]	Leaves area Plant[-1]	D.W. Plant[-1]	Plant height	Leaves Number Plant[-1]	Leaves area Plant[-1]	D.W. Plant[-1]
100	95.12$^{A•}$	9.40^A	558.14^B	45.53^A	97.57^A	9.41^A	61.42^A	48.51^A
80	95.03^A	9.43^A	595.05^A	41.45^B	97.66^A	9.39^A	58.79^B	42.12^B
60	80.23^B	8.23^B	347.62^C	23.09^C	84.61^B	8.30^B	42.97^C	25.90^C
Potassium (K$_2$O fed[-1])								
24	81.81^C	8.40^C	363.28^D	26.98^D	40.83^D	8.37^D	388.12^D	25.54^D
48	90.91^B	8.97^B	494.31^C	35.85^C	44.84^C	8.89^C	470.41^C	35.34^C
72	93.80^A	9.14^B	560.47^B	38.67^B	46.68^B	9.27^B	535.27^B	43.07^B
96	93.97^A	9.57^A	583.02^A	45.26A	48.63^A	9.61^A	598.82^A	51.42^A
Mulch (type)								
Bare soil	89.11^B	8.84^B	469.89^B	32.61^B	91.72^B	8.90^B	477.64^B	36.05^B
Rice straw	91.13^A	9.20^A	530.65^A	40.77^A	94.83^A	9.17^A	518.67^A	41.64^A

•Values marked with the same letter(s) within the main effect are statistically similar using Revised LSD. Test at probability = 0.05. Uppercase refer to the main effect.

Table 2. The 1st interaction of irrigation percent, potassium rate and mulch type on plant height (cm), leaves number, leaves area (cm^2) and dry weight plant^{-1} (g) during the winter seasons of 2016/2017 and 2017/2018

Treatments			2016				2017			
I	K	M	Plant height	leaves number plant^{-1}	leaves area plant^{-1}	dry weight plant^{-1}	Plant height	leaves number plant^{-1}	leaves area plant^{-1}	dry weight plant^{-1}
100	24		84.90e	8.67ef	416.5g	29.33e	84.37h	8.83a	482.1f	33.92g
	48		94.87c	9.40bc	565.4d	49.78ab	95.10de	9.17a	553.5d	45.79e
	72		101.6a	9.67ab	637.3b	51.33ab	104.07b	9.70a	632.5b	53.32c
	96		99.10b	9.87a	613.3bc	51.69a	106.73a	9.93a	650.0a	61.02a
80	24		89.77d	8.93de	462.5f	35.80d	93.60e	8.60a	432.0g	26.63h
	48		95.40c	9.17cd	584.3cd	36.86d	96.00d	9.23a	561.5d	37.50f
	72		97.97b	9.80a	704.0a	43.98c	98.73c	9.77a	598.6c	48.03d
	96		96.97bc	9.83a	629.5b	49.14b	102.30b	9.97a	625.7b	56.33b
60	24		70.77g	7.60h	210.9i	15.80g	74.80i	7.67a	250.2j	16.08j
	48		82.47f	8.33fg	333.3h	20.91f	84.37h	8.27a	296.2i	22.75i
	72		81.83f	7.97gh	340.1h	20.71f	95.10de	8.33a	374.7h	27.85h
	96		85.83e	9.00de	506.2e	34.95d	104.07b	8.93a	520.8e	36.91f
100		B.	94.48b	9.23a	516.1d	41.65c	25.84a	9.25a	564.6b	45.41a
		R.S.	95.75a	9.57a	600.2b	49.42a	26.65a	9.57a	594.5a	51.62a
80		B.	94.43b	9.32a	553.5c	35.86d	23.15a	9.32a	536.6c	39.43a
		R.S.	95.62ab	9.55a	636.6a	47.03b	25.01a	9.47a	572.3b	44.81a
60		B.	78.42d	7.97a	340.0e	20.32f	16.48a	8.13a	331.8e	23.31a
		R.S.	82.03c	8.48a	355.2e	25.86e	18.21a	8.47a	389.2d	28.48a
	24	B.	80.93a	8.13a	327.3a	21.19f	82.82a	8.18a	364.5a	22.99h
		R.S.	82.69a	8.67a	399.3a	32.76e	85.69a	8.56a	411.8a	28.09g
	48	B.	89.82a	8.73a	451.6a	33.35de	90.69a	8.62a	447.4a	31.41f
		R.S.	92.00a	9.20a	536.1a	38.35c	93.71a	9.16a	493.5a	39.28e
	72	B.	92.56a	9.04a	536.3a	35.03d	95.27a	9.27a	517.1a	41.08d
		R.S.	95.04a	9.24a	584.7a	42.32b	98.38a	9.27a	552.6a	45.06c
	96	B.	93.13a	9.44a	564.4a	40.88b	98.11a	9.53a	580.8a	48.72b
		R.S.	94.80a	9.69a	601.6a	49.65a	101.56a	9.69a	616.9a	54.13a

• Values marked with the same letter(s) within the 1st interaction effects are statistically similar using Revised LSD. Test at probability = 0.05. Lowercase refer to the 1st interaction effect. I= irrigation (% ET$_C$) ‹ K= potassium (K$_2$O fed^{-1}) ‹ M= mulch type ‹ B= bare soil ‹ R.S.= rice straw mulch

The interaction of three studied factors on plant height and dry weight plant^{-1}, in both season, and leaves area plant^{-1}, in 2nd season, was, significant. However, leaves number plant^{-1} did not respond, in both seasons. Generally, the interaction of irrigation 100 % ET$_C$ × potassium at 72 and/or 96 kg K$_2$O fed^{-1} × rice straw mulch produced taller stature, heaviest dry weight and larger leaves area plant^{-1} than other combined treatments.

Table 3. The 2nd interaction of irrigation percent, potassium rate and mulch type on plant height (cm), leaves number, leaves area (cm^2) and dry weight plant^{-1} (g) during the winter seasons of 2016/2017 and 2017/2018

Treatments			2016				2017			
I	K	M	Plant height	leaves number plant^{-1}	leaves area plant^{-1}	dry weight plant^{-1}	Plant height	leaves number plant^{-1}	leaves area plant^{-1}	Dry weight plant^{-1}
100	24	B	84.80^{hi}	8.40 ^{a}	357.0 ^{a}	23.39^k	83.00^o	8.73 ^{a}	478.1^h	30.52^k
		R.S.	85.00^{hi}	8.93 ^{a}	475.9 ^{a}	35.27^h	85.73^{mno}	8.93 ^{a}	486.1^h	37.33^i
	48	B.	93.60^e	9.13 ^{a}	521.3 ^{a}	48.32^{bc}	92.20^{jk}	8.80 ^{a}	524.4^g	41.31^g
		R.S.	96.13^{cd}	9.67 ^{a}	609.5 ^{a}	51.24^b	98.00^{efg}	9.53 ^{a}	582.6^{de}	50.27^e
	72	B	99.33^b	9.67 ^{a}	603.3 ^{a}	46.59^{cd}	102.33^{cd}	9.67 ^{a}	613.4^{bc}	50.95^e
		R.S.	103.87^a	9.67 ^{a}	671.4 ^{a}	56.08^a	105.80^{ab}	9.73 ^{a}	651.6^a	55.69^c
	96	B.	100.20^b	9.73 ^{a}	582.9 ^{a}	48.31^{bc}	104.47^{bc}	9.80 ^{a}	642.3^{ab}	58.85^b
		R.S.	98.00^{bc}	10.00 ^{a}	643.9 ^{a}	55.08^a	109.00^a	10.07 ^{a}	657.7^a	63.19^a
80	24	B	91.00^f	8.60 ^{a}	437.8 ^{a}	27.38^j	93.87^{hij}	8.33 ^{a}	395.3^i	25.23^o
		R.S.	88.53^g	9.27 ^{a}	487.1 ^{a}	44.22^{de}	93.33^{ijk}	8.87 ^{a}	468.7^h	28.02^{lm}
	48	B.	95.13^{de}	9.00 ^{a}	514.0 ^{a}	33.60^{hi}	95.67^{ghi}	9.07 ^{a}	546.3^g	33.77^j
		R.S.	95.67^{cde}	9.33 ^{a}	654.5 ^{a}	40.11^{fg}	96.33^{fghi}	9.40 ^{a}	576.8^{ef}	41.22^{gh}
	72	B	97.87^{bc}	9.87 ^{a}	668.1 ^{a}	39.27^g	96.80^{fgh}	9.93 ^{a}	594.6^{cde}	45.40^f
		R.S.	98.07^{bc}	9.73 ^{a}	739.1 ^{a}	48.69^{bc}	100.67^{de}	9.60 ^{a}	602.6^{cde}	50.66^e
	96	B.	93.73^{de}	9.80 ^{a}	594.2 ^{a}	43.20^{ef}	99.47^{def}	9.93 ^{a}	610.2^{cd}	53.32^d
		R.S.	100.20^b	9.87 ^{a}	664.7 ^{a}	55.09^a	105.13^{bc}	10.00 ^{a}	641.1^{ab}	59.35^b
60	24	B.	67.00^l	7.40 ^{a}	186.9^a	12.80^n	71.60^q	7.47 ^{a}	220.0^l	13.23^q
		R.S.	74.53^k	7.80 ^{a}	234.1 ^{a}	18.79^m	78.00^p	7.87 ^{a}	280.5 ^{k}	18.93^p
	48	B.	80.73^j	8.07 ^{a}	319.6^a	18.12^m	84.20^{no}	8.00 ^{a}	271.4 ^{k}	19.16^p
		R.S.	84.20^{hi}	8.60 ^{a}	346.9 ^{a}	23.70^k	86.80^{mn}	8.53 ^{a}	321.0 ^{j}	26.34^{no}
	72	B.	80.47^j	7.60 ^{a}	337.4 ^{a}	19.23^{lm}	86.67^{mn}	8.20 ^{a}	345.9 ^{j}	26.88^{mn}
		R.S.	83.20^i	8.33 ^{a}	342.7^a	22.19^{kl}	88.67^{lm}	8.47 ^{a}	403.6 ^{i}	28.82^l
	96	B.	85.47^{hi}	8.80 ^{a}	516.2^a	31.13^i	90.4^{0kl}	8.87 ^{a}	489.8 ^{h}	33.98^j
		R.S.	86.20^{gh}	9.20^a	496.3^a	38.77^g	90.53^{kl}	9.00^a	551.7 ^{fg}	39.84^h

• Values marked with the same letter(s) within the 1st interaction effects are statistically similar using Revised LSD. Test at probability = 0.05. Lowercase refer to the 1st interaction effect. I= irrigation (% ET$_C$) ‹ K= potassium (K$_2$O fed^{-1}) ‹ M= mulch type ‹ B= bare soil ‹ R.S.= rice straw mulch

Bulbs yield and its components

The general effects (irrigation, potassium and mulch) of total bulbs yield and its components listed in Table 4 showed that were significant, in two investigated seasons.

Increasing the amount of irrigation at 80 and/or 100 % ET$_C$ was accompanied by increases in individual bulb weight, cloves weight and number bulb^{-1} and mean clove weight, in 1st season, over irrigation amount at 60 % ET$_C$ while, increasing the amount of irrigation from 60 to 80 and further to 100 % ET$_C$ increases in individual bulb weight, cloves weight and number bulb^{-1}, in 2nd season. Therefore, increasing the amount of irrigation up 100 % ET$_C$ progressively increased total bulbs yield. The increasing application of potassium to grown plants from 24 to 48 and further to 72 and 96 K$_2$O fed^{-1} gave, significant, gradual increases in total bulbs yield and its components. The exception was in cloves number bulb^{-1} where the difference potassium rate at 48 and 72 K$_2$O fed^{-1} was at par. The effect noticed from comparisons between two mulch types reflected that, rice straw mulch, significantly, increased total bulbs yield and its components over bare soil.

The influence of interaction between irrigation and potassium levels on total bulbs yield and its components was significant, in both seasons except cloves number bulb^{-1}, in 2nd season (Table 5). The combined treatment of irrigation 100 % ET$_C$-potassium 96 kg K$_2$O fed^{-1} was higher in total bulbs yield, blub weight, cloves weight bulb^{-1} and clove weight than the other combinations. However, the

combined treatment of irrigation 100 % ET_C-potassium 72 and/or 96 kg K_2O fed^{-1} was higher in cloves number bulb^{-1} than the other combinations.

The impact of interaction between irrigation and mulch levels on bulb weight and cloves weight bulb^{-1} was significant however, total bulbs yield was not responded, in both seasons. Meanwhile, clove weight and cloves number bulb^{-1} were significant in 1st and 2nd season, orderly (Table 5). The combination of irrigation 80 and/or 100 % ET_C and rice straw mulch seemed to be the highest mean values in a single bulb weight, cloves weight and number bulb^{-1} whereas, irrigation 80 % ET_C and rice straw mulch was the best in clove weight.

The effect of interaction between potassium and mulch on total bulbs yield and bulb weight, in both seasons and cloves weight, number bulb^{-1} and clove weight, in 1st season was significant (Table 5). The combination of potassium 96 kg K_2O fed^{-1}–rice straw mulch had the maximum values in total bulbs yield, bulb weight, cloves weight and number bulb^{-1}. Cloves number bulb^{-1} was the best as combined treatment at potassium 48 K_2O fed^{-1} with rice straw mulch.

The 2nd order interaction among three factors on total bulbs yield and clove weight was significant, in both seasons while, bulb weight and cloves weight bulb-1 was, truly, in 2nd season only meanwhile, cloves number bulb^{-1} was, intrinsically, in 1st season only. The combined treatment to grown plants; irrigation 100 % ET_C and application potassium 96 kg K_2O fed^{-1} as well as covering soil surface with rice straw attained higher, total bulbs yield, bulb weight, cloves weight bulb^{-1} and clove weight than the other combinations. Mean value of cloves number bulb^{-1} was the maximum when garlic plants irrigated with 100 % ET_C and fertilized with 72 kg K2O in addition to surface with rice straw mulch.

Table 4. The main effect of irrigation percent, potassium rate and mulch type on total bulbs yield (tones), bulb weight (g), clove weight plant^{-1}(g), cloves number plant^{-1} (g) and mean clove weight (g), during the winter seasons of 2016 and 2017

Treatments	2016					2017				
Irrigation (% ET_C)	Total bulbs yield	Bulb weight	Cloves weight bulb^{-1}	Cloves No. bulb^{-1}	Mean clove weight	Total bulbs yield	Bulb weight	Cloves weight bulb^{-1}	Cloves No. bulb^{-1}	Mean Clove weight
100	8.02^A	94.58^A	83.75^A	16.51^A	5.04^A	8.25^A	97.05^A	90.18^A	16.95^A	5.29^B
80	7.38^B	90.10^A	80.40^A	15.20^{AB}	5.30^A	7.59^B	93.80^B	87.03^B	15.14^B	5.71^A
60	5.42^C	56.26^B	51.67^B	14.75^B	3.46^B	5.60^C	59.58^C	55.33^C	14.16^C	3.85^C
Potassium (K2O fed^{-1})										
24	6.28^D	54.08^D	48.99^D	14.58^C	3.31^D	6.43^D	58.99^D	54.15^D	13.71^D	3.93^D
48	6.75^C	71.87^C	65.54^C	15.46^B	4.25^C	6.93^C	77.10^C	71.74^C	15.04^C	4.75^C
72	7.10^B	90.68^B	80.97^B	15.83^{AB}	5.13^B	7.40^B	90.36^B	83.94^B	16.21^B	5.14^B
96	7.63^A	104.6^A	92.25^A	16.08^A	5.72^A	7.83^A	107.4^A	100.22^A	16.70^A	5.98^A
Mulch(type)										
Bare soil	6.83^B	73.74^B	66.20^B	14.94^B	4.38^B	6.99^B	78.44^B	72.71^B	15.09^B	4.73^B
Rice straw	7.05^A	86.89^A	77.68^A	16.03^A	4.82^A	7.31^A	88.51^A	82.32^A	15.74^A	5.17^A

•Values marked with the same letter(s) within the main effect are statistically similar using Revised LSD. Test at probability = 0.05. Uppercase refer to the main effect.

Table 5. The 1st interaction of irrigation percent, potassium rate and mulch type on total bulbs yield (tones), bulb weight (g), clove weight plant^{-1}(g), cloves number plant^{-1} (g) and mean clove weight (g), during the winter seasons of 2016 and 2017

Treatments			2016					2017				
I.	K.	M.	Total bulbs yield	Bulb weight	Cloves weight bulb^{-1}	Cloves No. bulb^{-1}	Mean clove weight	Total bulbs yield	Bulb weight	Cloves weight bulb^{-1}	Cloves No. bulb^{-1}	Mean Clove weight
100	24		7.49^d	61.91^h	57.08^f	15.53^{bc}	3.67^e	7.77^e	68.92^h	63.54^{gh}	15.13^a	4.19^e
	48		8.06^{bc}	85.54^e	76.41^d	15.87^b	4.82^c	8.14^c	88.08^e	81.66^e	16.63^a	4.93^d
	72		8.19^{ab}	105.51^c	94.46^b	17.47^a	5.41^b	8.43^b	104.84^c	97.63^c	17.80^a	5.49^c
	96		8.33^a	125.36^a	107.05^a	17.17^a	6.24^a	8.64 a	126.36^a	117.9^a	18.23^a	6.54 a
80	24		6.73^f	69.09^g	61.33^f	15.00^{bc}	4.09^d	6.73^g	72.19^g	66.42^g	13.23^a	5.04^d
	48		7.26^e	79.05^f	72.56^{de}	15.43^{bc}	4.75^c	7.57^f	87.28^e	81.46^e	14.60^a	5.59^{bc}
	72		7.51d	100.69^d	89.31^c	14.57^c	6.13^a	7.89^d	98.64^d	91.67^d	16.00^a	5.73^b
	96		8.03^c	111.57^b	98.40^b	15.80^b	6.24^a	8.18^c	117.07^b	108.5^b	16.73^a	6.49 a
60	24		4.61^j	31.24^j	28.58^h	13.20^d	2.15^g	4.78^j	35.85^j	32.51^j	12.77^a	2.55^g
	48		4.95^i	51.02^i	47.64^g	15.07^{bc}	3.16^f	5.09^1	55.93^i	52.10^i	13.90^a	3.74^f
	72		5.61^h	65.85^{gh}	59.14^f	15.47^{bc}	3.84^{de}	5.88^h	67.60^h	62.51^h	14.83^a	4.22^e
	96		6.51^g	76.93^f	71.31^e	15.27^{bc}	4.68^c	6.66^g	78.93^f	74.19^f	15.13^a	4.91^d
100		B.	7.91^a	87.67^c	78.38^b	15.93^b	4.86^a	8.11^a	92.18^b	85.38^b	16.45^a	5.14^c
		R.S.	8.13^a	101.49^a	89.12^a	17.08^a	5.21^a	8.39^a	101.92^a	94.99^a	17.45^a	5.44^b
80		B.	7.27^a	82.11^d	73.42^c	14.28^d	5.12^a	7.45^a	87.14^c	80.53^c	15.00^a	5.33^{bc}
		R.S.	7.49^a	98.09^b	87.38^a	16.12^b	5.49^a	7.74^a	100.45^a	93.52^a	15.28^a	6.09^a
60		B.	5.30^a	51.43^f	46.80^e	14.60^{cd}	3.14^a	5.41^a	56.00^e	52.21^e	13.83^a	3.72^e
		R.S.	5.54^a	61.09^e	56.53^d	14.90^c	3.78^a	5.80^a	63.16^d	58.45^d	14.48^a	3.99^d
	24	B.	6.09^f	46.73^g	42.18^g	13.40^d	3.12^f	6.24^h	54.54^h	49.91^a	13.36^a	3.71^a
		R.S.	6.46^e	61.43^f	55.81^f	15.76^{ab}	3.49^e	6.62^g	63.43^g	58.40^a	14.07^a	4.14^a
	48	B.	6.69^d	66.98^e	61.42^e	14.56^c	4.25^d	6.77^f	71.44^f	66.41^a	14.49^a	4.55^a
		R.S.	6.82^d	76.76^d	69.65^d	16.36^a	4.24^d	7.10^e	82.76^e	77.07^a	15.60^a	4.95^a
	72	B.	7.05^c	84.95^c	75.56^c	15.62^b	4.86^c	7.31^d	86.36^d	79.90^a	16.02^a	4.94^a
		R.S.	7.16^c	96.41^b	86.38^b	16.04^{ab}	5.39^b	7.49^c	94.36^c	87.97^a	16.40^a	5.34^a
	96	B.	7.47^b	96.29^b	85.65^b	16.18^{ab}	5.27^b	7.63^b	101.42^b	94.61^a	16.51^a	5.70^a
		R.S.	7.78^a	112.95^a	98.86^a	15.98^{ab}	6.17^a	8.03^a	113.48^a	105.8^a	16.89^a	6.26^a

• Values marked with the same letter(s) within the 1st interaction effects are statistically similar using Revised LSD. Test at probability = 0.05. Lowercase refer to the 1st interaction effect. I= irrigation (% ET$_C$) ، K= potassium (K$_2$O fed^{-1}) ، M= mulch type ، B= bare soil ، R.S.= rice straw mulch

Table 6. The $2^{nd\ t}$ interaction of irrigation percent, potassium rate and mulch type on total bulbs yield (tones), bulb weight (g), clove weight plant^{-1}(g), cloves number plant^{-1} (g) and mean clove weight (g), during the winter seasons of 2016 and 2017

Treatments			2016					2017				
I	K	M	Total bulbs yield	Bulb weight	Cloves weight bulb^{-1}	Cloves No. bulb^{-1}	Mean clove weight	Total bulbs yield	Bulb weight	Cloves weight bulb^{-1}	Cloves No. bulb^{-1}	Mean Clove weight
100	24	B.	7.22^{gh}	55.23^a	50.81^a	14.27^{ghij}	3.57^{ij}	7.54^f	65.35^l	59.65^k	14.4^a	4.14^{ij}
		R.S.	7.76^{de}	68.58^a	63.34^a	16.80^{abc}	3.77^{hij}	8.00^d	72.49^k	67.42^j	15.8^a	4.25^{ij}
	48	B.	8.03^{bcd}	80.45^a	73.05^a	15.33^{defgh}	4.77^{def}	7.99^d	81.89^{hi}	75.74^i	15.7^a	4.82^{gh}
		R.S.	8.09^{bc}	90.63^a	79.78^a	16.40^{bcd}	4.88^{def}	8.30^c	94.27^f	87.58^f	17.5^a	5.03^{fg}
	72	B.	8.13^{abc}	99.57^a	90.55^a	17.07^{ab}	5.30^{bcd}	8.40^{bc}	105.00^e	97.81^e	17.6^a	5.54^{de}
		R.S.	8.26^{ab}	111.45^a	98.37^a	17.87^a	5.52^{bc}	8.46^{bc}	104.67^e	97.44^e	17.9^a	5.43^{def}
	96	B.	8.25^{ab}	115.42^a	99.12^a	17.07^{ab}	5.81^b	8.50^b	116.48^c	108.31^c	18.0^a	6.04^{bc}
		R.S.	8.42^a	135.30^a	114.98^a	17.27^{ab}	6.67^a	8.79^a	136.24^a	127.5^a	18.4^a	7.04^a
80	24	B.	6.47^j	59.74^a	53.37^a	13.33^{jk}	4.02^{ghi}	6.50^h	64.85^l	59.32^k	13.1^a	4.53^{hi}
		R.S.	6.99^{hi}	78.45^a	69.30^a	16.67^{abc}	4.17^{gh}	6.97^g	79.53^{ij}	73.52^i	13.3^a	5.54^{de}
	48	B.	7.22^{gh}	74.49^a	68.47^a	13.53^{jk}	5.08^{cd}	7.39^f	83.86^h	77.74^{hi}	14.4^a	5.40^{def}
		R.S.	7.29^{fg}	83.60^a	76.64^a	17.33^{ab}	4.42^{efg}	7.76^e	90.69^{fg}	85.18^{fg}	14.8^a	5.77^{cd}
	72	B.	7.49^{fg}	92.86^a	81.38^a	14.13^{hij}	5.78^b	7.88^{de}	89.17^g	82.39^{gh}	15.8^a	5.22^{efg}
		R.S.	7.53^{ef}	108.52^a	97.25^a	15.00^{efgh}	6.48^a	7.89^{de}	108.12^e	100.9^{de}	16.2^a	6.24^b
	96	B.	7.90^{cc}	101.37^a	90.48^a	16.13^{bcde}	5.60^{bc}	8.02^d	110.67^d	102.68^d	16.6^a	6.16^{bc}
		R.S.	8.16^{ab}	121.78^a	106.32^a	15.47^{defg}	6.88^a	8.35^{bc}	123.47^b	114.45^b	16.8^a	6.82^a
60	24	B.	4.59^m	25.23^a	22.37^a	12.60^k	1.78^l	4.66^m	33.42^o	30.76^m	12.5^a	2.46^l
		R.S.	4.63^m	37.25^a	34.78^a	13.80^{ij}	2.52^k	4.89^l	38.29^n	34.25^m	13.0^a	2.63^l
	48	B.	4.831^{lm}	45.99^a	42.74^a	14.80^{fghi}	2.89^k	4.93^l	48.55^m	45.75^l	13.3^a	3.43^k
		R.S.	5.07^l	56.06^a	52.54^a	15.33^{defgh}	3.44^j	5.25^k	63.31^l	58.46^k	14.4^a	4.05^j
	72	B.	5.52^k	62.42^a	54.76^a	15.67^{cdef}	3.50^{ij}	5.65^j	64.91^l	59.49^k	14.6^a	4.07^j
		R.S.	5.69^k	69.2^a	63.51^a	15.27^{defgh}	4.18^{gh}	6.11^i	70.29^k	65.54^j	15.0^a	4.36^{ij}
	96	B.	6.27^j	72.10^a	67.34^a	15.33^{defgh}	4.40^{fg}	6.38^h	77.12j	72.85^i	14.8^a	4.91^{gh}
		R.S.	6.76^i	81.76^a	75.28^a	15.20^{defgh}	4.96^e	6.95^g	80.74^{hij}	75.53^i	15.4^a	4.91^{gh}

• Values marked with the same letter(s) within the 2nd interaction effects are statistically similar using Revised LSD. Test at probability = 0.05. Lowercase refer to the 1st interaction effect. I= irrigation (% ET$_C$) ، K= potassium (K$_2$O fed^{-1}) ،M= mulch type ، B= bare soil ، R.S.= rice straw mulch

Discussion

The obtained results showed that, irrigation 80 and/or 100 % ET$_C$ enhanced the effect of morphological, total bulbs yield and its components over irrigation 60 % ET$_C$. Such favourable effect of irrigation at the intermediate and/or higher treatments than lower irrigation treatment might be due to better availability of moisture in root zone during entire garlic growth period and it is well known that water plays a crucial in nutrients uptake and transport and photosynthesis which favoured the growth and then reflected bulbs yield and its components [3]. Similar findings were obtained by [15] and [16] who showed that, drought is one of the major stress that adversely influences on growth and yield of crops. [17], who reported that, irrigation 80 or 100 % ET$_C$ provided, significantly, higher total and marketable bulbs yield, bulb weight, clove weight and cloves number bulb^{-1}than 60 % ET$_C$ of garlic.

The desirable effect of potassium rates up to 96 kg K$_2$O fed^{-1} on improving growth, total bulbs yield and its components was imputed to the fact that, potassium element is producing the stocky and

healthy appearance with thick leaves and larger bulbs of garlic plants. Also, potassium is a beneficial in soil nutrient solution and improvement absorption efficiency which reflected on stimulate on plant growth. Moreover, potassium has an essential role in translocation of synthesized carbohydrates from plant leaves towards bulbs. Typical findings on growth, total bulbs yield and its components were reported by [8] and [5] who documented that, increasing application potassium to growing garlic plants from 0 to 24 and further to 48, 72 and 96 kg K_2O fed[-1] resulted in, significant, gradual increases on plant height, leaves number plant[-1], leaf area plant[-1], dry weight plant[-1], total bulbs yield, bulb weight and clove weight whereas, cloves number bulb[-1] was not affected.

The promoting of rice straw mulch over bare soil on all growth, total bulbs yield and its components can be explained on basis that, using rice straw mulch depressed infiltration rate caused efficient in reduction of nutrients leaching, regulated soil temperature, much conserved soil moisture, stimulated soil flora activity, reduced weed growth, adding organic matter to soil and adequating micro atmosphere surrounding plants which reflected on growth and productivity [18] and [19]. Similar information were published on growth of garlic plants by [20] and [10] who showed that, rice straw mulch produced the highest plant height (70.68 cm), leaves number plant[-1](11.74), fresh leaves weight plant[-1] (7.51 g) and dry weight leaves plant[-1] (2.91 g). Our results on bulbs yield and its components of garlic were in line with those of [10], [21] and [22] who indicated that, plants of garlic grown under rice straw mulch attained total bulbs yield (5.48 t ha^{-1}) which was 31.41% higher than the bare soil (4.17 t ha^{-1}).

The synergetic effect of interaction between irrigation 80 and/or 100 % ET_C × potassium rate at 72 and/or 96 kg K_2O fed[-1] over irrigation percent at 60 % ET_C × potassium rate at 24 kg K_2O fed[-1] on plant height, leaves number, area and dry weight plant[-1], total bulbs yield, bulb weight, cloves weight and number and clove weight might be attributed to increase, as an average of both seasons, by 43.1, 29.7, 196.8, 253.3, 83.8, 276.9, 268.6, 37.6 and 173.4 %, respectively.

The favorable effect of interaction between irrigation 80 and/or 100 % ET_C × rice straw mulch over irrigation 60 % ET_C × bare soil on leaves area plant[-1], in both seasons, plant height and dry weight plant[-1] was attributed to increase by 83.20, 22.10 and 143.21 %, orderly. Again, interaction between irrigation 100 % ET_C × rice straw mulch over irrigation 60 % ET_C × bare soil on bulb weight and cloves weight bulb[-1], in both seasons, cloves number bulb[-1], in 1st season was imputed to increase by 89.19, 86.18 and 16.99 %, respectively. However, irrigation 80 % ET_C × rice straw mulch over irrigation 60 % ET_C × bare soil on clove weight due to increase by 63.71 %.

The desirable effect of interaction between potassium 96 kg K_2O fed[-1] × rice straw mulch over potassium 24 kg K_2O fed[-1] × bare soil on dry weight plant[-1], total bulbs yield, bulb weight, in both seasons, cloves weight bulb[-1] and clove weight, in 1st season possibly attributed to increase by 134.88,28.22, 124.89, 134.38 and 97.76 %, respectively. However, the interaction between potassium 48 kg K_2O fed-1 × rice straw mulch over potassium 24 kg K_2O fed[-1] × bare soil on cloves number bulb[-1], in 1st season, properly to increase by 22.09 %.

Conclusion

Results of the current study clarified that the morphological characters and bulbs yield and its components of garlic can be improved by increasing the irrigation percent from 60 to 80 and 100 % ET_C, fertilizing growing garlic plants by 96 kg K_2O fed[−1] and cover soil with rice straw. The results, also, indicated that the 1st order interaction between irrigation percent at 100 and/or 80 % ET_C × potassium rate at 96 and/or 72 kg K_2O fed[−1], irrigation percent at 80 and/or 100 % ET_C × rice straw, potassium rate at 96 kg K_2O fed[−1] × rice straw and the 2nd interaction of irrigation percent at 100 % ET_C × potassium rate at 96 kg K_2O fed[−1] × rice straw mulch generally, had pronounced effects on morphological characters and bulbs yield and its components.

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