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Improving Dry Onion Yield, Bulbs Nutrients Status, Water Productivity and Calcareous Soil Properties under Water Stress Using Bio-Stimulants

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ABSTRACT: There is little information on how improve onion dry yield and status of nutrients in plants and soil under water scarcity. To fill this gap, two field experiments were conducted during two consecutive winter seasons. Three treatments of irrigation levels were designed in the main plot (100% of crop evapotranspiration, 80% ETc and 60% ETc). Four bio-stimulants soil treatments were designed in the sub-plot: control, yeast extract (YE), potassium humate (KH) and YE+KH. Generally, bio-stimulants increased onion productivity significantly and decreased the negative impact of water shortage. During both seasons, YE followed by YE+KH recorded the highest bulb yield, water use efficiency and irrigation water use efficiency for bulb dry yield, dry matter content, NPK content, NPK uptakes, protein yield and soil water holding capacity. While KH followed by YE+KH or YE recorded the highest available soil NPK, EC and soluble ions values. The pH lowest values were recorded in soil treated with KH or KH+YE. Comparing the 80% ETc with YE treatment and the 100% ETc with YE treatment, it was found that the amount of reduction in dry onion yield amounted to only 3.18% as an average for the two seasons with saving 20% of irrigation water. However, onion dry production was greater with YE at 80% ETc than with untreated plants under 100% ETc irrigation level by 24.36% as average of two seasons. In conclusion, YE and or YE plus KH may be major factors in enhancing soil fertility and plant stress tolerance by insufficient irrigation water.

Keywords: Crop evapotranspiration, Drip irrigation, Drought stress, Potassium humate, Yeast extract.

INTRODUCTION

The world is now suffering from overpopulation. Not only that, but the world population is expected to rise dramatically, reaching 9.7 billion people by 2050. Therefore, there is great pressure on arable land, water, energy and biological resources to produce enough food. On the other hand, arid and semi-arid regions suffer from water shortages and what makes matters worse is that climate change and expected global warming will lead to an increase in the possibility of drought and thus a decrease in crop productivity and land degradation (Zahran et al., 2020; Abeed, et al., 2021). As a result, water scarcity and droughts have become increasingly important on the political and scientific agendas of many countries, including Egypt.

Egypt's water resources consist only of its 55.5 billion m^3 share of the Nile River's flow, deep groundwater in desert regions (mostly non-renewable), and limited precipitation in the Sinai and northern coastal regions (Eissa and Negim 2019). Over the past 50 years, the annual per capita water supply has been steadily declining due to Egypt's growing population. Currently, the value of the annual per capita share of water is about 560 m^3 per person in 2022. This is below the global annual limit of chronic water scarcity per capita of 1,000 m^3 per year and slightly above the annual absolute water scarcity level less than 500 m^3 per capita (Tekken and Kropp, 2012; Fouad et al., 2023). Therefore, there is a vital and essential requirement to save and conserve water by making many efforts to know what crops actually need from water and their behaviour under drought conditions, especially strategic crops that do not need large quantities of water under modern irrigation systems, using special treatments to save irrigation water and gaining a greater understanding of the fertility of newly reclaimed Egyptian soil under normal and drought conditions.

Egypt has an area of one million square kilometers. The desert constitutes 94% of Egypt's total land area. About 0.65 million feddans (0.27 million hectares) or 25–30% of Egypt's total soil area, is made up of calcareous soil (Abou Hussien et al., 2020; Zahran et al., 2020). Calcareous soils are defined as those that contain 8-10% total calcium carbonate. Because there is little leaching, they naturally occur in arid and semi-arid regions (Hassanein, et al., 2015). There are multiple problems with the calcareous soil's physical, chemical, and biological characteristics, such as elevated calcium carbonate content, elevated infiltration rate, elevated soil crusting, increased subsurface layer hardening, and elevated pH. In the meantime, there is low organic matter content, low water holding capacity, poor structure, low cation exchange capacity (CEC), limited availability of macro and micronutrients, nutritional imbalance among certain elements (Mg and K) and Ca, and low microbial activity (Zahran, et al., 2020; Brownrigg et al., 2022; Al-Elwany, et al., 2023; Mahmoud, et al., 2023; Nada, et al., 2023). On the other hand, a calcareous character often combines with a sandy texture, forming sandy calcareous soil, as in our current study. Sandy soils cover about 900 million hectares worldwide, especially in arid and semi-arid regions (Yost and Hartemink, 2019). The productivity of sandy soils is mostly limited by poor physical, chemical and biological properties; it has low organic matter content, low water and nutrient supply capacity, limited buffering capacity, low biological diversity, and high hydraulic conductivity rates. These problems require high levels of external inputs (Promkutkaew, et al., 2005; El-Etr, et al., 2016, Alghamdi, et al., 2023). Better irrigation and fertilization management techniques are required to maximize the economic benefits of deteriorated sandy calcareous soils in arid and semi-arid regions and enhance fertility, particularly with important crops like onions.

Onion is considered one of the most important strategic vegetable crops in Egypt, is widely consumed locally in fresh or dried form. However, there is little information on the dry onion yield with various treatments. Egyptian onions are one of the main sources of hard currency as they enjoy a high competitive advantage compared to similar products in other countries (El–Shaboury and Ewais, 2020). Therefore, increasing the productivity of onions with high quality is an important goal by scientific and farmers for the local market and export. On the other hand, Onions are a shallow-rooted crop. Its roots have a penetration of about 0.18 m, so it cannot absorb moisture from deeper soil (Gökçe, et al., 2022; Terán-Chaves, et al., 2023). Thus, the amount of soil water available to onions, especially when grown in coarse-textured soil, is limited, so onions are very sensitive to water stress. Therefore, there is an urgent need to study irrigation management. Drip irrigation has been introduced as an effective method that can add sufficient amount of water to the root zone with high and controlled accuracy and hence it is the right method that can improve the water productivity of onions and also save more water (Terán-Chaves, et al., 2023; Wu, et al., 2023). To calculate the water requirements of onions, there are many studies that have used meteorological data (maximum and minimum temperature, relative humidity, wind speed and sunshine) to estimate the reference evapotranspiration (ETo) using the FAO-Penman Monteith equation (Enciso, et al., 2009; Zheng, et al., 2013; Dingre et al., 2016; El-Metwally, I., et al., 2022; El Bergui, et al., 2023), with the possibility of using the CROPWAT computer program based on the equation (Bekele and Tilahun; 2007; Ibrahim, et al., 2022b). Crop evapotranspiration (ETc) for onions is calculated by multiplying the reference evapotranspiration by the onion coefficient or onion Kc (Zheng, et al., 2013; Semida, 2020). Many studies have applied different levels of irrigation based on different percentages of ETc (100, 80, 75, 60 and 50%) for onion crops under a drip irrigation system. The greatest results for the onion yield and its components were obtained when full irrigation (100 ETc %) was applied, however this level produced the lowest water use efficiency and irrigation water use efficiency or WUE and IWUE (Abdelkhalik, et al., 2019; Piri and Naserin, 2020; Abouabdillah, et al., 2022; El–Metwally, et al., 2022; El Bergui, et al., 2023). Irrigation levels of 75 to 80% ETc led to good results for the onion yield, IWUE, WUE and it saved between 20 to 25% of irrigation water (Enciso, et al., 2009; Piri and Naserin, 2020; Semida, et al., 2020; Abouabdillah, et al., 2022; El–Metwally, et al., 2022). Also, some studies indicated that there are no significant differences in onion yield between the full irrigation (100% ETc) level and the 80 or 75 ETc irrigation level (Enciso, et al., 2009; Piri and Naserin, 2020; Semida, et al., 2020; Abouabdillah, et al., 2022). On the other hand, a drought level of 60 or 50% ETc gives the lowest yield of onions, but it has a high IWUE and WUE efficiency and saves 40 to 50 of irrigation water (Dingre, et al., 2016; Abdelkhalik, et al., 2019; Piri and Naserin, 2020; Semida, et al., 2020; Abouabdillah, et al., 2022; El Bergui, et al., 2023). Therefore, many efforts are needed to develop strategies to improve crop productivity, nutrient uptake, water productivity and soil fertility under normal and drought conditions. One such strategy is to find a suitable biostimulant or biofertilizer for plants grown in low-fertility soil.

Active dry yeast extract (YE) and potassium humate (KH) are examples of biostimulants that have been used to improve the quality and productivity of crops under different soil conditions. Active dry yeast extract or active dry yeast (*Saccharomyces cerevisiae*) is a safe natural biofertilizer that is usually added to the soil or used as a foliar application on various crops due to its biological activity and safety for humans and the environment (Abd-Elbaky, et al., 2021). Furthermore, under different soils textures, researchers have found that applying yeast extract in soil or foliar application at the right dose improves soil fertility, crop development, crop chemical structure, nutrient absorption capacity, yield quality, and yield for a range of diverse field crops and vegetables, such as onion (Abd-Elbaky, et al., 2021; Awad, et al., 2024), lettuce (Abd El Galil, et al., 2021), sweet pepper (Abd-Alrahman and Aboud, 2021), maize (Ahmed and Fahmy, 2014) and sesame (Ahmed, et al., 2023). On the other side, several commercial products containing humic acid (HA), including potassium humate (KH) have been promoted for use on different crops as bio-stimulator. Potassium humate (KH) is an important natural substance that can be used to improve the biological, chemical and physical soil properties, enhance crop productivity, increase the quality of the yield and support the plant's tolerance to salinity, heat, drought, cold, pests, and diseases. Many investigators have cleared up the positive advantages of potassium humate as foliar or soil application in soil fertility, nutrient absorption and the production of different field crops and vegetables, such as wheat (Farid, et al., 2023), Faba Bean (Faiyad and Abd El-Azeiz 2024), potato (Shabana, et al., 2023), maize, (Baddour and El-Shaboury, 2023), onion (El-Shaboury and Ewais 2020; El-shaboury and Sakara, 2021), canola (Amer and El-Ramady, 2015), sugar beet and cotton (Amer, et al., 2019).

Therefore, the current study aimed to investigate the effect of three irrigation treatments (100% ETc, 80% ETc and 60% ETc) and different bio-stimulants treatments (control, active dry yeast extract, potassium humate and active dry yeast extract plus potassium humate), as well as the interaction between both factors on the following 1) onion dry bulb yield 2) water use efficiency and irrigation water use efficiency for onion dry yield 3) nutrients contents and uptakes 4) fertility of sandy calcareous soil after onion harvesting.

2. MATERIALS AND METHODS

2.1. Experimental location

The present experiments were carried out at the farm of Arab Al-Awammer Research Station, Agricultural Research Center (ARC), Asyut, Egypt. At the confluence of 27°, 03° N latitude and 31°, 01° E longitude, the experimental farm is located at a height of 71 metres above sea level. According to Soil Taxonomy (Soil Survey Staff 2022), the soil of the experimental farm was calcareous sandy and was categorized as a Typic Torripsamment. Table 1 provides a summary of some physical and chemical parameters of the experiment site while Table 2 displays climate data for the two growth seasons at the experimental site. Two sequential winter seasons, 2017/2018 and 2018/2019, were planted to test a set of treatments on onion dry bulb yield (*Allium cepa* L., cv. Giza-6), water use efficiency and irrigation water use efficiency for onion dry bulb yield (dry-WUE and dry-IWUE), NPK content, NPK uptakes and protein yield, soil available NPK and some soil properties at the end of seasons.

Table 1. Some physical and chemical properties of the studied soil (0-25 cm), yeast and humic.

Property	Unit	Value
	Soil	
Sand	(g kg^{-1})	911
Silt	(g kg^{-1})	57
Clay	(g kg^{-1})	32
Texture		Sand
Water holding capacity	(g kg^{-1})	178.3
Bulk density	(ton m^{-3})	1.61
OM	(g kg^{-1})	4.44
$CaCO_3$	(g kg^{-1})	319.3
pH $_{(1:1)}$		8.44
EC $_{(1:1)}$	(ds m^{-1})	0.61
Soluble Ca	(mmol kg^{-1})	1.79
Soluble Mg	(mmol kg^{-1})	0.72
Soluble Na	(mmol kg^{-1})	0.87
Soluble K	(mmol kg^{-1})	0.22
Soluble HCO_3	(mmol kg^{-1})	0.40
Soluble Cl	(mmol kg^{-1})	1.63
Soluble SO_4	(mmol kg^{-1})	2.04
Available N	(mg kg^{-1})	33.6
Available P (Olsen)	(mg kg^{-1})	8.34
Available K	(mg kg^{-1})	38.5
	Yeast	
Total N	(g kg^{-1})	85.22
Total P	(g kg^{-1})	16.39
Total K	(g kg^{-1})	22.78
	Humic	
Total N	(g kg^{-1})	10.00
Total P	(g kg^{-1})	2.36
Total K	(g kg^{-1})	100.00

Each value represents a mean of three replicates.

2.2. Experimental layout

Under a drip irrigation system, the field experiments were conducted in a split-plot layout with three replications in both growing seasons. Three irrigation treatments (100%, 80% and 60% of crop evapotranspiration) were designated as the first factor in the main plot. Four bio-stimulants treatments (control, active dry yeast extract = YE, potassium humate = KH and active dry yeast extract plus potassium humate = YE+KH) were given as the second factor in the subplot. Thus, the full plots of the experiment were 3 × 4 × 3 = 36 plots. The soil of the experimental field was twice ploughed perpendicularly and levelled. The drip irrigation system is set up to provide three branch pipes that are separately controlled for both irrigation and fertilization. The in-line GR dripper laterals were set up at a distance of 0.5 m. A flow rate of 3.8 L h^{-1} at 110-120 KPa (1.1-1.2 bar) was maintained with the emitters 0.30 m apart. Each two drip irrigation lines (the length of each is 20 m) was used to irrigate an experimental plot (plot area = 1m × 20m = 20m^2).

2.3. Treatments description

2.3.1. Irrigation water levels

According to Allen et al., 1998, the equation ETc = ETo × Kc was used to estimate actual crop evapotranspiration (ETc). CROPWAT model (version 8) was used to calculate reference evapotranspiration (ETo) according to the modified Penman-Monteith equation (Allen et al., 1998; Smith, 1991). The ETo values were computed based on the climatic information in Table 2. Crop coefficient (Kc) was employed for different onion growth stages (initial, developmental, mid-season and late-season) in line with Allen et al., 1998. The onion plants were watered for the first 20 days in accordance with the calculated irrigation needs (100% ETc), while in other stages the plants irrigated by 100% ETc, 80 and 60%. The estimated ETc was 574.61 and 518.39 mm in 2017/2018 and 2018/2019 respectively. In the first and second seasons, the mid-season period accounted for 45.4 and 43.2% of ETc, respectively, while the late season period accounted for 36.6 and 37.9% of ETc, respectively.

Table 2. Average monthly climatic data for experimental site and reference evapotranspiration (ETo) during the two growing seasons of 2017/2018 and 2018/2019.

Parameter	Temperature (˚C)		Relative humidity (%)	Wind speed (km/day)	Sunshine (hours)	ETo (mm/day)
	Max	Min				
Month			**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
Month			**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	14.0	36.5	21.3	10.3	8.93

Rainfall was 0 for the two growth season.

2.3.2. Applied irrigation water

According to James (1988) the equation of I. Ra = (ETc + Lf)/Er was used to calculate the total actual irrigation water applied mm/ interval (I. Ra), where ETc = Crop evapotranspiration, Lf = leaching factor (was considered as 10% of applied irrigation water) and Er = irrigation system efficiency (was considered as 85%).

2.4. Bio-stimulants preparation

2.4.1. Yeast extract (YE)

Active dry yeast extract was prepared by heating the necessary amount of water to a temperature of 35 ± 2 °C. Pure active dry baker's yeast (*Saccharomyces cerevisiae*) was added at 5 g/l and treacle at a rate of 5 ml/l (as a source of C and N) to activate and reproduce yeast. The mixture was stirred until completely homogeneous and then stored in a dark, warm place overnight (35 ± 2 °C) to activate and multiply to obtain more reactive yeast cells before application to the soil. Hence, the yeast extract was prepared using a technology that allows yeast cells (pure dry yeast) to grow and multiply efficiently during favourable aerobic conditions that allow the production of beneficial vital components (sugars, carbohydrates, amino acids, proteins, fatty acids, vitamins, hormones, etc.). Yeast extract were added to the soil application at rate of 600 L/ha with irrigation water each time of addition.

2.4.2. Potassium humate (KH)

Pure black granules potassium humate high soluble in water made in China specifically to Shoura chemical company in name Uitra HumiMax was added at 5 g/l. The mixture was stirred until it homogeneous and became completely dissolved. Uitra HumiMax contains 80% humic acid and 10% potassium. Potassium humate were added to the soil application at rate of 600 L/ha with irrigation water each time of addition.

2.4.3. Use of bio-stimulants

Bio-stimulants treatments were added in soil application in four treatments (control, YE, KH and YE+KH). In the combined treatment, the yeast (5 g/l) or potassium humate (5 g/l) was 600

L/ha was added individually. In both seasons, treatments were administered 15 days following transplantation and were given four times with a two-week interval between each application. Total NPK analyses of the bio-stimulants used were shown in Table 1.

2.5. Plant growth conditions

The onion extension manual issued by the Egyptian Ministry of Agriculture served as the basis for all agricultural techniques used. Sixty day old onion seedlings were replanted at a distance of seven cm between each seedling on both sides of each drip line (about five hundred and seventy seedlings per plot). The healthy and uniform seedlings were transplanted during the first week of December in both seasons. In terms of mineral fertilization, phosphorus was applied as granular superphosphate (15% P_2O_5) in a single dosage at a rate of 107.1 kg P_2O_5/ha throughout soil preparation and prior to seedling culture. Nitrogen fertilizer was administered in the form of ammonium nitrate (33.5% N) at a rate of 250 kg N/ha, which was divided into six equal doses beginning twenty days after the transplant. As a supply of K, potassium sulphate fertilizer (50% K_2O) was applied at a rate of 150 kg K_2O/ha, divided into five equal doses, the first was added after transplanting and the four rest doses beginning a month and a half after the transplant. Cheated zinc, manganese, and iron were sprayed over leaves twice at a rate of 476 L/ha. The liquid solution included 150 ppm of each element and triton B to act as a wetting agent.

2.6. Estimation of onion productivity

2.6.1. Onion dry bulb yield

According to the instructions of the Egyptian Ministry of Agriculture, the harvest was done and the marketable onions were obtained. The bulbs of each plot were weighed separately to obtain the fresh weight of the onion crop. A sample of 10 randomly selected bulbs from each plot was taken, and the bulb samples were sent straight to the lab. The bulb samples were cleaned, weighted, and sliced. To reduce the amount of moisture, the sliced samples were divided out on the lab benches for three days. After that, bulb samples were dried in an oven set at 70 °C for three days, or until their weight remained constant then dry bulb samples were weighted. In accordance with Zahran et al. (2020) the following formulas were used to get the dry matter percentage and onion dry bulb yield:

Dry matter (%) = {(Dry weight (g)/ Fresh weight (g)} × 100.

Onion dry bulb yield ton ha^{-1} = {(Dry mater (%) × Fresh onion bulb yield (ton ha^{-1})/100}.

2.6.2. Onion nutrients status

Dried onion samples were crushed, ground and stored for chemical analysis. To estimate the total K, N and P in ground samples, 15 ml of the digestion mixture were used to digest 0.50 g of each sample. The digestion mixture consisted of three hundred and fifty ml H_2O_2 + 0.42g selenium powder + Fourteen g $LiSO_4.H_2O$ + Four hundred and twenty ml of concentrated H_2SO_4 was added cautiously with cooling (Parkinson and Allen 1975). Potassium (K), nitrogen (N), and phosphorus (P) were measured in the digested samples. The flame photometric technique was used to quantify total potassium (Page, 1982). The micro-Kjeldahl method was used to determine nitrogen (Jackson 1973). The total phosphorus was measured colorimetrically by the stannous chloride phosphomolybdic-sulfuric acid method in the same line as Jackson (1973). Potassium, nitrogen and phosphorus gathered data expressed as g kg^{-1} of dry matter. Protein content is the product of nitrogen content multiplied by 6.25 (Zahran et al., 2020). Potassium or nitrogen or phosphorus uptakes kg ha^{-1} was computed using the following equation:

K or N or P uptakes (kg ha^{-1}) or protein yield (kg ha^{-1}) = onion dry bulb yield (ton ha^{-1}) × K or N or P or protein (%) ×10 (Zahran, et al., 2020).

2.7. Estimation of water productivity

2.7.1. Water use efficiency for onion dry bulb yield (Dry-WUE) and irrigation water use efficiency for onion dry bulb yield (Dry-IWUE)

Water use efficiency for onion dry bulb yield (Dry-WUE) was calculated using the equation {onion dry bulb yield (kg ha^{-1})/ ETc (mm)}. Irrigation water use efficiency for onion dry bulb yield (Dry-IWUE) was calculated as follows equation {onion dry bulb yield (kg ha^{-1})/ applied irrigation water (m^3 ha^{-1})}.

2.8. Estimation of soil properties

Before transplanting onion plants, a composite soil sample (0-25 cm) was taken from the experimental site. Similarly, following the harvest of onion plants at the end of each season, composite soil samples were taken from each plot unit. An auger was used to gather soil samples, which were then air-dried, pulverised, and put through a 2-mm sieve. According to Burt (2004), certain physical and chemical characteristics of the studied soil were determined. The water holding capacity (WHC) of the soil was determined by the gravimetric method in line with Mohamed et al. (2016). The soil pH was measured in 1:1 (soil: water) suspension using a glass electrode on a digital pH meter (Jackson, 1973). The soil extracts 1:1 (soil in g to distilled water in ml) were organized after one hour of shaking. Filter paper was used to filter the mixes and the electrical conductivity (EC) was determined in the extract through the salt bridge technique by an electrical conductivity meter (Hesse, 1998). The soluble cations and anions (calcium, magnesium, potassium, sodium, bicarbonate, carbonate and chloride) were estimated in line with Jackson, 1973. Available soil nitrogen was extracted and by using Devarda's alloy and a micro-Kjeldahl distillation apparatus, the extract was distilled. Available nitrogen (ammonium and nitrate) in the distillate was determined by titrating it with standardized, diluted H_2SO_4 (Page, 1982). According to Olsen et al. (1954), available soil phosphorus (Olsen-P) was extracted using 0.5 M $NaHCO_3$ (pH 8.5) at a ratio of 1:20 soil (g): solution (ml). In line with Jackson (1973), the phosphorus content of extracts was quantified using a spectrophotometer at 660 nm and evaluated colorimetrically using the chlorostannous phosphomolybdic acid technique. A flame photometer was used to measure the amount of available potassium after it was extracted using 1 M ammonium acetate with a pH of 7.0 (Baruah and Barthakur 1997).

2.9. Data statistical analysis

The treatments were laid out in a split-plot design with triple replicates. A two-way analysis of variance (ANOVA) was used to ascertain the significance of differences among the examined treatments. The results are shown as mean ± standard error (SE), and Duncan multiple range tests were used to compare the means at $P < 0.05$. The data were statistically analyzed using IBM SPSS Statistics version 25 (Analytical Software, 2017), which was also utilized to determine the standard error.

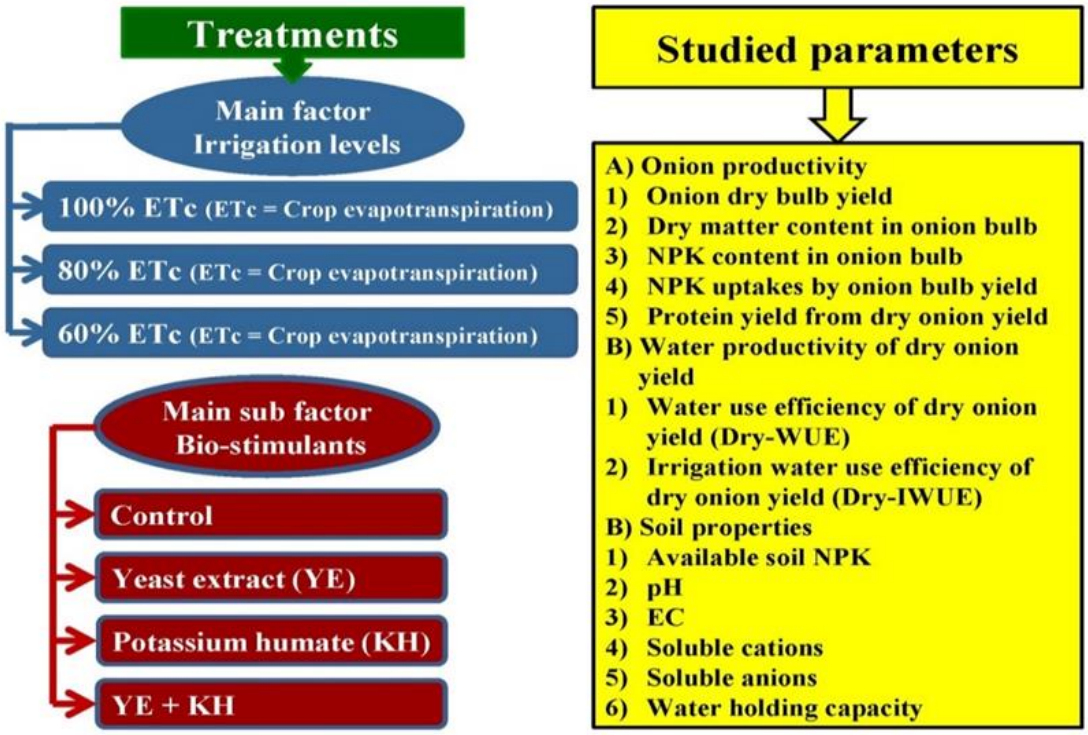

Figure 1. General description of the research paper.

3. RESULTS

3.1. Onion Productivity

3.1.1. Onion dry bulb yield

Data regarding onion dry bulb yield (ton ha^{-1}) under irrigation levels, bio-stimulants and their interaction are illustrated in Table 3. In irrigation treatments, the biggest onion dry bulb yield was recorded with the irrigation levels of 100 and 80% ETc, while treatment under drought stress (60% ETc) achieved the lowest values. In line with Duncan's multiple range tests at $P < 0.05$, irrigation level 100 or 80% ETc was significantly superior to treatment 60% ETc. The improvement by irrigation level of 80% ETc treatment about drought stress treatment (60% ETc) was 48.29% and 49.56% in onion dry bulb yield during both succeeding seasons. This indicates the importance of adding the last 20% of ETc. In bio-stimulants treatments, YE application recording the biggest dry bulb yield, while YE+KH treatment was in the second rank. According to Duncan's multiple range tests at $P < 0.05$, yeast extract is far better than other bio-stimulants treatments significantly in the first season and insignificant between YE and YE+KH in the second season. Comparing with the untreated treatment (control) that came in last rank, the treatment of YE increased dry bulb yield by 20.55 and 23.47% in the two seasons respectively, whereas the treatment of YE + KH enhanced dry bulb yield by 17.56 and 20.18% in the two seasons, respectively. According to data on the interaction between irrigation levels and bio-stimulants, soil applications with any bio- stimulant (YE, KH and

YE+KH) with 100 and 80% ETc irrigation levels came in first place, producing the biggest onion dry bulb yield. Control treatments (untreated treatments) under irrigation levels of 100 and 80% ETc were in the second rank, producing a modest onion dry bulb yield. Under irrigation level of 60% ETc, YE alone or in combination with KH came in third and alleviated the detrimental impacts of the water deficit stress. Control or KH treatment with irrigation level of 60% ETc, came in last. Furthermore, as compared to the control treatment with stress irrigation (60% ETc) on average over two seasons, the improvements in onion dry bulb production due to YE with 100% ETc treatment were 69.06%, 60.73% with irrigation 80% ETc, and 9.11% with irrigation 60% ETc. On the other hand, the increases in onion dry bulb yield as a result of YE + KH with 100% ETc treatment were 63.45%, 59.23% with irrigation 80% ETc and 2.35% with irrigation 60% ETc.

Table 3. Onion dry bulb yield (ton ha^{-1}) as influenced by various irrigation levels and different bio-stimulants as well as their interaction in end of seasons.

Treatments		Onion dry bulb yield (ton ha^{-1})	
		Season 1	**Season 2**
Irrigation levels (I)			
100% ETc		4.087±0.11a	4.428±0.14 a
80% ETc		4.073±0.09 a	4.397±0.13 a
60% ETc		2.747±0.04 b	2.940±0.05 b
Bio-stimulants (B)			
Control		3.204±0.16 c	3.427±0.16 c
Yeast extract (YE)		3.862±0.24 a	4.232±0.27 a
K-humate (KH)		3.711±0.26 b	3.908±0.28 b
YE+KH		3.766±0.25 b	4.119±0.29 a
Interaction (I×B)			
100% ETc	Control	3.467±0.05 c	3.727±0.02 c
	YE	4.400±0.07 a	4.834±0.11 a
	KH	4.206±0.07 b	4.420±0.11 b
	YE+KH	4.276±0.07 ab	4.733±0.15 ab
80% ETc	Control	3.558±0.09 c	3.758±0.09 c
	YE	4.264±0.07 ab	4.685±0.19 ab
	KH	4.237±0.06 ab	4.500±0.13 ab
	YE+KH	4.233±0.06 ab	4.643±0.09 ab
60% ETc	Control	2.586±0.03 f	2.797±0.02 e
	YE	2.922±0.05 d	3.176±0.04 d
	KH	2.690±0.07 ef	2.803±0.05 e
	YE+KH	2.790±0.02 de	2.981±0.09 de
P: I		**	**
P: B		**	**
P: I×B		**	**

ETc = Crop evapotranspiration. Values are given as the mean ± standard error (n = 12 in main effect of irrigation levels treatments, n = 9 in main effect of bio-stimulants and n = 3 in interaction treatments). Different letters indicate statistically differences according to Duncan's multiple range tests at $P < 0.05$.**highly significant at $P < 0.01$ following a two-way ANOVA.

3.1.2. Dry matter content (%), nitrogen, phosphorus and potassium content (g kg dry matter^{-1})

Content of dry matter and NPK in response to various irrigation levels and bio-stimulants treatments was investigated and shown in Figure 2 and Table 5. Regarding the major effect, dry matter percentage was not affected by different irrigation levels in both seasons. On the other hand, the irrigation level with 100% ETc treatment (full irrigation) had the highest NPK content with values of 31.2, 5.9 and 37.9 (g kg^{-1}) in the first season and 29.7, 5.3 and 34.3 (g kg^{-1}) in the second season respectively. The lowest NPK content was found in the irrigation level with 60% ETc treatment (drought irrigation), with values of 28.8, 5.0, and 31.9 (g kg^{-1}) in the first season and 27.2, 4.6, and 28.8 (g kg^{-1}) in the second season, respectively. Generally, NPK concentrations were significantly decreased in both seasons under 60% ETc compared to 100% ETc and 80% ETc. In bio-stimulants treatments, the results of YE, KH, and YE+KH reflect significant boosted in dry matter, nitrogen, phosphorus, and potassium content in the dry bulb as compared with control. Generally, the differences between different bio-stimulants treatments in dry matter and NPK content were insignificant.

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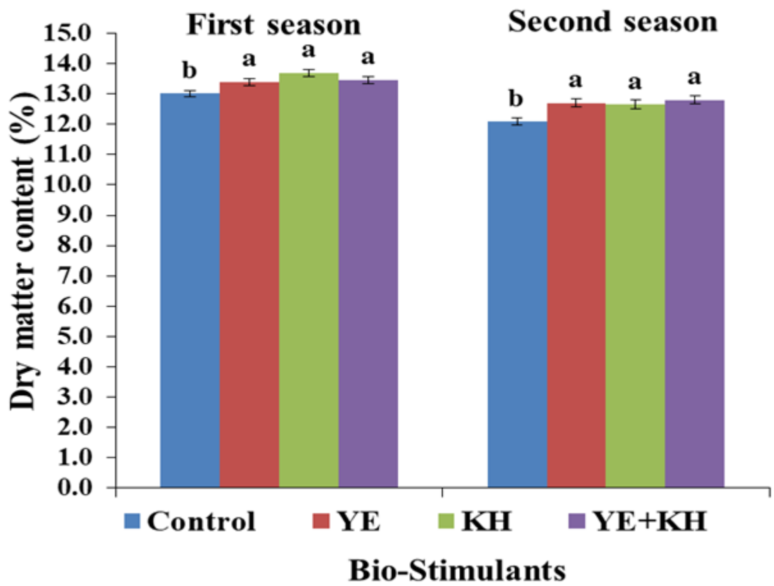

Figure 2. Effect of bio-stimulants (control, yeast extract = YE, potassium humate = KH, and YE+KH) on onion dry matter content (%) during the first and second seasons. Data are presented as means, line bars indicate ± standard errors, and the different upper letters demonstrate significant differences at $P < 0.05$ level according to Duncan's multiple range tests (n = 9 in main effect of bio-stimulants).

Table 4. Impact of irrigation levels and bio-stimulants treatments on NPK content (g kg dry matter^{-1}) of onion dry bulb in two seasons end.

Treatments	N (g kg dry matter^{-1})		P (g/kg dry matter^{-1})		K (g/kg dry matter^{-1})	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Irrigation levels (I)						
100% ETc	31.23±0.36 a	29.74±0.40 a	5.92±0.13 a	5.32±0.12 a	37.94±0.96 a	34.28±0.89 a
80% ETc	30.24±0.27 a	28.42±0.32 b	5.39±0.20 ab	4.82±0.15 b	35.51±0.61 b	31.74±0.58 b
60% ETc	28.83±0.40 b	27.19±0.46 c	5.02±0.17 b	4.56±0.15 b	31.88±0.86 c	28.84±0.80 c
Bio-stimulants (B)						
Control	28.85±0.51 b	27.05±0.54 b	4.90±0.16 c	4.38±0.16 c	31.86±0.72 b	28.38±0.64 b
Yeast extract (YE)	30.77±0.44 a	29.02±0.49 a	5.90±0.16 a	5.23±0.12 a	36.14±1.12 a	32.10±1.02 a
K-humate (KH)	30.42±0.43 a	28.79±0.46 a	5.32±0.22 b	4.87±0.21 b	36.04±1.39 a	32.95±1.25 a
YE+KH	30.36±0.49 a	28.94±0.59 a	5.66±0.21 a	5.13±0.14 ab	36.40±1.17 a	33.06±0.92 a
P: I	**	**	*	*	**	**
P: B	**	*	**	**	**	**
P: I×B	ns	ns	ns	ns	ns	ns

ETc = Crop evapotranspiration. Data are presented as means ± standard error (n = 12 in irrigation levels treatments, n = 9 in bio-stimulants treatments). The different upper letters indicate significant differences at $P < 0.05$ level according to Duncan's multiple range tests. ns non-significant; *significance at $P < 0.05$ following a two-way ANOVA; **highly significant at $P < 0.01$ following a two-way ANOVA.

3.1.3. Nitrogen, phosphorus and potassium uptakes (kg ha^{-1}) and protein yield (kg ha^{-1})

Table 5 and figure 3 provided data on NPK accumulation and protein yield under three irrigation levels, four bio-stimulants kinds, and their interactions. According to Duncan's multiple range tests at $P < 0.05$ in NPK and protein yields, irrigation level 100% ETc was significantly superior to treatment 80% ETc, which was also significantly superior to 60% ETc, which came at the end. Moreover, as compared to the 60% ETc (drought level), the full irrigation level (100% ETc) boosted NPK and protein yields by 61.4, 75.4, 78.3% and 61.4% in the first season and 64.9, 75.2, 80.2 and 64.9% in the second season, respectively, while the medium irrigation level (80% ETc) treatment raised NPK and protein yield by 55.6, 59.2 , 65.7 and 55.6% in the first season and 56.4, 57.9, 65.22 and 56.4% in the second season, respectively. Application of any type of bio-stimulants produced a significant enhancement in NPK and protein yield as compared with control. Yeast extract soil application produced the highest NPK and protein yield followed by the treatment with YE+KH. Furthermore, as compared with the control, YE raised NPK and protein yield by 28.6, 44.3, 37.8 and 28.6% in the first season and 32.3, 46.5, 40.6 and 32.3% respectively in the second season. According to the statistics of interactions between irrigation levels and bio-stimulants, watered seedlings onion with full irrigation level (100% ETc) with any bio-stimulants type (YE, KH, and YE+KH) ranked first for capturing the biggest amount of NPK and protein yield, which ranged between 131.8 and 145.3 kg N ha^{-1}, 20.4 and 25.0 kg P ha^{-1}, 81.6 and 94.8 kg K ha^{-1}, and 823.8 and 908.1 kg protein ha^{-1} during the two successful seasons. Watered onion seedlings with medium irrigation level (80% ETc) and any bio-stimulants type (especially containing YE) ranked second with insignificant differences, with first rank in some cases and saving 20% of irrigation. Lastly, onion seedlings with a drought stress irrigation level of 60% ETc produced the lowest values of NPK and protein yield, with an average of 71.3 kg N ha^{-1}, 11.3 kg P ha^{-1}, 76.3 kg K ha^{-1}, and 445.6 kg protein ha^{-1} during the two successful seasons. Treatments with bio-stimulants under drought stress were successful in lessening the intensity of water stress, particularly the addition of YE, which significantly boosted NPK and protein yields. Compared with the 60% ETc treatment, YE with a full irrigation level (100% ETc) achieved a boost in NPK and protein yield by 100.8, 133.3, 126.2 and 100.8%, respectively, as an average in the two seasons. Also, YE with a medium irrigation level (80% ETc) achieved an increase in NPK and protein yield of 86.8, 118.2, 100.3, and 86.8%, respectively, as an average in the two seasons. Meanwhile, YE with stress irrigation level of 60% ETc achieved a rise in NPK and protein yield of 23.4, 46.6, 22.2 and 23.4%, respectively, as an average in the two seasons.

Table 5. Nitrogen, phosphorus and potassium uptakes (kg ha^{-1}) as influenced by various irrigation levels and different bio-stimulants as well as their interaction in end of seasons.

Treatments		**Nitrogen uptake (kg ha^{-1})**		**Phosphorus uptake (kg ha^{-1})**		**Potassium uptake (kg ha^{-1})**	
		Season 1	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
Irrigation levels (I)							
100% ETc		127.9±4.53 a	132.0±5.02 a	24.3±1.07 a	23.6±1.05 a	156.1±7.63 a	152.8±7.67 a
80% ETc		123.3±3.62 b	125.1±4.27 b	22.0±1.07 b	21.3±1.14 a	145.1±5.39 b	140.1±5.74 b
60% ETc		79.3±1.96 c	80.0±2.39 c	13.9±0.64 c	13.5±0.67 b	87.6±2.72 c	84.8±2.66 c
Bio-stimulants (B)							
Control		92.8±5.70 c	93.2±5.59 c	15.8±1.17 c	15.1±1.13 c	102.6±6.41 b	97.8±6.07 b
Yeast extract (YE)		119.4±8.45 a	123.3±8.81 a	22.8±1.65 a	22.2±1.59 a	141.3±12.06 a	137.5±11.92 a
K-humate (KH)		113.4±8.72 b	113.2±9.18 b	20.0±1.89 b	19.2±1.87 b	135.7±12.87 a	130.8±12.75 a
YE+KH		115.1±8.76 ab	119.9±9.71 a	21.6±1.96 a	21.4±1.90 a	138.9±12.24 a	137.4±11.85 a
Irrigation levels × Bio-stimulants (I×B)							
	Control	103.4±4.18 c	105.6±3.21 c	18.7±0.64 c	18.2±0.87 c	113.0±2.38 c	109.9±1.37 d
100%	YE	140.7±2.43 a	145.3±1.46 a	26.7±1.42 a	25.9±0.63 a	174.3±0.86 a	170.6±1.35 a
ETc	KH	131.8±1.91 b	132.7±5.25 b	25.8±0.89 a	24.8±1.19 a	166.6±2.55 ab	161.8±5.74 ab
	YE+KH	135.8±1.92 ab	144.2±1.93 a	26.1±0.84 a	25.6±1.09 a	170.6±3.90 a	168.8±3.16 a
	Control	104.0±4.13 c	102.5±1.61 c	17.3±1.27c	16.2±0.94 cd	116.7±2.72 c	109.1±3.13 d
80%	YE	130.9±2.54 b	135.2±4.36 ab	25.0±1.54 a	24.3±1.71 a	155.0±3.39 b	150.4±2.68 bc
ETc	KH	129.6±1.99 b	129.5±3.73 b	21.1±0.63 b	20.4±0.75 b	154.3±8.65 b	148.9±7.05 c
	YE+KH	128.8±3.40 b	133.3±3.92 b	24.7±1.19 a	24.3±1.42 a	154.6±2.65 b	151.8±4.09 bc
	Control	71.1±0.39 e	71.4±1.71 f	11.5±0.18 e	11.1±0.58 f	78.0±4.95 e	74.5±4.50 f
60%	YE	86.6±3.35 d	89.2±3.92 d	16.8±0.29 c	16.3±0.84 cd	94.8±3.87 d	91.5±2.74 e
ETc	KH	78.9±2.85 de	77.3±1.35ef	13.1±0.70 de	12.4±0.65 ef	86.0±4.37 de	81.6±3.72 ef
	YE+KH	80.6±1.95 d	82.3±4.44 de	14.1±0.94 d	14.2±0.90 de	91.5±4.91 de	91.5±3.23 e
P: I		**	**	**	**	**	**
P: B		**	**	**	**	**	**
P: I×B		**	**	*	*	**	**

ETc = Crop evapotranspiration. Values are given as the mean ± standard error (n = 12 in main effect of irrigation levels treatments, n = 9 in main effect of bio-stimulants and n = 3 in interaction treatments). Different letters indicate statistically differences according to Duncan's multiple range tests at $P < 0.05$. *significance at $P < 0.05$ following a two-way ANOVA; **highly significant at $P < 0.01$ following a two-way ANOVA.

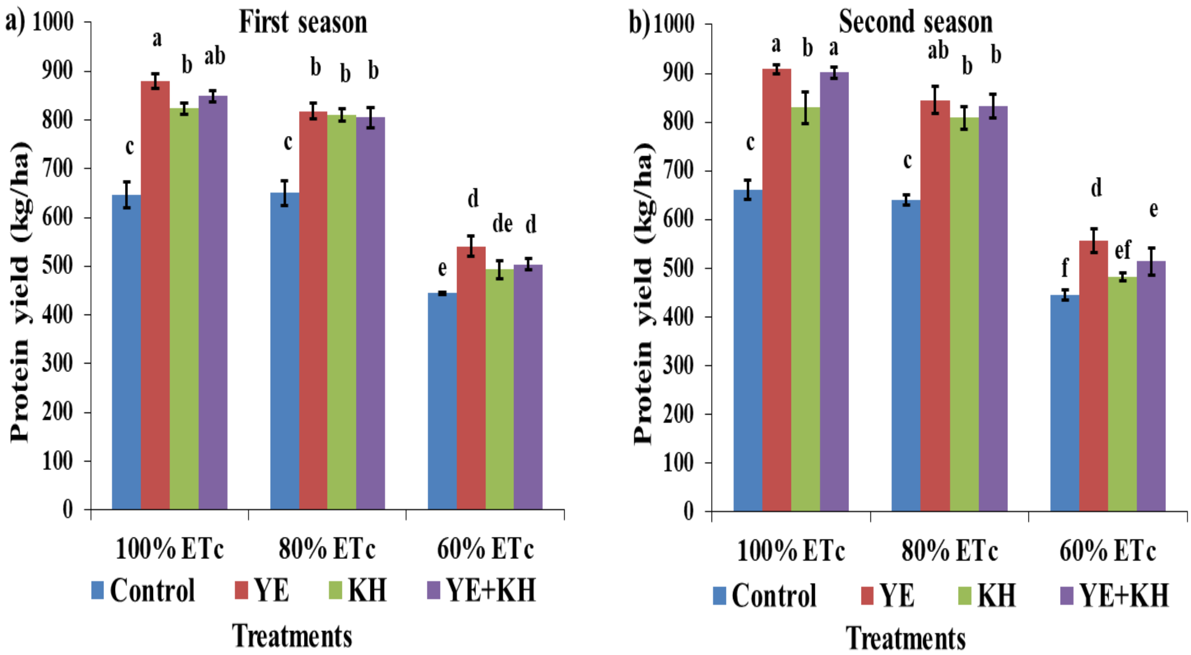

Figure 3. Effect of interaction between irrigation levels (100, 80 and 60% ETc), and bio-stimulants (control, yeast extract = YE, potassium humate = KH, and YE+KH) on onion protein yield (kg/ha) during the first season (a) and second season (b). ETc means crop evapotranspiration. Data are presented as means, line bars indicate ± standard errors, and the different upper letters demonstrate significant differences at $P < 0.05$ level according to Duncan's multiple range tests (n = 3 in interaction treatments).

3.2. Water productivity

3.2.1. Dry-water use efficiency (Dry-WUE) and dry-irrigation water use efficiency (Dry-IWUE)

Information about dry-WUE and dry-IWUE under irrigation levels, bio-stimulants, and their interactions is clarified in Table 6 and Figure 4. Regarding the main effect outcome, the greatest Dry-WUE and Dry-IWUE was recorded with the irrigation level of 80% ETc, while treatment under drought stress (60% ETc) achieved greater Dry-WUE and Dry-IWUE as compared with full irrigation level (100% ETc) that archived the lowest value. In line with Duncan's multiple range tests at $P < 0.05$, irrigation level 80% ETc was significantly superior to treatment 60% ETc, which was also significantly superior to 100% ETc, which came at the end. On average, over two seasons, there was a 24.34% improvement in Dry-WUE and Dry-IWUE by irrigation level of 80% ETc compared to the 100% ETc treatment, saving 20% ETc of irrigation water. Analyzing the sub-effect data showed that compared with the untreated treatment (control), YE significantly (according to Duncan's multiple range tests at $P < 0.05$) raised Dry-WUE and Dry-IWUE by 19.43 and 22.14% in the two seasons, respectively, whereas YE + KH enhanced dry-WUE and dry-IWUE significantly by 16.30 and 18.48% in the two seasons, respectively. Data on how irrigation level and bio-stimulants interact show that soil applications with any kind of bio-stimulants (YE, KH, and YE+KH) at 80% ETc irrigation level were the most successful in producing the greatest Dry-WUE and Dry-IWUE, and they outperformed the other treatments by a significant margin. Under water scarcity (60% ETc), YE significantly alleviated the detrimental impacts of the water deficit stress as compared with 60% ETc without bio-stimulants application. Finally, control treatment under irrigation level 100% ETc produced significantly lowest Dry-WUE and Dry-IWUE as compared with other treatments. Furthermore, as compared with the control treatment with full irrigation level (100% ETc), the average increases in Dry-WUE and Dry-IWUE as a result of any bio-stimulants (YE, KH, and YE+KH) with medium irrigation level (80% ETc) were 53.05% in the first season and 54.60% in the second season. Also, YE with drought stress (60% ETc) produced increases about 40.47% in the first season and 42.05% in the second season.

Table 6. Dry - IWUE (kg mm^{-1}) as influenced by various irrigation levels and different bio-stimulants as well as their interaction in end of seasons.

Treatments		Dry - IWUE (kg mm^{-1}) Season 1	Season 2
Irrigation levels (I)			
100% ETc		5.50±0.15 c	6.60±0.21 c
80% ETc		6.85±0.16 a	8.19±0.24 a
60% ETc		6.16±0.09 b	7.30±0.13 b
Bio-stimulants (B)			
Control		5.48±0.21c	6.50±0.24 c
Yeast extract (YE)		6.54±0.19 a	7.94±0.25 a
K-humate (KH)		6.27±0.23 b	7.31±0.29 b
YE+KH		6.37±0.20 b	7.70±0.26 a
Interaction (I×B)			
100% ETc	Control	4.66±0.07 f	5.56±0.03 f
	YE	5.92±0.10 de	7.20±0.16 de
	KH	5.66±0.10 e	6.59±0.17 e
	YE+KH	5.75±0.09 de	7.05±0.22 de
80% ETc	Control	5.98±0.14 cd	7.00±0.17 de
	YE	7.17±0.11 a	8.73±0.36 a
	KH	7.12±0.11 a	8.38±0.24 ab
	YE+KH	7.12±0.10 a	8.65±0.16 a
60% ETc	Control	5.80±0.06 de	6.95±0.04 de
	YE	6.55±0.11 b	7.89±0.10 bc
	KH	6.03±0.15 cd	6.96±0.13 de
	YE+KH	6.25±0.04 c	7.41±0.22 cd
P:I		**	**
P: B		**	**
P: I×B		**	*

ETc = Crop evapotranspiration. Values are given as the mean ± standard error (n = 12 in main effect of irrigation levels treatments, n = 9 in main effect of bio-stimulants and n = 3 in interaction treatments). Different letters indicate statistically differences according to Duncan's multiple range tests at $P < 0.05$. *significance at $P < 0.05$ following a two-way ANOVA; **highly significant at $P < 0.01$ following a two-way ANOVA.

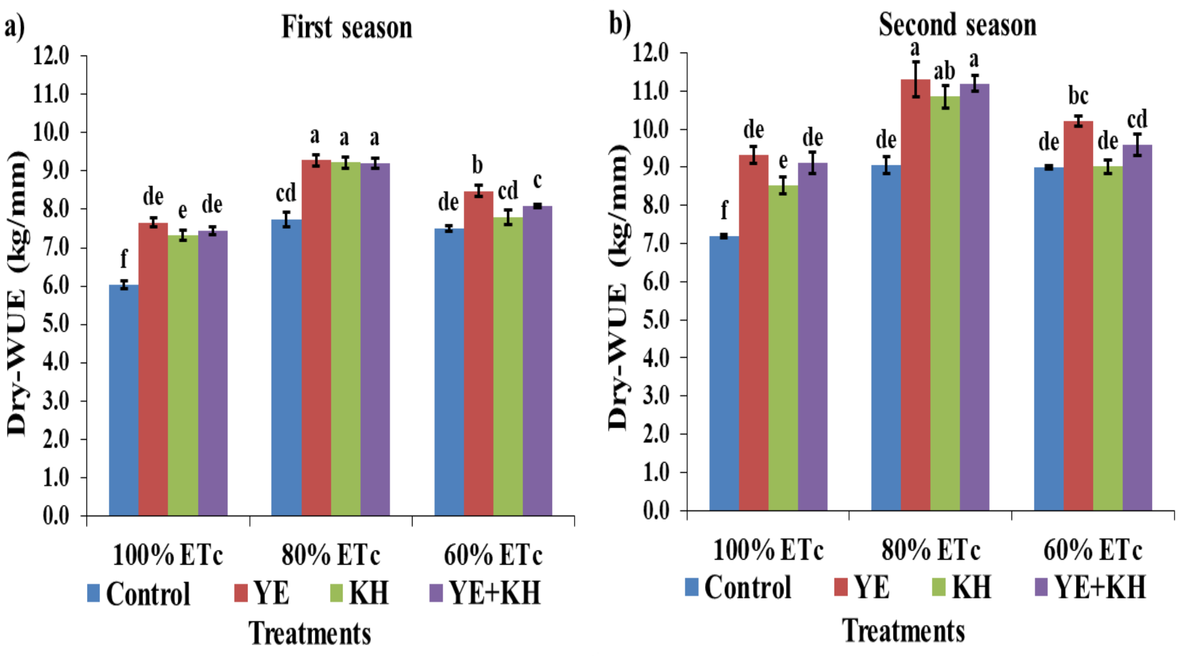

Figure 4. Effect of interaction between irrigation levels (100, 80 and 60% ETc), and bio-stimulants (control, yeast extract = YE, potassium humate = KH, and YE+KH) on onion dry-WUE (kg/mm) during the first season (a) and second season (b). ETc = Crop evapotranspiration. Data are presented as means, line bars indicate ± standard errors, and the different upper letters demonstrate significant differences at $P < 0.05$ level according to Duncan's multiple range tests (n = 3 in interaction treatments).

3.3. Soil properties

3.3.1. Soil chemical properties

3.3.1.1. Available soil Nitrogen, phosphorus and potassium (mg kg^{-1})

Details of data about available NPK under irrigation level, bio-stimulants and their interaction treatments are presented in Table 7. Concerning the irrigation levels of 80 and 60% ETc attained the highest soil available N. Meanwhile, the full irrigation level (100% ETc) produced the significantly lowest value of available N. On the other hand, available P took the opposite direction; irrigation with a complete level (100 ETc) attained the highest soil available P. Meanwhile, the medium and deficit irrigation levels (80 and 60% ETc) produced significantly lower values in the available P. Regarding the influence of bio-stimulants treatments, nutrient availability increased significantly in the experimental soil compared to untreated plants. Potassium humate treatment gave the greatest values of NPK availability, with insignificant differences between it and YE and YE + KH treatments. Concerning the effect of interaction between bio-stimulants and irrigation, any bio-stimulant type with a full irrigation level (100% ETc) resulted in a significant enhancement in available P in both seasons as compared with all treatments under 80 and 60% ETc irrigation levels.

Table 7. Available NPK (mg kg^{-1}) as effected by various irrigation levels and different bio-stimulants as well as their interaction in end of seasons.

Treatments		Soil available nitrogen (mg kg^{-1})		Soil available phosphorus (mg kg^{-1})		Soil available potassium (mg kg^{-1})	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Irrigation levels (I)							
100% ETc		33.23±1.64 b	28.76±1.41 b	15.52±0.62 a	14.54±0.58 a	42.39±1.08 a	37.40±0.91 a
80% ETc		36.84±1.02 a	32.13±0.97 a	5.90±0.18 b	5.28±0.17 b	40.57±0.88 a	36.44±0.81 a
60% ETc		39.36±0.96 a	34.88±0.82 a	4.79±0.19 b	4.37±0.18 b	40.61±0.78 a	35.91±0.56 a
Bio-stimulants (B)							
Control		31.27±1.86 b	27.57±1.75 b	7.43±1.32 b	6.87±1.25 b	38.19±0.77 b	34.35±0.60 c
Yeast extract (YE)		37.77±1.14 a	33.03±1.11 a	9.04±1.89 a	8.32±1.77 a	40.83±0.92 ab	35.98±0.87 bc
K-humate (KH)		39.17±1.06 a	34.11±1.09 a	9.56±1.87 a	8.90±1.82 a	43.41±0.96 a	38.68±0.83 a
YE+KH		37.70±1.06 a	32.98±0.97 a	8.92±1.82 a	8.18±1.75 a	42.33±0.84 a	37.32±0.65 ab
Irrigation levels × Bio-stimulants (I×B)							
100% ETc	Control	24.85±0.68 c	21.57±0.47 c	12.64±0.51 b	11.80±0.41 b	39.00±1.75 b	34.91±1.27 b
	YE	35.25±2.19 ab	30.49±1.64 ab	16.42±1.09 a	15.27±0.87 a	41.75±2.02 ab	36.48±1.92 ab
	KH	37.45±1.91 ab	31.89±1.81 ab	16.93±0.64 a	16.05±0.67 a	45.74±0.79 a	40.47±0.42 a
	YE+KH	35.37±1.40 ab	31.07±1.57 ab	16.10±0.88 a	15.05±0.91 a	43.06±2.45 ab	37.74±2.15 ab
80% ETc	Control	32.96±1.75 b	28.73±1.56 b	5.22±0.29 cd	4.69±0.29 cd	38.05±1.44 b	34.18±0.91 b
	YE	37.56±1.93 ab	32.54±1.96 ab	5.95±0.11 cd	5.31±0.14 cd	40.65±1.94 ab	36.22±2.08 ab
	KH	39.47±1.27 a	34.57±1.66 a	6.69±0.17 c	6.03±0.18 c	42.20±2.31 ab	38.05±2.20 ab
	YE+KH	37.37±1.70 ab	32.69±1.58 ab	5.72±0.19 cd	5.10±0.18 cd	41.40±0.91 ab	37.32±0.21 ab
60% ETc	Control	36.00±2.16 ab	32.40±1.98 ab	4.44±0.30 d	4.12±0.32 d	37.54±1.21 b	33.97±1.26 b
	YE	40.49±0.30 a	36.05±0.51 a	4.75±0.47 d	4.37±0.50 d	40.09±1.29 b	35.22±0.73 b
	KH	40.59±2.35 a	35.88±2.05 a	5.07±0.50 cd	4.62±0.48 cd	42.30±1.07 ab	37.53±0.84 ab
	YE+KH	40.35±1.55 a	35.18±1.41 a	4.92±0.37 d	4.37±0.33 d	42.52±1.01 ab	36.90±0.42 ab
P: I		**	**	**	**	ns	ns
P: B		**	**	**	**	**	**
P: I×B		ns	ns	*	*	ns	ns

ETc = Crop evapotranspiration. Values are given as the mean ± standard error (n = 12 in main effect of irrigation levels treatments, n = 9 in main effect of bio-stimulants and n = 3 in interaction treatments). Different letters indicate statistically differences according to Duncan's multiple range tests at $P < 0.05$. ns non-significant; *significance at $P < 0.05$ and **highly significant at $P < 0.01$ following a two-way ANOVA.

3.3.1.2 pH

The data in Table 8 illustrates the effect of irrigation levels and bio-stimulants on the soil pH. Bio-stimulant type was a highly significant effect on the soil pH. The highest significant pH values were recorded in untreated soil (control) or soil treated with YE, while the lowest values were recorded in soil treated with KH or KH + YE. Treated soil with KH reduced the soil pH from 8.44 (the initial value of soil pH, Table 1) to 8.32 after onion harvesting, as average on both seasons.

Table 8. pH, EC, soluble cations and anions (mmol kg^{-1}) and water holding capacity (WHC, g kg^{-1}) as effected by various irrigation levels and different bio-stimulants in end of seasons.

Treatments	**First season**									
	pH	**EC**	**Ca (mmol kg^{-1})**	**Mg (mmol kg^{-1})**	**Na (mmol kg^{-1})**	**K (mmol kg^{-1})**	**HCO_3 (mmol kg^{-1})**	**Cl (mmol kg^{-1})**	**SO_4 (mmol kg^{-1})**	**WHC (g kg^{-1})**
Irrigation levels (A)										
100% ETc	8.38±0.02 a	0.50±0.02 b	1.42±0.07 b	0.61±0.03 b	0.73±0.02 c	0.20±0.01 b	0.40±0.01 c	1.30±0.0.4 b	1.64±0.09 c	202.6±2.52 a
80% ETc	8.38±0.03 a	0.63±0.02 a	1.71±0.05 a	0.75±0.02 a	1.01±0.07 b	0.23±0.01 a	0.43±0.01 b	1.67±0.05 a	2.03±0.07 b	188.5±1.55 b
60% ETc	8.42±0.02 a	0.71±0.02 a	1.91±0.07 a	0.77±0.02 a	1.26±0.04 a	0.24±0.01 a	0.46±0.02 a	1.81±0.05 a	2.30±0.09 a	184.5±1.11 b
Bio-stimulants (B)										
Control	8.47±0.02 a	0.56±0.04 b	1.54±0.09 b	0.60±0.04 d	0.91±0.08 b	0.20±0.01 c	0.38±0.01 b	1.48±0.07 b	1.77±0.13 c	185.9±2.61 b
Yeast extract (YE)	8.45±0.02 a	0.56±0.03 b	1.53±0.09 b	0.69±0.03 c	0.90±0.07 b	0.22±0.01 b	0.43±0.02 a	1.53±0.08 ab	1.80±0.10 c	195.6±4.79 a
K-humate (KH)	8.31±0.02 b	0.68±0.03 a	1.87±0.08 a	0.79±0.03 a	1.15±0.09 a	0.24±0.01 a	0.46±0.02 a	1.67±0.09 a	2.29±0.10 a	191.0±2.72 a
YE+KH	8.35±0.02 b	0.65±0.04 a	1.78±0.10 a	0.74±0.02 b	1.05±0.10 a	0.23±0.01 b	0.46±0.01 a	1.68±0.12 a	2.09±0.09 b	194.9±2.01 a
P: I	ns	**	*	**	**	**	**	**	**	**
P: B	**	**	**	**	**	**	**	*	**	**
P: I×B	ns	ns	ns	ns	*	ns	ns	ns	ns	ns
Treatments	**Second season**									
Irrigation levels (A)										
100% ETc	8.42±0.02 a	0.47±0.02 b	1.34±0.06 b	0.58±0.03 b	0.67±0.02 c	0.19±0.01 b	0.38± 0.01 b	1.23±0.03 b	1.55±0.08 b	193.9±2.44 a
80% ETc	8.41±0.04 a	0.60±0.03 a	1.58±0.05 a	0.69±0.02 a	0.92±0.07 b	0.21±0.01 a	0.41± 0.01a	1.58±0.06 a	1.84±0.09 a	180.3±1.30 b
60% ETc	8.46±0.02 a	0.66±0.03 a	1.74±0.07 a	0.72±0.02 a	1.13±0.05 a	0.22±0.01 a	0.43± 0.02a	1.69±0.05 a	2.07±0.09 a	176.5±0.81 b
Bio-stimulants (B)										
Control	8.48±0.01 a	0.51±0.03 b	1.38±0.08 b	0.56±0.03 d	0.81±0.08 b	0.18±0.01 c	0.35±0.01 c	1.37±0.06 b	1.58±0.12 b	178.8±2.34 b
Yeast extract (YE)	8.51±0.02 a	0.52±0.03 b	1.41±0.06 b	0.64±0.02 c	0.81±0.06 b	0.20±0.01 b	0.40±0.01 b	1.42±0.07 b	1.65±0.07 b	186.9±4.73 a
K-humate (KH)	8.33±0.03 b	0.66±0.04 a	1.74±0.07 a	0.75±0.03 a	1.04±0.09 a	0.23±0.01 a	0.43±0.02 a	1.59±0.09 a	2.11±0.10 a	182.4±2.47 ab
YE+KH	8.40±0.03 b	0.61±0.04 a	1.69±0.07 a	0.71±0.01 b	0.96±0.09 a	0.21±0.01 b	0.44±0.01 a	1.62±0.10 a	1.95±0.10 a	186.2±1.93 a
P: I	ns	**	*	**	**	**	*	**	*	**
P: B	**	**	**	**	**	**	**	**	**	**
P: I×B	ns	ns	ns	**	*	ns	ns	ns	ns	ns

pH (1:1 suspension), EC extract ds m^{-1} (1:1), ETc = Crop evapotranspiration. Values are given as the mean ± standard error (n = 12 in main effect of irrigation levels treatments and n = 9 in main effect of bio-stimulants). Different letters indicate statistically differences according to Duncan's multiple range tests at $P < 0.05$. ns non-significant; *significance at $P < 0.05$ following a two-way ANOVA; **highly significant at $P < 0.01$ following a two-way ANOVA.

3.3.1.3. EC (ds m^{-1}) and soluble ions (mmol kg^{-1})

Data regarding EC and soluble ions under irrigation levels, bio-stimulants and their interactions are illustrated in Tables 8. EC was significantly increased as a result of water deficit treatments at 80% ETc and 60% ETc compared with 100% ETc. Under deficit irrigation (60% ETc), the increases in percent of the soluble Ca, Mg, Na, K, HCO_3, Cl and SO_4 were reached at 35.1, 25.8, 72.3, 24.4, 15.5 and 39.2% in the first season and 29.7, 23.9, 69.0, 20.7, 13.3 and 38.0% in the second season over 100% ETc treatment, respectively. Concerning the bio-stimulants treatments, the highest significant EC values were recorded in soil treated with KH or KH + YE. While the lowest values were recorded in untreated soil (control) or soil treated with YE. Compared with control treatment, the application of potassium humate increased soil EC by 24.6% on average in both seasons. Potassium humate (KH) soil application increased the percent of the soluble Ca, Mg, Na, K, HCO_3, Cl and SO_4 by 21.0, 31.1, 25.5, 21.8, 21.9, 12.6 and 17.6 % in the first season and 25.6, 34.6, 28.2, 26.6, 25.7, 15.8 and 23.9 % in the second season as compared to control treatment, respectively.

3.3.2. Soil physical properties

3.3.2.1. Water holding capacity (WHC, g kg^{-1})

Data regarding WHC under irrigation levels and bio-stimulants are illustrated in Table 8. The irrigation levels of 100 % ETc achieved the highest significant WHC values, while treatment under drought stress (60% ETc) achieved the lowest values. The enhancement by irrigation level of 100% and 80% ETc treatment about drought stress treatment (60% ETc) was 9.8 and 2.2 % as average in both succeeding seasons, respectively. On the other hand, YE, KH and YE+KH attained the highest significant WHC values. The enhancement by YE treatment about control treatment was 4.9 % as average in both succeeding seasons.

4. DISCUSSION

4.1. Overview of the trial soil

Egypt is among the driest countries on Earth; hyper-arid regions make up 86% of its total territory, while dry and semi-arid regions make up the remaining portion (Hussein, 2011). Location of field experiment, Tables 1 and 2, revealed that the study was conducted on newly reclaimed soil in a hyper-arid area characterized by extreme heat and little to no precipitation, resulting in a tendency of the soil pH towards the alkaline side, a decrease in accumulated plant residues, low organic matter content, virginity of soil and little weathering. On the other hand, soil parent materials containing high calcium carbonate. Challenging physical characteristics, such as high bulk density (1.61 ton m^{-3}) and poor water retention capacity (178.3 g kg^{-1}), were caused by low clay content (32 g kg^{-1}), high sand content (911 g kg^{-1}) and low organic matter content (4.44 g kg^{-1}). The previous characteristics of the soil led to a decrease in the availability of nutrients, and maybe the symptoms of nutrient deficiency will appear. Therefore, the type of fertilizer, its quantity, number of doses, and timing were used optimally. All of this, along with proven treatments, was done to maintain soil health and increase the production of sandy calcareous soils.

4.2. Onion productivity

Measurements of dry matter content, dry yield and quality of onions in terms of their nutritional content are extremely important measurements for onion storage and use throughout the year in the Egyptian market, as well as for the export market, the main source of hard currency. In this study, onion dry bulb yield, NPK content, NPK uptake and protein yield per hectare were significantly or highly significantly increased by increasing the irrigation level in both seasons. The greatest values were recorded with 100% ETc, while the lowest values were observed with 60% ETc. Sometimes there are no significant differences between 80 and 100% ETc. Generally, the onion has shallow roots and requires meticulously planned irrigation, which includes figuring out how much and when to apply irrigation in order to produce excellent yields (Abdelrasheed, et al., 2021). Many researchers reported gradual increases in fresh onion yields and crop components as a result of raising the irrigation level from the drought level (50: 60 ETc) to the medium irrigation level (70:80 ETc) and then the full irrigation level 100 ETc (Enciso, et al., 2009; Abdelkhalik, et al., 2019; Semida, et al., 2020; Abouabdillah,et al., 2022; El Bergui, et al., 2023). Despite all this research, there is no information about the onion dry bulb yield. Meanwhile, under the climate of Egypt, many investigators reported an increase in the productivity of many crops as a result of increased irrigation levels, from drought or shortage irrigation levels to full irrigation levels. These crops, such as lettuce (Refai, et al., 2019; Hassan, et al., 2019; Abd–Elrahman, et al., 2022), potato (Zahran, et al., 2020), faba bean (Abd-Eladl, et al., 2016; Desoky et al., 2021), maize (Ibrahim, et al., 2022a), Tomato (Khalifa, 2023) and sunflower (Saudy, et al., 2023). Generally, under drought conditions, there is a reduction in the amount of water in the root zone and thus shrinkage of the vascular tissue, which reduces water and nutrient absorption (El-Metwally, et al., 2022). The negative effects of drought include deterioration of the cell wall, decreased water content in tissues, decreased turgor pressure, decreased cellular expansion, closure of stomata, decreased levels of carbon dioxide in cells and between cells, all of which directly affect the rate of photosynthesis (Neseim, et al., 2014; Desoky, et al., 2021; Saudy, et al., 2023). Drought also leads to the deterioration of the total chlorophyll, a decrease in the wet weight of the leaves, a decrease in the leaf area and size, and thus the area of the leaf exposed to light decreases, which leads to a decrease in the coefficient of conversion of light to dry matter and thus the dry yield. These negative effects hinder plant growth and development and reduce crop productivity (Neseim, et al., 2014; Semida, et al., 2020). There is a disruption in biochemical properties such as proline, total amino acids, and total soluble sugars content. The lack of irrigation led to a decrease in transpiration and absorption of nutrients from the soil, and thus a significant decrease in the N, P, and K content of the bulbs compared to regular irrigation conditions (Abdelrasheed, et al., 2021). Drought stimulates the production of reactive oxygen species (ROS) causing cellular components to suffer oxidation and thus decreased plant growth and yield (El-Metwally, et al., 2022).

Yeast extract or potassium humate, applied singly or in combination, significantly or highly significantly boosted onion dry bulb yield, NPK content, NPK uptake, and protein production per hectare in both seasons. Several researchers have reported an increase in fresh onion yield and yield components as a result of yeast extract as a foliar or soil application (Abd-Elbaky, et al., 2021; Awad, et al., 2024; El-Sirafy, et al., 2014). On the other hand, several studies found that applying potassium humate or humic acid topically or through soil application increased the production of onion yield, their constituent parts, nutrient content, and nutrient uptake (El-Sirafy, et al., 2014; Mehrizi, et al., 2015; El-Shaboury and Ewais 2020; El-shaboury and Sakara, 2021). Moreover, there are other studies that have dealt with the positive effect of combining yeast extract and potassium humate with a flood irrigation system on the productivity of a number of crops grown in clay loam soil, such as soybean (El-Shaboury and Abd Elrahman, 2021), faba pean (Abdel-Gawad and Youssef, 2019), stevia (Al-Shaheen et al., 2022) and roselle (El-Serafy, 2018). However, there is still little information available on the effects of these bio-stimulants on onion dry bulb yield, nutrients uptake and soil fertility, especially under drought conditions. The enhancing effect of yeast or yeast extract on onion production parameters and stimulation of nutrient absorption may be due to the fact that yeast extract or active dry yeast (*Saccharomyces cerevisiae*) contains high-quality protein (especially amino acids), essential minerals and trace elements, carbohydrates, reducing sugars, lipids, enzymes, nucleic acids, folic acid, and B complex vitamins such as B1, B2, B3, B6, and B12 (Attia, et al., 2024; Awad, et al., 2024; Abd-Elbaky, et al., 2021; Al-Juthery, et al., 2020). Additionally, baking yeast contains natural plant hormones and similar compounds and compounds that regulate growth such as auxins, cytokinins, gibberellins and auxin-like compounds that have a stimulating effect on cell division and expansion, the synthesis of protein, nucleic acids, and chlorophyll and delaing leaf senescence and thus a protective role against environmental stress. (Abd-Elbaky, et al., 2021, Abd-Alrahman and Aboud, 2021; Ahmed, et al., 2023). On the opposite side, numerous studies have demonstrated that potassium humate or humic acid improves and enhances the physiological and biochemical characteristics of plants such as cell division and elongation, total chlorophyll, carotenoids and photosynthetic pigments, photosynthesis, relative water content, cell respiration, protein and carbohydrate synthesis, other enzymatic activities, total amino acid and proline content, total soluble sugars, cell membrane permeability and nutrient absorption (Al-Fraihat, et al., 2018; Hegazi, et al., 2023; El-Bassiouny, et al., 2014 - Faiyad, et al., 2024, Baddour and El-Shaboury, 2023). All of these may account for the enhanced nutrient absorption and positive effects on onion production or other crops grown in various environments. Furthermore potassium humate contains potassium and trace elements such as Zn, Fe, Mn, Cu, Mo and Co (Abdelrasheed, et a., 2021).

The positive effect between irrigation levels and bio-stimulants (YE, KH and YE+KH) were consistent with that obtained by some researchers on productivity of cauliflower (Refai et al., 2018), potato (Badawy et al., 2019a) and garlic (Badawy et al., 2019b) grown in sandy calcareous soils (total calcium carbonate above 32%) under different irrigation regimes (60, 80 and 100% ETc) and they reported alleviating the detrimental impacts of the water deficit stress by using YE and KH together or alone.

4.3. Water productivity

Common indicators used to assess the effectiveness of irrigation water usage in fresh crop production are water use efficiency (WUE) and irrigation water use efficiency (IWUE). However, as onions are mostly utilized in dried form, I suggest in this article calculating WUE and IWUE based on the onion dry bulb yield, which is really more significant than the fresh onion crop. Not only that, but the calculation of water productivity should extend to sugar production in sugar crops such as sugar cane, sugar beets, and stevia, as well as oil production in oil crops such as sunflower, canola, jojoba, and safflower. Among irrigation treatments, the greatest Dry-WUE and Dry-IWUE were recorded with the irrigation level of 80% ETc, while treatment under drought stress (60% ETc) achieved greater Dry-WUE and Dry-IWUE as compared with the full irrigation level (100% ETc) which recorded the lowest value. Furthermore, any bio-stimulants treatments applied to the soil improved Dry-WUE and Dry-IWUE. Also, Dry-WUE and Dry-IWUE improved with interaction between bio-stimulants and irrigation treatments. These results are in line with those obtained by some investigators who demonstrated the positive effect of optimum irrigation level (80% ETc) or drought level (60% ETc), bio-stimulators (YE, KH and YE+KH), interaction between bio-stimulants and irrigation treatments (60, 80 and 100% ETc) in obtaining higher WUE and IWUE in some crops such as cauliflower (Refai et al., 2018), potato (Badawy et al., 2019a), and garlic (Badawy et al., 2019b) grown in sandy calcareous soil. Also, Rashwan and Elsaied, 2022 reported the same trend on IWUE by lettuce grown in sandy soil under same treatments of irrigation and bio-stimulants but with replacing yeast by bio-stimulants EM. The role of bio-stimulants in increasing the efficiency of water use may be due to the fact that they enhance the water stored in the active root zone. Adding bio-stimulants reduces the harmful effect of water stress because the stressed stomatal cells close most of the time, and thus the rate of transpiration decreases. Therefore, there is no need to absorb more water by plant roots, which in turn reduces the amount of water absorbed (Rashwan and Elsaied, 2022).

4.4. Soil properties

4.4.1. Soil chemical properties

4.4.1.1. Available soil NPK and pH

The irrigation levels of 80 and 60% ETc attained the highest soil available N in the first and second season. Meanwhile, the full irrigation level (100% ETc) produced the significantly lowest value of available N. These findings are in harmony with those outlined by Hassan, et al., 2017. This may be due to the high amount of nitrogen uptake by onion yield, in addition to the high leaching of nitrogen from the soil at the full irrigation level. On the other hand, available P took the opposite direction; irrigation with a complete level (100 ETc) attained the highest soil available P in the first and second seasons, respectively. Meanwhile, the medium and deficit irrigation levels (80 and 60% ETc) produced significantly lower values in the available P. These results were confirmed with those recorded by Abd-Eladl, et al., 2016; Zein El-Abdeen, et al., 2018. This may be due to the increase in the amount of phosphorus released into the soil from fixation at the full irrigation level, despite the increase in phosphorus uptake by the onion crop. Meanwhile, in drought irrigation, there was an increase in phosphorus fixation and, thus, a decrease in its availability in the soil. Nitrogen is found in mobile or volatile forms in the soil. However, phosphorus and potassium are more stable in the soil compared to nitrogen (Sharma and Gobi, 2016; Zahran, et al., 2020).

Potassium humate it was the most effective bio-stimulants in reducing the pH on both seasons and it, increased nutrient availability (NPK) significantly in the experimental soil compared to untreated plants. Scientists have discovered that administering potassium humate or humic acid externally as a soil application at the proper dose enhances nutrient availability under different soils textures for a variety of various field crops and vegetables, including onion (Hafez, et al., 2020; El –Shaboury and Sakara, et al., 2021); fodder beet (Abbas, et al., 2014); maize (Awwad, et al., 2015); faba bean (Bayoumi and Selim, 2012; El-Galad, et al., et al., 2013); wheat (El-Etr and Hassan, 2017); corn and sesame (El-Etr et al., 2011); peanut (El-Hamid, et al., 2013) and cucumber (Khalil, et al., 2011).On the other hand, a number of researchers have indicated that humic acid and potassium humate work to improve soil properties such as aggregation, aeration, permeability, the ability to retain water, drainage, preventing soil leaching, and reducing soil erosion by increased cohesive forces of fine soil particles, decreased soil pH, which is reflected in increased solubility and the availability of nutrients which are absorbed by plant roots (Din, et al., 2018; Sharif, et al., 2002; Abd El-Kader, 2016).

Combination of irrigation levels and bio-stimulants, YE, KH and YE+KH at a full irrigation level (100% ETc) resulted in a significant enhancement in available P in both seasons as compared with all treatments under 80 and 60% ETc irrigation levels. These results are supported by the findings of Amer, et al., 2019, who used KH with full irrigation in salt-affected soil cultivated by sugar beet and cotton, as well as Awwad, et al., 2015, who used KH with full irrigation in loamy clay soil cultivated by maize. On the other hand, I did not find available research examining the interaction of yeast with irrigation levels and its effect on soil properties.

4.4.1.2. EC and soluble ions (soluble Ca, Mg, Na, K, HCO_3, Cl and SO_4)

Watered soil by irrigation level 60% ETc increased soil EC from 0.61 (the initial value of soil EC, Table 1) to 0.69 after onion harvesting, as average on both seasons. On the other hand, there were significant or highly significant increases in soluble ions as a result of irrigation levels decreasing from 100% to 60%. This probably due to leaching effect of irrigation treatments, the highest amount of irrigation water (ETc 100%) led to leach a considerable amount of salts in soil profile away from the surface layer, consequently lowest values of soil salinity (EC) and soluble ions were recorded in case of 100 % ETc. Similar results were previously described by Amer, et al., 2019; Hassan, et al. 2017; El-Maddah, et al., 2012. Concerning the bio-stimulants treatments, the highest significant EC values were recorded in soil treated with KH or YE+KH, while soluble ions increased significant or highly significant as a result of soil bio-stimulants application. This finding is at par with Awwad, et al., 2015.

4.4.2. Soil physical properties

4.4.2.1. Water holding capacity (WHC)

WHC significantly increased when irrigation levels were raised from 60% to 100% ETc, as well as, the application of soil bio-stimulants (YE, KH, and YE+KH) resulted in a significant rise in WHC. Results of this study agree with the findings by El-Kotb and Borham, 2013; Rizk, et al., 2010; Khalil, et al., 2011. These increases may be due to the fact that organic substances (humate) contain pronouncedly active organic groups that encourage the water molecules to be chelated. As a result, potassium humate is regarded as an organic conditioner that enhances the hydrophysical characteristics of the soil by absorbing water.

5. CONCLUSION

Understanding and enhancing onion dry yield, water productivity, and soil fertility under drought, deficit, and normal irrigation on sandy calcareous soils is crucial, especially under limited information. Therefore, the effects of three treatments of irrigation levels (100% crop evapotranspiration, 80% ETc and 60% ETc), and four bio-stimulants soil treatments (control, yeast extract (YE), potassium humate (KH) and YE+KH) were studied during two successive winter seasons. Generally, bio-stimulants greatly enhanced onion output and soil fertility while mitigating the adverse effects of water scarcity. Soil application of bio-stimulants under various irrigation levels significantly enhanced onion dry bulb yield, NPK content, NPK uptakes, protein yield, water use efficiency and irrigation water use efficiency for onion dry bulb yield. Also, had positive effect on available NPK, pH, EC, soluble cations and anions, and improved soil water holding capacity. The results of the current study open the way for calculating water productivity in relation to the real yield such as sugar production in sugar crops and oil production in oil crops.

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Conflict of Interest

The author declare no conflict of interest.

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الملخص العربي

تحسين محصول البصل الجاف، حالة العناصر الغذائية للأبصال، إنتاجية المياه وخواص التربة الجيرية تحت الإجهاد المائي باستخدام المنشطات الحيوية

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هناك القليل من المعلومات حول كيفية تحسين إنتاجية محصول البصل الجاف وحالة العناصر الغذائية في النباتات والتربة في ظل ندرة المياه. ولسد هذه الفجوة، أجريت تجربتين حقليتين خلال موسمين شتويين متتاليين. تم تصميم ثلاث معاملات لمستويات الري في القطعة الرئيسية (100% من بخر نتح المحصول ETc، 80% من بخر نتح المحصول ETc ، 60% من بخر نتح المحصول ETc). تم تصميم أربع معاملات للتربة بالمنشطات الحيوية في القطعة الفرعية: كنترول، مستخلص الخميرة، هيومات البوتاسيوم و مستخلص الخميرة + هيومات البوتاسيوم. بشكل عام أدت المنشطات الحيوية إلى زيادة إنتاجية البصل بشكل ملحوظ وتقليل التأثير السلبي لنقص المياه. خلال كلا الموسمين، سجلت معاملة مستخلص الخميرة تليها مستخلص الخميرة + هيومات البوتاسيوم أعلى إنتاجية للأبصال وكفاءة استخدام المياه وكفاءة استخدام مياه الري بالنسبة للإنتاجية البصل الجاف ومحتوى المادة الجافة ومحتوى النيتروجين والفوسفور والبوتاسيوم وامتصاص النيتروجين والفوسفور والبوتاسيوم وإنتاجية البروتين وقدرة التربة على الاحتفاظ بالمياه. بينما سجلت معاملة هيومات البوتاسيوم متبوعة بمستخلص الخميرة + هيومات البوتاسيوم أو مستخلص الخميرة أعلى قيم لتيسر النيتروجين والفوسفور والبوتاسيوم و ال EC والأيونات القابلة للذوبان في التربة. تم تسجيل أدنى قيم لي ال pH في التربة المعالجة بهيومات البوتاسيوم أو مستخلص الخميرة + هيومات البوتاسيوم. بمقارنة نسبة 80% من بخر نتح المحصول ETc مع معاملة مستخلص الخميرة و معاملة 100% من بخر نتح المحصول ETc مع معاملة مستخلص الخميرة، تبين أن مقدار الانخفاض في محصول البصل الجاف بلغ 3.18% فقط كمتوسط للموسمين مع توفير 20% من مياه الري. ومع ذلك، كان إنتاج البصل الجاف أكبر في معاملة مستخلص الخميرة مع 80% من بخر نتح المحصول ETc مقارنة بالنباتات غير المعالجة تحت مستوى الري 100% من بخر نتح المحصول ETc بنسبة 24.36% كمتوسط للموسمين. في الختام، قد يكون مستخلص الخميرة و/ أو مستخلص الخميرة + هيومات البوتاسيوم من العوامل الرئيسية في تعزيز خصوبة التربة وتحمل إجهاد النبات بسبب عدم كفاية مياه الري.