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Enhancement of Onion (*Allium cepa* L.) Drought Tolerance in Calcareous Soils by Using Bio-Stimulants

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THE current investigation was aimed to investigate the influences of different irrigation regimes, bio-stimulants and their interaction on onion yield and yield components, to improve plant growth under water stress, to reduce the negative effect of water stress. A split-plot desing was used, which the main plot was irrigation treatments (100% of crop evapotranspiration, 80% ETc and 60% ETc), while the bio-stimulants (control, active dry yeast extract, potassium humate and active dry yeast extract plus potassium humate) were assigned in sub-plot. The results showed that soil application of the biostimulants reduced the negative impact of water deficit compared to control. Yeast extract followed by yeast extract plus potassium humate recorded the highest plant height, diameter of neck and bulb, shoots fresh weight, fresh weight of bulb and total yield of onion during both seasons. With decreasing the required amount of water (at 80% ETc), the reduction percentage was only 5.18% and 4.65% when plants treated with yeast extract compared to 100% ETc in the 1st and 2nd seasons, respectively. However, yeast extract at 80% ETc was higher in the total yield than untreated plants under 100% ETc irrigation regime by 16.37% and 16.03% during the first and second seasons. Moreover, the highest irrigation water use efficiency was recorded at an irrigation regime 80% ETc and yeast extract with no significant difference with yeast extract plus potassium humate. From obtained results, yeast extract and or yeast extract plus potassium humate could play an important role in increasing plant stress tolerance to water deficit irrigation.

Keywords: Drip Irrigation, Potassium humate, Sandy soil, Water use efficiency, Yeast extract.

Introduction

Abiotic stresses such as low temperature, salinity, and water scarcity cause significant losses in plant production throughout the world (Li et al., 2015). Water deficit is a major limiting factor of crop production (Csiszár et al. 2007; Jones, 2009; Mostafa et al. 2019 and Yang et al. 2020). Enhances of water use efficiency in agriculture as a result of water scarcity, increasing costs and increasing world population growth are needed (Bessembinder et al. 2005; Leskovar and Agehara, 2012 and Refai et al. 2019). Gewaily (2019) reported that, for Egyptian soil, the irrigation water is relatively limited and insufficient for both reclamation and irrigation purposes. Moreover, most of newly reclaimed soil is sand or sandy calcareous soils that's naturally occur in arid and semi-arid regions. Calcareous soils constitute about 25-30% of the total area in Egypt (Abou-Elela, 2002). Mechanisms of plant tolerance to drought dtress can be regulated through developing tolerant genotypes, genetic modifications, application of plant growth regulatours and compatible solutes, seed treatments and use of mineral nutrients (Hussain et al. 2018). One of the methods to improve the drought tolerance of cultivated crops is to find a suitable bio-stimulant which enhances the onion resistance to drought. Parađiković et al. (2018)

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mentioned that any natural substances which have beneficial effects on growth and development of the plant, crop yield and quality, and stress tolerance can be defined as bio-stimulators or bio-stimulants. Previous studies showed that bio-stimulants could enhance nutrient uptake in plants (Parađiković et al., 2018). Ozfidan-Konakci et al. (2018) reported that using bio-stimulant in plants grown for enhancing nutrition efficiency and crop quality traits under stress conditions is an effective approach. Among diverse bio-stimulants, active dry yeast extract or potassium humate have been used to enhance tolerance to water deficit irrigation of cauliflower grown in sandy calcareous soils (Refai et al. 2018).

Humic acids (HA) have important roles in growth, the regulation of carbon and nitrogen cycling, and stability of soil structure (Ozfidan-Konakci et al. 2018; El-Naqma, 2020). On the other hand, it has been reported that potassium humate and yeast extract can improve plant growth, and yield under different irrigation regimes of cauliflower (Refai et al. 2018), garlic (Badawy et al. 2019a) and potato (Badawy et al. 2019b) under sandy calcareous soil condition. Active dry yeast extract, which is a natural safety biofertilizer, usually added to soil or used as a foliar application because it is rich in phytohormones, carbohydrates, vitamins, protein, amino acids, enzymes and minerals (Dawood et al. 2019). The application of yeast extract led to reducing the harmful effect of drought stress and improved wheat productivity and grain quality (Hammad and Ali, 2014).

Despite the importance of fruit and vegetable because their cash value is usually higher than field crops, most of researches on climate change impacts focus on majors (Bulgari et al. 2019). Onion is one of the most important vegetable crops and it is very important in the human diet. Also, onion has several pharmacological activities (Pérez Ortolá and Knox, 2014). Previous studies have reported that onion water requirements are very high (Rajput and Patel, 2006; Kumar et al., 2007 and Lo´pez-Urrea et al., 2009) and onion productivity is entirely dependent on irrigation water (Pérez Ortolá and Knox, 2014). Moreover, it is classified as a sensitive plant and highly sensitive to soil moisture distribution (Job et al. 2016). In most cases, HA is used in research as soil amendments and only focus on its effect on soil water content to promote the growth of the plant (Yang et al. 2020). However, information regarding the interactive effects of bio-stimulants (HA and yeast extract) and water deficit on onion production and quality is very limited.

Considering the above information, the current study was conducted to investigate the influences of different irrigation regimes, bio-stimulants and their interaction on onion yield and yield components. Also, to improve plant growth under water stress and to reduce the negative effect of water stress.

Materials and Methods

Plant materials

Onion cultivar Giza-6 were used in the present study during growing seasons of 2017/2018 and 2018/2019 at Asyut Agriculture Research Station (latitude 27. 03°, 11 ׳ N and longitude 31. 01° ׳ E), Asyut governorate, Egypt. Climatic data for experimental sites during the two growing seasons are shown in Table 1. The experiments were conducted in sandy calcareous soil. According to U.S. Soil Taxonomy, the soil was classified as TypicTorripsamments. Experimental soil consisting of sandy 91.1%, silt 5.7%, and clay 3.2%. The main chemical characteristics of soil are summarized as follows: pH 8.4, $CaCO_3$ (319 g kg^{-1}), EC (0.4 dS m^{-1}), total nitrogen (0.01 %), available phosphorus 8.3 mg kg^{-1} and organic matter 4 g kg^{-1}. The preceding crop was maize in both seasons.

TABLE 1. Average monthly climatic data for experimental sites during the two growing seasons of 2017/2018 and 2018/2019

Parameter / Month	Temperature (˚C) Max	Temperature (˚C) Min	Relative humidity (%)	Wind speed (km/day)	Sunshine (hours)	ETo (mm/day)
2017/2018						
December	23.2	9.0	58.8	14.6	9.0	3.98
January	19.9	6.5	57.4	15.3	8.9	3.77
February	26.1	11.2	44.3	14.4	9.7	5.63
March	30.5	14.2	36.2	16.9	9.9	7.90
April	32.4	16.6	36.2	18.4	10.3	9.15
2018/2019						
December	20.8	8.0	62.8	16.3	9.0	3.62
January	19.3	5.8	52.8	13.9	8.9	3.70
February	21.8	7.6	51.4	17.3	9.7	4.93
March	24.7	9.9	42.9	19.8	9.9	6.64
April	29.6	14	36.5	21.3	10.3	8.93

ETo= Reference evapotranspiration

Growth conditions and experimental design

Two months old onion seedlings were transplanted on both sides of each dripper line at 7 cm apart. Seedlings were planted in the first week of December in both seasons. The experiment was a randomized complete block design in split-plot with three replications. The main plot was irrigation treatments (100% of crop evapotranspiration, 80% ETc and 60% ETc), while the bio-stimulants (control, active dry yeast extract, potassium humate and active dry yeast extract plus potassium humate) were assigned in sub-plot. Each plot consisted of two drip irrigation lines with 20 meters in length and 50 cm in between, the plot area was 20 m^2 (~570 seedlings per plot). On the other hand, inorganic fertilizers were added as follows: For nitrogen, the rate of 250 kg N/ha as (ammonium nitrate 33.5%) was added in six equal doses. Amount of granular superphosphate (15% P_2O_5) at the rate of 714.3 kg/ha was added during soil preparation. Potassium fertilizer in this experiment was added at the rate of 119 kg/ha as potassium sulphate (50% K_2O) in four equal doses.

Irrigation regime treatments

Crop evapotranspiration (ETc) according to Allen (1998)

$$ET_C = ET_C \text{ x } K_c$$

Where:-

ETc = Crop evapotranspiration.

ET_0 = Reference evapotranspiration.

Kc = Crop coefficient (from FAO 56)

Irrigation water applied

The amounts of actually applied irrigation water requirement under each irrigation treatment were determined according to James (1988) using the following equation:

$$I.Ra = \frac{ETc + Lf}{Er}$$

Where:

I. Ra = total actual irrigation water applied mm/ interval.

ETc = Crop evapotranspiration using Penman Monteith equation.

The CROPWAT model was used to calculate Penman Monteith equation (Smith, 1991).

Lf = leaching factor 10 %.

Er = irrigation system efficiency.

Bio-stimulant application

The bio-stimulants treatments were applied in the form of soil application, which was zero (control, ck), 5g/L active dry yeast (Y), 5 g/l potassium humate (H), and active dry yeast plus potassium humate (Y+H). In the mixed treatment (Y+H), the amount of each one was 5g/L and was added separately. Treatments were applied after 15 days from transplanting in both seasons and were applied four times with two weeks in between. Baker's active dry yeast (*Saccharomyces cerevisiae*) was prepared in 2 liter of warm water with addition of treacle as a source of carbon and kept overnight at 35±2°C.

Data collection

Data were measured by selecting 10 plants randomly from each replicate after 90 days. Plant height (cm), leaf number, neck diameter (mm), bulb diameter (mm), fresh weight of whole plant (g), shoots fresh weight (g), fresh weight of bulb (g). Moreover, at about 75% fo tops the plants were down in each plot, the plants were harvested and left for curing (about 10-15 days). After curing, shoots were removed and bulbs from each plot were weighted and data were converted into total bulb yield in ton/ha.

Irrigation water use efficiency

The irrigation water use efficiency (IWUE) values were calculated as follows:

IWUE = (Total bulb yield, kg ha^{-1}) / (Irrigation water applied, m^3 ha^{-1})

Statistical analysis

The statistical analysis of obtained data was performed by using Statistix 8.1 software (Analytical Software, 2005). The least significant difference (LSD) test was used to compare the treatments at $P \leq 0.05$ and data are presented as the means ± standard deviations.

Results

Crop evapotranspiration

The calculated data for crop evapotranspiration (ETc) during 2017/2018 and 2018/2019 to the various treatments were 574.61 mm and 518.39 mm, respectively. The highest difference between first and second season was observed during the mid-season stage, which was 261.11 mm in the 2017/2018 and 224.20 mm in the 2018/2019.

Irrigation water applied

The total amount of applied irrigation water during the first season was higher than the second season in all growth stages due to the effect of climate conditions in the first season (Fig. 2). The total quantity of applied water during the first season was 7436.16 m^3/ha, 5948.93 m^3/ha and 4461.70 m^3/ha for irrigation regime of 100% ETc, 80% ETc and 60% ETc, respectively. However, in the second season was 6708.52 m^3/ha, 5366.82 m^3/ha and 4025.11 m^3/ha for irrigation regime of 100%ETc, 80%ETc and 60% ETc, respectively. Required irrigation water under various irrigation regimes was varied according to the growth stage, which was lowest at the initial growth stage and reached the maximum value at the mid-season stage then decreased at the late-season stage in both seasons (Fig. 2).

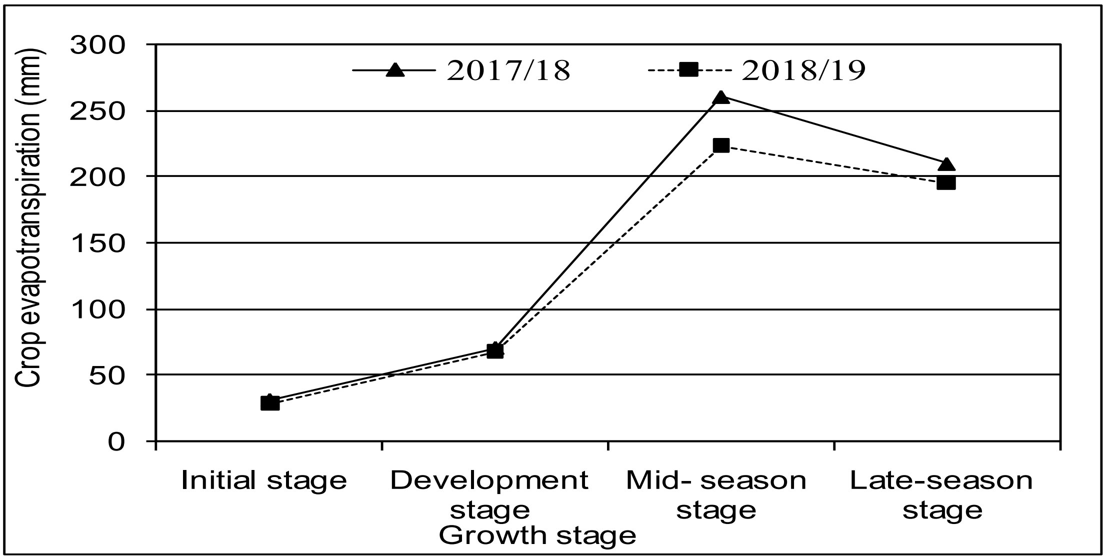

Fig. 1. Mean of crop evapotranspiration (ETc, mm) during 2017/2018 and 2018/2019 seasons at different growth stages on the onion

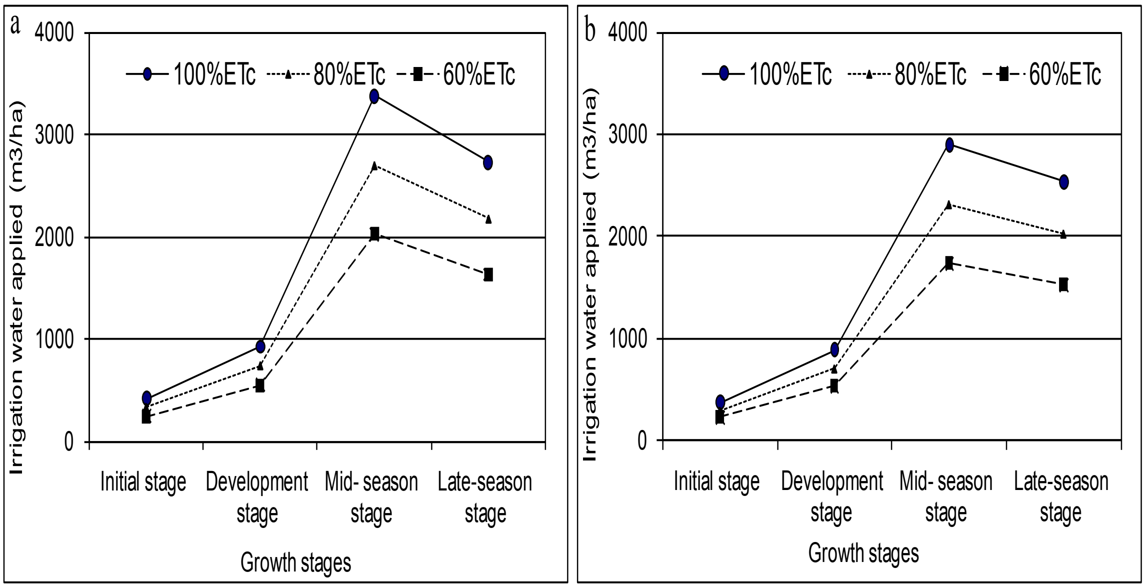

Fig. 2. Irrigation water applied (m^3/ha) as influenced by different irrigation regimes at various onion growth stages: (a) 2017/2018 season; (b) 2018/2019 season

Plant height

Different irrigation regimes and bio-stimulant treatments as well as their interaction significantly affected the plant height (Table 2). 100% ETc showed a greater average of plant height during both seasons (50.21 cm and 57.07 cm, respectively), followed by 80% ETc. Among bio-stimulant treatments, yeast extract recorded the highest plant height compared with control and other bio-stimulants (48.65 cm and 55.43 cm in 2017/2018 and 2018/2019, respectively). This was followed yeast extract plus potassium humate, which were 46.37 cm and 53.20 cm in both seasons, respectively. According to the interaction effects of irrigation regimes and bio-stimulant treatments, yeast extract under 100% ETc had the greatest value of plant height during two seasons (54.52 cm and 61.93 cm, respectively), followed by Y+H. In addition, the results showed that under irrigation regime 80%ETc the reduction percentage in plant height were 9.48% and 8.98% when seedlings treated with yeast extract or 11.39% and 9.69% when used Y+H compared to yeast under 100%ETc in both seasons.

Number of leaves per plant

The statistical analysis showed that there were significant differences in the number of leaves per plant among irrigation regimes and bio-stimulant treatments (Table 2). Among irrigation regimes, 100% ETc had the greatest leaves number per plant in both seasons (9.19 and 10.75), followed by 80% ETc. Compared to control, all bio-stimulant treatments recorded the highest leaves number per plant. Meanwhile, no statistically significant differences were found among bio-stimulant treatments in the number of leaves per plant.

Neck and bulb diameter

Different irrigation regimes and bio-stimulants, as well as their interaction, significantly affected the neck and bulb diameter during 2017/2018 and 2018/2019 (Tables 2 & 3). The maximum neck and bulb diameter were noted from the irrigation regime 100% ETc, which were 19.86 mm and 65.35 mm in the first season, and 22.55 mm and 74.58 mm in the second season, respectively. This was followed by 80% ETc in both seasons for both traits, with 18.34 mm and 64.08 mm in the seasons of 2017/2018 and 21.06 mm and 73.21 mm during 2018/2019. Yeast extract produced the greatest neck diameter among all bio-stimulants (19.39 mm and 22.11 mm during first and second seasons, respectively), followed by yeast extract plus potassium humate. The same trend was observed in the bulb diameter, which were 66.37 mm and 75.94 mm during 2017/2018 and 2018/2019, followed by Y+H in the two seasons (63.44 mm and 72.07 mm, respectively). The interaction effect between irrigation regimes and bio-stimulant treatment results revealed that yeast extract under irrigation regime 100% ETc induced greater average neck and bulb diameter (21.63 mm and 24.50 mm neck diameter; 70.63 mm and 80.80 mm bulb diameter during 2017/2018 and 2018/2019, respectively). This was followed by Y+H under the same irrigation regime.

Fresh weight of whole plant

The fresh weight of the whole plant is an important trait for total yield production. Data illustrated in Table 3, indicated that the effect of irrigation regimes, bio-stimulate treatments and their interactions on the fresh weight of the whole plant was highly significant ($P < 0.01$). In total, the highest fresh weight of the whole plant was produced from plants irrigated with 100%ETc (221.00g and 251.08g during 2017/2018 and 2018/2019, respectively), followed by 80% ETc (212.30 g and 241.26 g). In addition, the fresh weight of the whole plant was greater when plants were treated with yeast extract than other bio-stimulant treatments and control (222.16 g and 252.67 g for 2017/2018 and 2018/2019 seasons, respectively). Moreover, the interaction effects of irrigation regimes and bio-stimulant treatments were also evaluated Table 3. The maximum fresh weight of the whole plant was noted from plants treated with yeast extract under 100%ETc in both seasons (256.90 g and 294.67 g, respectively). This was followed by the irrigation regime with 80%ETc and yeast extract during the first and second seasons (242.18 g and 274.67 g, respectively).

Shoots fresh weight

There were significant differences ($P <0.01$) among irrigation regimes, yeast extract as well as their interaction regarding the fresh weight of shoots Table 3. There was a decrease in the shoots fresh weight with decreased irrigation quantity. The maximum fresh weight shoots (70.44 g and 79.37 g during 2017/2018 and 2018/2019, respectively) was produced from plants irrigated with 100 % ETc. Additionally, yeast extract produced the greatest fresh weight of shoots in both seasons among all bio-stimulant treatments, which was 63.39 g in the first seasons and 71.11g in the second season. Among the interactions between irrigation regimes and bio-stimulant treatments, the highest fresh weight of shoots was recorded in plants treated with yeast extract under 100%ETc (83.40 g and 94.00 g during 2017/2018 and 2018/2019, respectively). This was followed by yeast extract plus potassium humate under the same irrigation regime, which were 75.50 g and 85.67 g for the 1st and 2nd seasons, respectively.

TABLE 2. Influence of irrigation regimes, bio-stimulant treatments and their interaction on plant height, number of leaves, and neck diameter of onion.

bio-stimulant treatments	2017/2018				2018/2019			
	100% ETc	**80% ETc**	**60% ETc**	**Mean**	**100% ETc**	**80% ETc**	**60% ETc**	**Mean**
				Plant height (cm)				
CK	46.10±0.64d	40.94±0.28ef	36.30±0.73h	41.12d	52.63±0.45d	47.47±0.40ef	41.37±1.35h	47.16d
Yeast (Y)	54.52±1.07a	49.35±1.22c	42.07±0.35e	48.65a	61.93±1.59a	56.37±0.95bc	48.00±1.14e	55.43a
Humic (H)	48.80±1.02c	45.81±0.77d	38.83±0.35g	44.48c	55.73±0.42c	52.30±1.35d	44.27±0.97g	50.77c
Y+H	51.41±1.35b	48.31±0.94c	39.41±0.69fg	46.37b	57.97±0.59b	55.93±0.81bc	45.70±1.11fg	53.20b
Mean	50.21a	46.10b	39.15c		57.07a	53.02b	44.83c	
				Number of leaves/plant				
CK	8.01±0.77de	7.59±0.41ef	6.84±0.32f	7.48b	9.60±0.62de	8.80±0.80ef	7.90±0.44f	8.77b
Yeast (Y)	9.94±0.87a	8.79±0.07bcd	8.59±0.29cd	9.11a	11.37±1.00a	10.03±0.21bcd	9.77±0.15cde	10.39a
Humic (H)	9.15±0.59abc	8.54±0.68cd	8.19±0.27de	8.63a	10.90±0.95abc	9.87±0.76cd	9.27±0.58de	10.01a
Y+H	9.65±0.24ab	8.69±0.48cd	8.29±0.35cde	8.88a	11.13±0.23ab	10.03±0.60bcd	9.50±0.40de	10.22a
Mean	9.19a	8.40b	7.98b		10.75a	9.68b	9.11b	
				Neck diameter (mm)				
CK	17.16±0.12g	16.03±0.04h	12.40±0.18j	15.20d	19.73±0.16e	18.71±0.29f	14.06±0.13i	17.50d
Yeast (Y)	21.63±0.35a	19.47±0.07d	17.06±0.15g	19.39a	24.50±0.10a	22.36±0.44c	19.47±0.20e	22.11a
Humic (H)	19.89±0.12c	18.75±0.15f	14.95±0.12i	17.87c	22.50±0.10c	21.18±0.66d	17.38±0.18h	20.35c
Y+H	20.74±0.29b	19.12±0.15e	15.74±0.14h	18.53b	23.46±0.54b	21.99±0.19c	18.06±0.23g	21.17b
Mean	19.86a	18.34b	15.04c		22.55a	21.06b	17.24c	

Values are given as the mean ± standard deviation and different letters indicate statistically differences

TABLE 3. Bulb diameter, fresh weight of the whole plant and shoots fresh weight of onion as influenced by various irrigation regimes, bio-stimulant treatments and their interaction.

bio-stimulant treatments	2017/2018				2018/2019			
	100% ETc	80% ETc	60% ETc	Mean	100% ETc	80% ETc	60% ETc	Mean
Bulb diameter (mm)								
CK	56.51±1.28e	51.61±0.99g	44.57±0.60h	50.90d	65.00±0.31	60.10±0.74	51.60±0.44	58.91d
Yeast (Y)	70.63±0.92a	69.35±0.69ab	59.12±0.92d	66.37a	80.80±0.67	79.40±0.43	67.60±1.12	75.94a
Humic (H)	66.63±0.65c	67.14±0.46c	52.44±1.35g	62.07c	75.90±0.31	76.10±0.56	59.20±0.77	70.36c
Y+H	67.63±0.88bc	68.22±1.15bc	54.47±0.46f	63.44b	76.60±1.16	77.30±0.65	62.30±0.55	72.07b
Mean	65.35a	64.08b	52.65c		74.58a	73.21b	60.16c	
Shoots fresh weight (g)								
CK	160.72±0.72g	157.43±1.11h	94.14±1.33k	137.43d	181.00±7.79f	181.00±2.06f	107.50±2.50i	156.50d
Yeast (Y)	256.90±2.01a	242.18±1.13b	167.39±1.15f	222.16a	294.67±5.35a	274.67±6.81b	188.67±3.21f	252.67a
Humic (H)	229.57±1.06d	218.41±2.07e	135.87±2.02j	194.61c	260.17±4.75d	247.33±2.52e	154.33±5.13h	220.61c
Y+H	236.81±0.74c	231.19±1.03d	151.00±0.72i	206.34b	268.50±3.04bc	262.04±2.63cd	172.50±2.50g	234.35b
Mean	221.00a	212.30b	137.10c		251.08a	241.26b	155.75c	
Fresh weight of above ground (g)								
CK	50.51±1.19g	42.16±0.48ij	28.35±1.05k	40.34d	56.17±3.62e	48.00±1.80fg	31.83±1.61h	45.33c
Yeast (Y)	83.40±0.74a	62.25±0.62d	44.52±1.26h	63.39a	94.00±2.60a	69.67±1.53c	49.67±0.58fg	71.11a
Humic (H)	72.35±1.09c	56.64±0.68f	40.51±1.16j	56.50c	81.67±6.51b	62.83±1.04d	44.67±0.58g	63.06b
Y+H	75.50±1.11b	59.80±1.30e	42.49±0.89i	59.26b	85.67±2.75b	68.00±1.32cd	50.67±5.51f	68.11a
Mean	70.44a	55.21b	38.97c		79.37a	62.12b	44.21c	

Values are given as the mean ± standard deviation and different letters indicate statistically differences

Fresh weight of bulbs

To determine whether the irrigation regimes and bio-stimulant treatments affected total yield production, the bulb fresh weight was measured (Table 4). Irrigation regime with 100%ETc produced the greatest fresh weight of bulb (157.09 g and 179.22 g for 2017/2018 and 2018/2019 seasons, respectively), followed by 80%ETc (150.09 g and 171.71 g during first and second seasons, respectively). Yeast extract recorded the greatest fresh weight of bulb among all bio-stimulant treatments in two seasons (159.10 g and 181.56 g for 1st and 2nd seasons, respectively). This was followed by Y+H, which recorded 147.18 g in 2017/2018 and 167.35 g in 2018/2019. Furthermore, the different irrigation regime and bio-stimulant treatment combinations significantly affected the bulb fresh weight ($P < 0.01$). The highest fresh weight of bulb was recorded from yeast extract under irrigation regime of 100% ETc (179.93 g and 205.00 g in the first and second seasons, respectively) with no significant difference from yeast extract under 80% ETc in the second season (200.67 g).

Total yield of onion

As shown in Table 4, the total yield of onion was significantly ($P < 0.01$) affected by irrigation regimes, bio-stimulant treatments and their interaction during 2017/2018 and 2018/2019 seasons. Irrigation regime at 60% ETc decreased the total yield of onion by ~ 34.36% during two seasons. Irrigation regime at 100% ETc produced the highest total yield of onion in both seasons (30.91 and 35.53 ton/ha during the 1st and 2nd seasons, respectively). This was not significantly different from the irrigation regime 80% ETc in the second season (34.99 ton/ha). Plants treated with yeast extract produced greater total yield than other bio-stimulant treatments and control, which were 28.89 and 33.34 ton/ha during 2017/2018 and 2018/2019 seasons, respectively. This was followed by plants received yeast extract plus potassium humate (28.04 and 32.21 ton/ha in the 1st and 2nd seasons, respectively. The results of the interaction effect between irrigation regimes and bio-stimulant treatments showed that yeast extract under irrigation regime at 100% ETc recorded the greatest total yield of onion in both seasons (33.41 and 38.49 ton/ha, respectively). This was followed by Y+H under 100% ETc and yeast extract under irrigation regime 80% ETc in both seasons. Yeast extract and 80% ETc recorded only 5.18% and 4.65% reduction compared to yeast extract under irrigation regime at 100% ETc. However, untreated plants (control) irrigated with 100% ETc gave 16.33% and 16.5% reduction during 2017/2018 and 2018/2019 seasons, respectively.

Irrigation water use efficiency

Determination of irrigation water use efficiency is important in the efficient use of available water and agriculture sustainability. IWUE was significantly affected by irrigation regimes, bio-stimulants treatment, and their interaction Table 4. For the irrigation regime effect, IWUE was higher (5.10 kg/m^3 and 6.52 kg/m^3 in both seasons) under 80% ETc than other irrigation regimes. However, the result of bio-stimulants overall irrigation regimes revealed that IWUE recorded higher value when onion seedlings were treated with yeast extract (4.88 kg/m^3 and 6.25 kg/m^3 in the 1st and 2nd seasons, respectively) compared with control treatment. The interaction effects indicated that yeast extract under irrigation regime 80%ETc obtained the highest IWUE with no significant difference with yeast extract plus potassium humate during 2017/2018 and 2018/2019 seasons. IWUE under 80% ETc and yeast extract increased by 46.15% and 47.10% in both seasons compared to control under irrigation regime 100% ETc.

Discussion

Global warming will significantly impact agriculture by limiting crop production and reducing water availability. Some plants can handle water shortage much better than others and could be a useful tool for crop management to improve the crop quality such as lettuce by stimulating the secondary metabolism and concentration of various phytochemicals to improve the nutritive and health-promoting value and taste (Bulgari et al. 2019). However, deficit irrigation is less successful with onion because it's classified as drought-sensitive plant. Furthermore, due to the negative impacts of global climate change on the crop productivity (El-Ramady et al. 2020) and water resources, researchers agree with the perspective that several regions could become arid (Elliott et al. 2014; Bulgari et al. 2019). Several strategies could be used to alleviate the negative effects of abiotic stresses such as choice of the cultivar, growing period, and fertilizer (Mariani and Ferrante, 2017). However, the use of genetic improvement methods to enhance crop stress tolerance requires long breeding programs (Bulgari et al. 2019). Bio-stimulants could improve plant tolerance to mitigate drought damages and improve plant growth (Du-Jardin, 2015 and Rouphael et al. 2018).

TABLE 4. Fresh weight of the bulb, total yield and irrigation water use efficiency

bio-stimulant treatments	2017/2018				2018/2019			
	100% ETc	**80% ETc**	**60% ETc**	**Mean**	**100% ETc**	**80% ETc**	**60% ETc**	**Mean**
	Fresh weight of bulb (g)							
CK	115.28±1.57g	110.22±1.50h	65.80±1.32j	97.10d	133.33±3.82d	124.83±4.19e	75.67±2.08g	111.28d
Yeast (Y)	179.93±1.04a	174.49±1.33b	122.87±0.53f	159.10a	205.00±10.00a	200.67±3.06ab	139.00±2.65d	181.56a
Humic (H)	161.77±1.12d	157.22±1.36e	95.36±1.66i	138.12c	184.50±1.80c	178.50±1.32c	109.67±3.51f	157.56c
Y+H	171.39±1.70 c	161.32±1.16d	108.84±1.25h	147.18b	194.04±3.23b	182.83±2.75c	125.17±2.84e	167.35b
Mean	157.09a	150.51b	98.22c		179.22a	171.71b	112.37c	
	Total yield (ton/ha)							
CK	27.00±1.00e	27.13±0.48e	19.76±0.41gh	24.65d	31.22±0.28e	31.24±0.36e	22.78±0.50g	28.41d
Yeast (Y)	33.41±0.53a	31.68±0.39bc	21.58±0.32f	28.89a	38.49±0.33a	36.70±1.13b	24.83±0.30e	33.34a
Humic (H)	30.83±0.18d	31.20±0.33cd	19.39±0.25h	27.14c	35.20±0.37d	35.70±0.21cd	21.92±0.24h	30.94c
Y+H	32.33±0.41b	31.42±0.24cd	20.38±0.25g	28.04b	37.19±0.49b	36.31±0.18bc	23.14±0.48g	32.21b
Mean	30.91a	30.36b	20.27c		35.53a	34.99a	23.17b	
	IWUE (Kg/m3)							
CK	3.64±0.13g	4.56±0.08c	4.43±0.09de	4.21d	4.65±0.04h	5.82±0.07d	5.66±0.12de	5.38d
Yeast (Y)	4.49±0.07cd	5.32±0.07a	4.84±0.07b	4.88a	5.74±0.05d	6.84±0.21a	6.17±0.08c	6.25a
Humic (H)	4.15±0.02f	5.24±0.06a	4.35±0.06e	4.58c	5.25±0.05g	6.65±0.04b	5.45±0.06f	5.78c
Y+H	4.35±0.06e	5.28±0.04a	4.57±0.06c	4.73b	5.54±0.07ef	6.76±0.03ab	5.75±0.12d	6.02b
Mean	4.16c	5.10a	4.54b		5.30c	6.52a	5.76b	

Water application at a rate and volume lower than the evapotranspiration throughout the whole growth period defiend as water deficit irrigation and might be used to improve plant quality by reducing excessive vigor and increasing water use efficiency (Alvarez et al. 2009 and Abdel-Fattah et al. 2020). Crop evapotranspiration and irrigation water applied were higher in the first seasons than second season might be due to the high temperature during the first season. During mid-season stage the crop evapotranspiration and the irrigation amount increased due to soil evaporation, canopy growth and increasing evaporative demand (ET_o) (López-Urrea et al. 2009). Our results are in accordance with those of Refai et al. (2018; 2019), Badawy et al. (2019b) and Mostafa et al. (2019). The amount of irrigation water applied influenced the plant growth and yield of onion which indicates that added more water resulted in higher yield. Similar trend was observed in other crops i.e. bell pepper (Aladenola and Madramootoo, 2014), cauliflower (Refai et al. 2018), potato (Badawy et al. 2019b), spinach (Leskovar and Piccinni, 2005) and tomato (Al-Qerem et al. 2012).

The uses of yeast extract or yeast extract plus potassium humate increased plant height, neck and bulb diameter, fresh weight of whole plant, shoots fresh weight, weight of bulb and bulb yield under various irrigation regimes compared to control treatment. Forsburg (2001) indicated that between active dry yeast and plants a large number of metabolic pathways and molecular mechanisms are similar. The yeast affect growth and yield of onion might be due to it is rich in tryptophan which is defined as a precursor of indole acetic acid, which stimulates cell division and elongation (Warring and Phillips, 1973 and Dawood et al. 2019). Additionally, Mustafa and El-Shazly (2013) stated that active dry yeast might enhance plant growth due to its content of various nutrients such as N, P, and K and some common amino acid. Also, its very effective in releasing carbon dioxide and stimulating photosynthesis, which could be reflected on plant performance (Subba-Rao 1984). According to Sanchez-Sampedro et al. (2005) yeast extract activated the endogenous hormone jasmonic acid (JA) and/or methyl jasmonate (MEJA) production, which influence the production of secondary metabolites. We assume that such triggered might prevent the plants from being influenced by water deficit. Mostafa et al. (2020) and Pérez-Jiménez (2014) reported that phytohormones such as abscisic acid and jasmonic acid are involved in the tolerance to abiotic stresses. Previous studies revealed that application of yeast increased yield and yield attributes of cauliflower (Refai 2018), soybean (Mekki and Ahmed, 2005), *Lupinus termis* (Khalil and Ismael (2010) and flax (Dawood et al. 2019). Application of active yeast enhanced the vegetative growth characters, productivity, tubers quality, and percentage of tuber dry matter in potato plants (Ahmed et al., 2011). Moreover, Hassanpanah et al. (2008) reveled that potassium humate is an active hormone could causes increased chlorophyll accumulation, amino acids, sugar and improves nitrogen utilization efficiency, the ability of plants to resist drought stress. Treated potato plants with potassium humate increased root system, number of tuber and tuber yield. Several researchers mentioned that humic substance can be used to counteract the negative consequence of stress factors (Calvo et al., 2014; Ouni et al. 2014, Khalesro et al. 2015). Humic improve growth of root system, which lead to increase the plant shoot system (Garcia et al. 2008). Badawy et al. (2019b) showed that under irrigation regime 80% ETc and application of yeast extract plus potassium humate increased the potato tuber yield and marketable tuber yield.

Calvo et al. (2014) reported that one of the main effects of biostimulants is to improve water use efficiency and their application could be a possible strategy to reduce the required amount of water for crops. MacCarth et al. (2001) reported that humic promote soil water holding capacity and reduce the required water for plants. Previous studies reported that application of potassium humate increased the value of irrigation water use efficiency in potato (Ati et al. 2013. Badawy et al. 2019b) and sweet potato (Abd-All et al. 2017). Moreover, Refai et al. (2018) revealed that soil application of yeast extract or potassium humate and irrigation regime 80% ETc recorded the highest irrigation water use efficiency value for cauliflower. Amer et al. (2020) concluded that irrigated sugar beet and cotton plants with 80% from standard evaporation pan class A, potassium hummat (24 kg/ha) and the application of recommended N was 40% organic-N and 60% mineral-N was more effective in water productivety and yield under salt condition.

Conclusion

In conclusion, compared to control treatment, soil application of bio-stimulants gave the highest value for studied characters. Moreover, with 20 % water-saving from required amount of irrigation water at 80% ETc, yeast extract recorded only 5.18% and 4.65% reduction compared to yeast extract under irrigation regime at 100% ETc and increased IWUE by 46.15% and 47.10% in both seasons compared to control and 100% ETC. Consequently, applicationn of biostimulants could represent an effective tool to increase onion growth, yield, and water use efficiency. Application of active dry yeast extract with or without potassium humate could alleviate the negative impact of water deficit.

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