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Impact of Licorice Extract Foliar Application on Some Growth and Yield Parameters on Wheat Grown under Water Stress Conditions

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THIS experiment was conducted with the wheat cultivar Sakha 93 (*Triticum aestivum* L.) throughout the two growing winters of the 2022–2023 and 2023–2024 seasons. The experiment tried to increase wheat growth and yield under varying levels of water stress (100, 75, and 50% of evapotranspiration ETc) by spraying licorice extract at varied concentrations (0, 5, and 10 g/l) under a sprinkler irrigation system. These treatments represented optimal water stress, moderate water supply, and severe water supply circumstances, respectively. In the Belbeis area of the El Sharkia Governorate, Egypt, a private orchard grows wheat on sandy loam soil under water stress. According to the results, it was found that the best results were always in favor of the interaction between 100% of evapotranspiration and spraying with 10 grams of licorice extract, except for the water productivity trait, where the best results were with irrigation with 75% of ETc and spraying application with 10 grams of licorice extract. Therefore, we recommend irrigation with 75% of evapotranspiration and spraying with 10 grams of licorice extract, as it achieves commercial growth, yield characteristics and water productivity of the wheat cultivar Sakha 93, while saving 25% of irrigation water, this is very important and necessary because of the scarcity of water nowadays.

Keywords: Wheat cultivar Sakha 93, Water stress, Sprinkler irrigation, Licorice extract.

Introduction

Drought stress is one of the abiotic environmental factors that could negatively impact wheat plants' ability to produce and lower crop efficiency. On the other hand, wheat plants are extremely vulnerable to situations where there is a shortage of water. In semi-arid and rain-fed regions, drought stress lowers agricultural production, availability, and output. Drought stress affects many physiological and biochemical processes, to differing degrees depending on the growth stage and exposed area. Transport, respiration, photosynthesis, ion absorption, stem growth, root propagation, disruptions of solute accumulation and ionic imbalances, changes in metabolic activity, suppression of enzyme activity, and the interaction of all these components are among them. It is believed to differ from other common ecological stresses (Ghazi, 2017; Youssef and Hozayen, 2019a; Youssef and Hozayen, 2019b; Soroori and Danaee, 2023; Youssef, 2023 and Youssef and Abdelaal, 2023).

70% of crop zones, sometimes referred to as hardiness zones, are semiarid or arid regions where wheat is cultivated. As a result, the demand for agricultural resources is rising. (Zeng and Luo, 2012). Egypt produces 8 million tons of wheat annually, but this amount is insufficient to feed the nation's growing population of over 100 million people (Hassan *et al.*, 2017). Wheat is one of Egypt's most significant grain crops.

According to Kahlown *et al.* (2003), depending on the weather, growth season length, soil, and irrigation sources, wheat needs 400–650 mm of water. Ideally, 650 mm of water is applied. Elevated levels of water stress in plants can negatively impact their growth and morphological characteristics, such as a noticeable decrease in their total biomass yield, shoot and root lengths, and leaf area. (Aldesuquy *et al.*, 2012).

Furthermore, Zareian *et al.* (2014) discovered that reducing water stress at the ear reduced grain production as well as every component of the wheat plant, such as emergence and grain filling. Therefore, it is crucial to maximize the yield of wheat cultivated under water stress because varied soil water statuses generate varying degrees of biochemical changes in wheat grains.

Glycyrrhizin acid and Glabridin are found in the aqueous extract of the licorice plant. Glycyrrhizin, the most significant ingredient in licorice, functions similarly to hormones. Along with its acid, it is thought to be a type of plant hormone that accelerates plant growth rates and encourages the

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production of proteins in the plant (Zagier *et al.*, 2021) .

The current study used licorice extract foliar application to enhance wheat development and yield characteristics under water stress conditions.

Materials and Methods

This experiment was conducted with the wheat cultivar Sakha 93 (*Triticum aestivum* L.) throughout the winters of 2022–2023 and 2023–2024. The experiment tried to increase wheat growth and yield under varying levels of water stress (100, 75, and 50% of evapotranspiration ETc) by spraying licorice extract at varied concentrations (0, 5, and 10 g/l) under a sprinkler irrigation system. In the Belbeis area of the El Sharkia Governorate, Egypt, a private orchard grows wheat on sandy loam soil under water stress.

Every wheat plant in this study was exposed to the same relevant agricultural practices, with the exception of the experimental treatments. With three repetitions and a replication size of 10.50 m2 (3.00×3.50 m), the experiment employed a split plot arrangement of a full randomized block design (factorial experiment-split plot design). The main plot contained 100, 75, and 50% of ETc, and three licorice extract (0, 5, and 10 g/l) subplots as shown in Figure (1). Each feddan was manually sown with 80 kg of wheat seeds in the middle of November. Treatments with licorice extract were applied three times at the required rates in mid-December, mid-January, and mid-February (thirty, sixty, and ninety days after planting). The trial lasted until the end of April, but the irrigation stopped at the end of March. Water was sprayed at short intervals until germination, which took place twice a week, ten days before harvest.

Licorice extract, the water extraction process was used to extract the active components in the plant's roots. One liter of warm water was used to dissolve five or ten grams of the plant's dry, well-ground roots for three hours after they were weighed. After filtering the filtrate, the mixture was kept in a dark, airtight bottle until it was required.

The tested irrigation levels were based on several rates of irrigation water, namely 1154, 866, and 577 m^3 /fed./season 2022/2023 and 1189, 892, and 595 m3 /fed./season 2023/2024, as shown in Tables 1 and 2. These figures were generated by the CROPWAT (2012) version 8.0.1.1 computer program using the region's meteorological data (2022/2023-2023/2024 seasons). Additionally, the reference evapotranspiration (ETo) is multiplied by the specific crop coefficient (Kc) to determine the estimated crop water demand (ETc), which is equal to ETo × Kc.

Growth, yield parameters and water productivity

The tested treatments were evaluated through the following parameters

Plant height, plant numbers per m^2, number of tillers per plant, number of leaves per plant, leaf area m2, shoot dry weight, root dry weight, spike weight, spike length, number of grains per spike, and grain yield ton per feddan were measured and recorded at the conclusion of each experimental season (harvest time). Moreover, water productivity (WP) values were calculated according to the following equation (Jensen, 1983): WP = Yield (kg per feddan) / Seasonal ETc (m^3 per feddan).

Leaf photosynthetic pigments and proline contents

The photosynthetic pigments Photopigments were measured in fresh leaf samples using a SPAD device. Additionally, fresh leaves' proline content (µ moles/g fresh weight) was determined using the Bates et al., 1973 approach.

Leaf chemical composition

The micro-Kjeldahl device was used to digest and finely ground the dried leaves. In accordance with Naguib (1969), the percentage of nitrogen content was calculated. The proportion of phosphorus was calculated using AOAC, 1985. The proportion of potassium was calculated using Brown and Lilliland's 1964 methodology.

Physicochemical parameters

Physicochemical characteristics, including protein, gluten, fat, and ash, were measured using the techniques outlined in Anonymous (2000).

Statistical analysis

Three replicates, each measuring 10.5 m2 (3 x 3.5), were used in the experimental split plot design of the full randomized block design. Three licorice extracts (0, 5, and 10 g/l) were included in the sub-plot, while the main plot contained 100, 75, and 50% of ETc. According to Snedecor and Cochran (1980), The gathered data was statistically examined using the analysis of variance approach. Duncan's range test was used to distinguish between the mean differences (Duncan, 1955).

Results

Plant height, plant numbers per m^2 and number of tillers per plant

According to the data in Table (3), plant height dropped dramatically from 85.06 and 86.63 cm to 68.46 and 70.49 cm in the first and second seasons, respectively, when the irrigation water volume was reduced from 100% to 50% of ETc. Furthermore, the highest values were obtained by spraying 10 g of licorice extract per liter, reaching 89.66 and 90.32 cm, as opposed to 66.69 and 68.39 cm for licorice extract 0 g per liter in the first and second seasons, respectively.

The highest results were simultaneously obtained by spraying 10 g of licorice extract per liter with ETo100% of water irrigation, reaching 98.84 and 99.77 cm in the first and second seasons, respectively. Additionally, in the first and second seasons, respectively, licorice extract 10 g per l with 75% ETc of water irrigation achieved 93.47 and 93.73 cm, surpassing the control licorice extract 0 g per l with 100% ETc of water irrigation (72.36 and 74.44 cm).

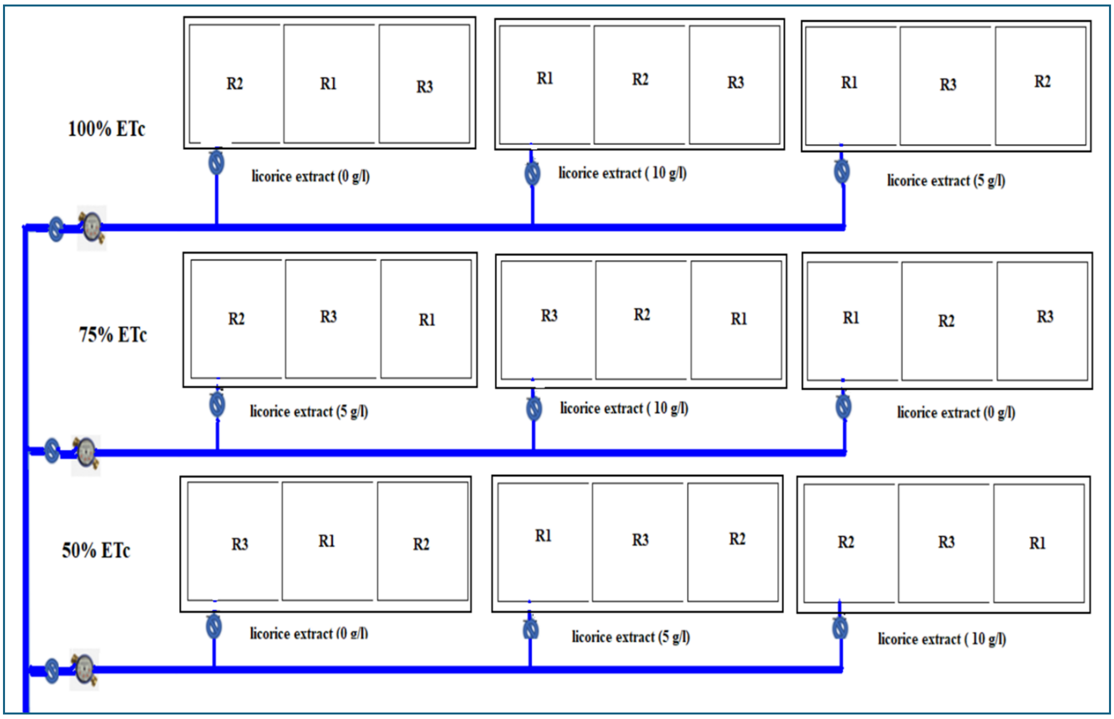

Fig. 1. The experiment layout.

Table 1. The rate of reference crop evapotranspiration (ETo) determined by Ndulue & Ramanathan, 2021; Youssef et al., 2023; and Mahmoud et al., 2024 method (season 2022/2023) using computer program (CROPWAT V.8.00) by climatic data under Belbeis region – El Sharkia Governorate.

Year	2022		2023			
Month	**November**	**December**	**January**	**February**	**March**	**Total**
No. of days/month	15.00	31.00	31.00	28.00	31.00	
Crop coefficient	**0.35**	**0.75**	**1.05**	**1.20**	**0.67**	
ETo-100%	2.48	1.89	1.93	2.50	3.42	
ETc-100%	0.87	1.42	2.03	3.00	2.29	
W.R (m^3/fed./Day)	3.65	5.95	8.51	12.60	9.62	
W.R (m^3/ fed. Month)	54.68	184.56	263.85	352.80	298.34	1154
ETo-75%	1.86	1.42	1.45	1.88	2.57	
ETc-75%	0.65	1.06	1.52	2.25	1.72	
W.R (m^3/fed./Day)	2.73	4.47	6.38	9.45	7.22	
W.R (m^3/ fed. Month)	41.01	138.42	197.89	264.60	223.76	866
ETo-50%	1.24	0.95	0.97	1.25	1.71	
ETc-50%	0.43	0.71	1.01	1.50	1.15	
W.R (m^3/fed./Day)	1.82	2.98	4.26	6.30	4.81	
W.R (m^3/ fed. Month)	27.34	92.28	131.93	176.40	149.17	577

Table 2. The rate of reference crop evapotranspiration (ETo) determined by Ndulue & Ramanathan, 2021; Youssef et al., 2023; and Mahmoud et al., 2024 method (season 2023/2024) using computer program (CROPWAT V.8.00) by climatic data under Belbeis region – El Sharkia Governorate.

Year	2023		2024			
Month	**November**	**December**	**January**	**February**	**March**	**Total**
No. of days/month	15.00	31.00	31.00	28.00	31.00	
Crop coefficient	**0.35**	**0.75**	**1.05**	**1.20**	**0.67**	
ETo-100%	2.48	1.89	1.93	2.5	3.82	
ETc-100%	0.87	1.42	2.03	3.00	2.56	
W.R (m^3/fed./Day)	3.65	5.95	8.51	12.60	10.75	
W.R (m^3/ fed. Month)	54.68	184.56	263.85	352.80	333.23	1189
ETo-75%	1.86	1.42	1.45	1.88	2.87	
ETc-75%	0.65	1.06	1.52	2.25	1.92	
W.R (m^3/fed./Day)	2.73	4.47	6.38	9.45	8.06	
W.R (m^3/ fed. Month)	41.01	138.42	197.89	264.60	249.93	892
ETo-50%	1.24	0.95	0.97	1.25	1.91	
ETc-50%	0.43	0.71	1.01	1.50	1.28	
W.R (m^3/fed./Day)	1.82	2.98	4.26	6.30	5.37	
W.R (m^3/ fed. Month)	27.34	92.28	131.93	176.40	166.62	595

Table 3. Effect of irrigation water levels and spraying with different concentrations of licorice extract on plant height, plant numbers per m^2 and numbers of tillers per plant of wheat c.v. Sakha 93.

Parameters / Treatments	Plant height (cm)	Plant numbers per m^2	Number of tillers per plant
	First season (2022/2023)		
ETc-00%	85.06A	506.97A	5.98A
ETc-75%	79.91B	474.29B	5.56B
ETc-50%	68.46C	409.75C	4.70C
L.E.0 g per l	66.69C	397.59C	4.61C
L.E.5 g per l	77.07B	457.89B	5.38B
L.E.10 g per l	89.66A	535.53A	6.25A
ETc-100%XL.E.0 g per l	72.36f	434.44f	5.16f
ETc-100%XL.E.5 g per l	83.98c	493.59c	5.87c
ETc-100%XL.E.10 g per l	98.84a	592.87a	6.90a
ETc-75%XL.E.0 g per l	66.86g	393.20h	4.53h
ETc-75%XL.E.5 g per l	79.41d	472.09d	5.58d
ETc-75%XL.E.10 g per l	93.47b	557.58b	6.57b
ETc-50%XL.E.0 g per l	60.86h	365.12i	4.12i
ETc-50%XL.E.5 g per l	67.83g	407.98g	4.69g
ETc-50%XL.E.10 g per l	76.69e	456.13e	5.28e
	Second season (2023/2024)		
ETc-00%	86.63A	517.27A	6.00A
ETc-75%	81.08B	485.81B	5.63B
ETc-50%	70.49C	419.80C	4.71C
L.E.0 g per l	68.39C	404.38C	4.53C
L.E.5 g per l	79.49B	476.98B	5.46B
L.E.10 g per l	90.32A	541.52A	6.35A
ETc-100%XL.E.0 g per l	74.44f	443.55f	5.05f
ETc-100%XL.E.5 g per l	85.68c	516.86c	6.02c
ETc-100%XL.E.10 g per l	99.77a	591.40a	6.95a
ETc-75%XL.E.0 g per l	68.71h	401.47h	4.46h
ETc-75%XL.E.5 g per l	80.79d	491.66d	5.71d
ETc-75%XL.E.10 g per l	93.73b	564.29b	6.71b
ETc-50%XL.E.0 g per l	62.03i	368.12i	4.09i
ETc-50%XL.E.5 g per l	71.98g	422.42g	4.64g
ETc-50%XL.E.10 g per l	77.46e	468.87e	5.39e

ETc = Evapotranspiration, L. E.= licorice extract
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

In keeping with this pattern, the number of plants per m^2 decreased to minimum values of 409.75 and 419.80 with 50% ETc, respectively, from 506.97 and 517.27 with 100% ETc in the first and second seasons. Furthermore, compared to licorice extract 0 g per l, which recorded 397.59 and 404.38 in the first and second seasons, respectively, spraying 10 g per l of licorice extract produced the greatest values, reaching 535.53 and 541.52. In contrast, the highest values were obtained in the first and second seasons, respectively, when licorice extract (0 g per l) was sprayed in conjunction with 100% ETc water irrigation. Additionally, the (control) licorice extract 0 g per l with 100% ETc of water irrigation recorded 434.44 and 443.55 in the first and second seasons, respectively, but the licorice extract 0 g per l with 75% ETc of water irrigation acquired 557.58 and 564.29.

In a similar vein, data showed that in the first and second seasons, respectively, fewer tillers per plant (4.70 and 4.71) were produced when irrigation water levels were reduced to 50% ETc as opposed to 5.98 and 6.00 when 100% ETc was used. Furthermore, the highest values were obtained by spraying 10 g of licorice extract per liter, reaching 6.25 and 6.35, in contrast to licorice extract 0 g per liter, which recorded 4.61 and 4.53 in the first and second seasons, respectively. Moreover, the highest values-6.90 and 6.95 in the first and second seasons, respectively-were obtained by combining 100% ETc water irrigation with 10 g of licorice extract per liter. Additionally, the (control) licorice extract 0 g per l with 100% ETc of water irrigation recorded 5.16 and 5.05 in the first and second seasons, respectively, while licorice extract 10 g per l with 75% ETc of water irrigation gained 6.57 and 6.71.

Number of leaves per plant, leaf area, shoot and root dry weight

Table (4)'s values demonstrated that there was a significant decrease in the number of leaves per plant, leaf area, shoot, and root dry weight when the irrigation water was reduced from 100% to 50% ETc. The number of leaves per plant dropped dramatically from 4.67 and 4.72 to 3.77 and 3.79 in the first and second seasons, respectively, when the irrigation water supply was reduced from 100% to 50% of ETc. Furthermore, the greatest values were obtained by spraying 10 g of licorice extract per liter, reaching 4.97 and 4.97 in comparison to 3.59 and 3.68 for licorice extract 0 g per liter in the first and second seasons, respectively. Furthermore, the highest values were obtained by spraying 10 g of licorice extract per liter along with 100% ETc of water irrigation; these values reached 5.41 in the first season and 5.41 in the second. In the first and second seasons, respectively, licorice extract 10 g per l with 75% ETc of water irrigation gained 5.24 and 5.16, surpassing the (control) licorice extract 0 g per l with 100% ETc of water irrigation (3.86 and 4.09). Nevertheless, in the first and second seasons, respectively, the leaf area cm^2 reached low values of 32.76 and 33.79 cm^2 with 50% ETc, as opposed to 39.23 and 40.13 cm^2 with 100% ETc. Furthermore, compared to licorice extract 0 g per l, which recorded 31.96 and 33.14 cm^2 in the first and second seasons, respectively, spraying 10 g per l of licorice extract produced the greatest results, reaching 41.28 and 41.37 cm^2. Additionally, the highest values were obtained in the first and second seasons, reaching 44.81 and 44.66 cm^2, respectively, when licorice extract (10 g per l) was sprayed in conjunction with 100% ETc water irrigation. The (control) licorice extract 0 g per l with 100% ETc of water irrigation recorded 33.86 and 35.55 cm^2 in the first and second seasons, respectively, while licorice extract 10 g per l with 75% ETc of water irrigation acquired 43.62 and 42.76 cm^2. Simultaneously, data showed that in the first and second seasons, respectively, lowering the amount of irrigation water (50% ETc) reduced shoot dry weight (4.67 and 4.66 g) in comparison to 5.76 and 5.88 g with 100% ETc. Furthermore, in comparison to licorice extract 0 g per l in the first and second seasons, respectively, spraying 10 g per l of licorice extract produced the greatest results, reaching 6.01 and 6.09 g. Additionally, the highest values—6.69 and 6.74 g in the first and second seasons, respectively—were obtained by spraying 10 g of licorice extract per liter in conjunction with 100% ETc water irrigation. The (control) licorice extract 0 g per l with 100% ETc of water irrigation recorded 4.91 and 4.95 g in the first and second seasons, respectively, while licorice extract 10 g per l with 75% ETc of water irrigation gained 6.29 and 6.33 g. Additionally, data showed that in the first and second seasons, respectively, reducing the amount of irrigation water (50% ETc) resulted in lower root dry weights (5.67 and 5.70 g) as opposed to 6.84 and 6.94 g) with 100% ETc. Furthermore, in comparison to licorice extract 0 g per l in the first and second seasons, respectively, spraying 10 g per l of licorice extract produced the greatest results, reaching 7.09 and 7.33 g. Furthermore, the highest results (7.83 and 7.96 g) were obtained in the first and second seasons, respectively, when licorice extract (10 g per l) was sprayed in conjunction with 100% ETc water irrigation. The (control) licorice extract 0 g per l with 100% ETc of water irrigation recorded 6.01 and 5.91 g in the first and second seasons, respectively, while licorice extract 10 g per l with 75% ETc of water irrigation gained 7.30 and 7.71 g.

Table 4. Effect of irrigation water levels and spraying with different concentrations of licorice extract on number of leaves per plant, leaf area, shoot and root dry weight of wheat c.v. Sakha 93.

Parameters / Treatments	Number of leaves per plant	Leaf area cm^2	Shoot dry weight (g)	Root dry weight (g)
First season (2022/2023)				
ETc-00%	4.67A	39.23A	5.76A	6.84A
ETc-75%	4.42B	37.21B	5.42B	6.39B
ETc-50%	3.77C	32.76C	4.67C	5.67C
L.E.0 g per l	3.59C	31.96C	4.58C	5.56C
L.E.5 g per l	4.29B	35.96B	5.25B	6.25B
L.E.10 g per l	4.97A	41.28A	6.01A	7.09A
ETc-100%XL.E.0 g per	3.86f	33.86f	4.91f	6.01f
ETc-100%XL.E.5 g per	4.74c	39.01c	5.67c	6.67c
ETc-100%XL.E.10 g	5.41a	44.81a	6.69a	7.83a
ETc-75%XL.E.0 g per l	3.59h	31.65h	4.60g	5.45h
ETc-75%XL.E.5 g per l	4.43d	36.37d	5.37d	6.42d
ETc-75%XL.E.10 g per	5.24b	43.62b	6.29b	7.30b
ETc-50%XL.E.0 g per l	3.32i	30.38i	4.23h	5.21i
ETc-50%XL.E.5 g per l	3.71g	32.50g	4.72g	5.67g
ETc-50%XL.E.10 g per	4.27e	35.42e	5.06e	6.14e
Second season (2023/2024)				
ETc-00%	4.72A	40.13A	5.88A	6.94A
ETc-75%	4.41B	38.28B	5.49B	6.63B
ETc-50%	3.79C	33.79C	4.66C	5.70C
L.E.0 g per l	3.68C	33.14C	4.54C	5.52C
L.E.5 g per l	4.26B	37.69B	5.40B	6.42B
L.E.10 g per l	4.97A	41.37A	6.09A	7.33A
ETc-100%XL.E.0 g per	4.09f	35.55f	4.95f	5.91f
ETc-100%XL.E.5 g per	4.66c	40.18c	5.95c	6.97c
ETc-100%XL.E.10 g	5.41a	44.66a	6.74a	7.96a
ETc-75%XL.E.0 g per l	3.61g	33.33h	4.54g	5.45h
ETc-75%XL.E.5 g per l	4.44d	38.73d	5.61d	6.71d
ETc-75%XL.E.10 g per	5.16b	42.76b	6.33b	7.71b
ETc-50%XL.E.0 g per l	3.35h	30.55i	4.14h	5.20i
ETc-50%XL.E.5 g per l	3.69g	34.15g	4.64g	5.58g
ETc-50%XL.E.10 g per	4.33e	36.68e	5.20e	6.30e

ETc = Evapotranspiration, L. E.= licorice extract
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Spike weight, spike length, number of grains per spike and grain yield ton per feddan

According to the results in Table (5), spike weight decreased dramatically from 3.10 and 3.09 g to 2.69 and 2.65 g in the first and second seasons, respectively, when the amount of irrigation water was reduced from 100% to 50% of ETc. Furthermore, the greatest results were obtained by spraying 10 g of licorice extract per liter, reaching 3.20 and 3.19 g, as opposed to 2.61 and 2.61 g for licorice extract 0 g per liter in the first and second seasons, respectively. Furthermore, the highest values were obtained by spraying 10 g of licorice extract per liter together with 100% ETc of water irrigation; these values reached 3.44 and 3.45 g in the first and second seasons, respectively. In the first and second seasons, respectively, licorice extract 10 g per l ppm with 75% ETc of water irrigation gained 3.28 and 3.32 g, surpassing the (control) licorice extract 0 g per l with 100% ETc of water irrigation (2.77 and 2.74 g). Additionally, spike length (cm) decreased to minimal values of 9.57 and 9.63 cm with 50% ETc, while in the first and second seasons, it was 11.38 and 11.34 cm with 100% ETc, respectively. Furthermore, the highest values were obtained by spraying 10 g of licorice extract per liter, reaching 11.80 and 11.78 cm, in contrast to licorice extract 0 g per liter, which recorded 9.36 and 9.30 cm in the first and second seasons, respectively. Additionally, the highest values were achieved in the first and second seasons, reaching 12.70 and 12.76 cm, respectively, when licorice extract (10 g per l) was sprayed in conjunction with 100% ETc water irrigation. The (control) licorice extract 0 g per l with 100% ETc of water irrigation recorded 10.19 and 10.00 cm in the first and second seasons, respectively, while licorice extract 10 g per l with 75% ETc of water irrigation acquired 12.25 and 12.22 cm. Data showed that in the first and second seasons, respectively, the number of grains per spike fell when the amount of irrigation water was reduced to 50% ETc (41.99 and 46.07) as opposed to 54.08% and 56.40% with 100% ETc. Furthermore, in comparison to licorice extract 0 g per l in the first and second seasons, respectively, spraying 10 g per l of licorice extract produced the greatest results, reaching 57.37 and 59.40. Additionally, the highest values-64.53 and 64.26 in the first and second seasons, respectively were obtained by spraying 10 g of licorice extract per liter in conjunction with 100% ETc water irrigation. The (control) licorice extract 0 g per l with 100% ETc of water irrigation recorded 43.37 and 49.20 in the first and second seasons, respectively, while licorice extract 10 g per l with 75% ETc of water irrigation gained 61.86 and 62.46. According to the same pattern, data showed that in the first and second seasons, respectively, grain yield ton per feddan (1.00 and 1.11 tons) was lower when irrigation water levels were reduced to 50% ETc than when 100% ETc was used. Furthermore, compared to licorice extract 0 g per l in the first and second seasons, respectively, spraying 10 g per l of licorice extract produced the highest results, reaching 2.02 and 2.20 tons. Furthermore, the highest values of 2.62 and 2.67 tons were obtained in the first and second seasons, respectively, when licorice extract (10 g per l) was sprayed in conjunction with 100% ETc water irrigation. The (control) licorice extract 0 g per l with 100% ETc of water irrigation recorded 1.17 and 1.35 tons in the first and second seasons, respectively, while licorice extract 10 g per l with 75% ETc of water irrigation gained 2.14 and 2.42 tons. Contrary to the yield results, the data showed that the trait water productivity was the largest in the first and second seasons, respectively, when irrigation water levels were reduced to 75% and 50% ETc which recorded 1.74 and 1.73 compared to using 100% ETc which recorded 1.59. the same trend was achieved in both seasons. Moreover, compared to licorice extract 0 g per l in the first and second seasons, respectively, spraying 10 g per l of licorice extract produced the highest results, reaching 2.34 and 2.50 of water productivity. In addition, the highest values of water productivity reached 2.47 and 2.71 in the first and second seasons, respectively, when licorice extract (10 g per l) was sprayed in conjunction with 75% ETc water irrigation.

Chemical composition, pigments and proline leaf content According to Table (6), 50% ETc had an impact on the chemical composition of leaves, reaching 0.737, 0.058, and 1.453 percent, while 100% ETc had an impact on N, P, and K, reaching 1.141, 0.076, and 1.856 percent, respectively. Furthermore, a 10 g per l application of licorice extract changed the chemical composition of the leaves, reaching 1.237, 0.079, and 1.943 percent N, P, and K, respectively. It is evident that the highest values for N, P, and K were obtained by spraying 10 g of licorice extract per liter with 100% ETc of irrigation water; these values were 1.466, 0.090, and 2.12%, respectively. Additionally, applying 10 g of licorice extract per liter with 75% ETc of irrigation water resulted in gains of 1.323, 0.083, and 2.032% for N, P, and K, respectively, which were statistically greater than or equal to (control). In contrast, applying 0 g of licorice extract per liter with 100% ETc of irrigation water produced gains of 0.833, 0.062, and 1.574 % for N, P, and K, respectively. The pigments in the leaves followed the same pattern. In both seasons, this was accurate. Conversely, proline leaf content rose as irrigation water level decreased from ETc 100% to ETc 50% of water irrigation. It's worth noting that proline content rose as irrigation water quantity decreased. At 50% ETc, the proline concentration rose to 12.60 µg/moles of fresh leaf, while at 100% ETc, it was 8.77 µg/moles of fresh leaf. Furthermore, when 10 g of licorice extract per liter was applied, the proline level decreased to 7.72 µg/moles of fresh leaf. As a result, the lowest proline concentration values (5.41 µ g/moles of fresh leaf) were obtained when licorice extract (10 g per l) was sprayed with 100% ETc of irrigation water. Additionally, 10.96 µg/moles of fresh leaf were obtained using 10 g of licorice extract per liter with 50% ETc of irrigation water. In both seasons, this was accurate.

Discussion

According to the data in Table (3 and 4), the plant height, number of plants per m2, numbers of tillers per plant, number of leaves per plant, leaf area m2, shoot dry weight and root dry weight were dropped dramatically, when the irrigation water volume was reduced from 100% to 50% of ETc for irrigation water quantities factor. As for the spray factor with licorice extract, these qualities obtained the highest values by spraying 10 g of licorice extract per liter, as opposed to licorice extract 0 g per liter. As for the interaction between the two factors, the highest results were obtained by spraying 10 g of licorice extract per liter with ETc 100% of water irrigation, but licorice extract 10 g per l with 75% ETc of water irrigation surpassing the control licorice extract 0 g per l with 100% ETc of water irrigation.

Table 5. Effect of irrigation water levels and spraying with different concentrations of licorice extract on spike weight, spike length, number of grains per spike and grain yield ton per feddan of wheat c.v. Sakha 93.

Parameters / Treatments	Spike weight (g)	Spike length (cm)	Number of grains per spike	Grain yield ton per feddan	Water productivity
First season (2022/2023)					
ETc-100%	3.10A	11.38A	54.08A	1.84A	1.59B
ETc-75%	2.96B	10.71B	51.05B	1.50B	1.74A
ETc-50%	2.69C	9.57C	41.99C	1.00C	1.73A
L.E.0 g per l	2.61C	9.36C	40.75C	0.90C	1.06C
L.E.5 g per l	2.93B	10.51B	49.00B	1.42B	1.66B
L.E.10 g per l	3.20A	11.80A	57.37A	2.02A	2.34A
ETc-100%XL.E.0 g per	2.77f	10.19f	43.37f	1.17f	1.01f
ETc-100%XL.E.5 g per	3.10c	11.26c	54.33c	1.72c	1.49d
ETc-100%XL.E.10 g	3.44a	12.70a	64.53a	2.62a	2.27b
ETc-75%XL.E.0 g per l	2.60h	9.09h	40.10h	0.84h	0.97f
ETc-75%XL.E.5 g per l	2.99d	10.80d	51.21d	1.54d	1.77c
ETc-75%XL.E.10 g per	3.28b	12.25b	61.86b	2.14b	2.47a
ETc-50%XL.E.0 g per l	2.48i	8.81i	38.78i	0.69i	1.20e
ETc-50%XL.E.5 g per l	2.70g	9.47g	41.47g	1.00g	1.73c
ETc-50%XL.E.10 g per	2.88e	10.43e	45.73e	1.32e	2.28b
Second season (2023/2024)					
ETc-00%	3.09A	11.34A	56.40A	1.97A	1.66B
ETc-75%	2.94B	10.69B	53.29B	1.67B	1.87A
ETc-50%	2.65C	9.63C	46.07C	1.11C	1.87A
L.E.0 g per l	2.61C	9.30C	44.49C	0.98C	1.09C
L.E.5 g per l	2.87B	10.58B	51.87B	1.57B	1.80B
L.E.10 g per l	3.19A	11.78A	59.40A	2.20A	2.50A
ETc-100%XL.E.0 g per l	2.74f	10.00f	49.20f	1.35f	1.14g
ETc-100%XL.E.5 g per l	3.08c	11.27c	55.75c	1.89c	1.59f
ETc-100%XL.E.10 g per l	3.45a	12.76a	64.26a	2.67a	2.24c
ETc-75%XL.E.0 g per l	2.58h	9.13h	44.26h	0.93h	1.04h
ETc-75%XL.E.5 g per l	2.93d	10.73d	53.14d	1.65d	1.85e
ETc-75%XL.E.10 g per l	3.32b	12.22b	62.46b	2.42b	2.71a
ETc-50%XL.E.0 g per l	2.51i	8.77i	40.01i	0.65i	1.09h
ETc-50%XL.E.5 g per l	2.62g	9.74g	46.73g	1.16g	1.95d
ETc-50%XL.E.10 g per l	2.81e	10.37e	51.47e	1.52e	2.56b

ETc = Evapotranspiration, L. E.= licorice extract

Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Table 6. Effect of irrigation water levels and spraying with different concentrations of licorice extract chemical composition, pigments and proline leaf contents of wheat c.v. Sakha 93.

Parameters / Treatments	N%	P%	K%	SPAD chll	Proline (µm/F.W.g)
First season (2022/2023)					
ETc-100%	1.141A	0.076A	1.856A	46.26A	8.77C
ETc-75%	1.029B	0.070B	1.735B	43.46B	9.97B
ETc-50%	0.737C	0.058C	1.453C	38.14C	12.60A
L.E.0 g per l	0.684C	0.056C	1.410C	36.88C	12.95A
L.E.5 g per l	0.985B	0.069B	1.692B	42.73B	10.66B
L.E.10 g per l	1.237A	0.079A	1.943A	48.24A	7.72C
ETc-100%XL.E.0 g per l	0.833f	0.062d	1.574f	39.78f	11.57c
ETc-100%XL.E.5 g per l	1.126c	0.077c	1.869c	45.86c	9.32e
ETc-100%XL.E.10 g per l	1.466a	0.090a	2.126a	53.13a	5.41g
ETc-75%XL.E.0 g per l	0.692h	0.055e	1.403h	36.89h	12.78b
ETc-75%XL.E.5 g per l	1.070d	0.074c	1.770d	43.88d	10.33d
ETc-75%XL.E.10 g per l	1.323b	0.083b	2.032b	49.62b	6.80f
ETc-50%XL.E.0 g per l	0.528i	0.052e	1.253i	33.98i	14.51a
ETc-50%XL.E.5 g per l	0.760g	0.058e	1.438g	38.44g	12.33b
ETc-50%XL.E.10 g per l	0.922e	0.065d	1.669e	41.99e	10.96d
Second season (2023/2024)					
ETc-00%	1.178A	0.076A	1.827A	45.23A	9.01C
ETc-75%	1.029B	0.071B	1.678B	42.35B	10.57B
ETc-50%	0.754C	0.059C	1.417C	36.40C	13.10A
L.E.0 g per l	0.682C	0.057C	1.379C	34.94C	13.64A
L.E.5 g per l	1.007B	0.068B	1.648B	41.11B	11.13B
L.E.10 g per l	1.271A	0.080A	1.896A	47.93A	7.91C
ETc-100%XL.E.0 g per l	0.847f	0.064f	1.524f	38.14f	11.97d
ETc-100%XL.E.5 g per l	1.213c	0.075c	1.828c	44.45c	9.76f
ETc-100%XL.E.10 g per l	1.473a	0.089a	2.128a	53.11a	5.30h
ETc-75%XL.E.0 g per l	0.658h	0.055h	1.364h	34.28h	14.12b
ETc-75%XL.E.5 g per l	1.081d	0.073d	1.704d	42.90d	10.62e
ETc-75%XL.E.10 g per l	1.347b	0.084b	1.965b	49.87b	6.97g
ETc-50%XL.E.0 g per l	0.541i	0.052i	1.248i	32.40i	14.85a
ETc-50%XL.E.5 g per l	0.727g	0.058g	1.411g	35.98g	13.00c
ETc-50%XL.E.10 g per l	0.993e	0.068e	1.593e	40.81e	11.46d

ETc = Evapotranspiration, L. E.= licorice extract
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

The results presented in Table (5) indicates that, the spike weight, spike length, number of grains per spike and grain yield ton per feddan were experienced a significant decline when the irrigation water volume was decreased from 100% to 50% of ETc, on contrary the water productivity was the largest, when irrigation water levels were reduced to 75% and 50% ETc for irrigation water amounts factor. Regarding the spray factor, spraying 10 g of licorice extract per liter had the best results in terms of the spray factor. In addition, for the interaction between the two factors, spraying 10 g of licorice extract per liter with ETc 100% of water irrigation had the best results in terms of the spray factor; however, licorice extract 10 g per liter with 75% ETc of water irrigation outperformed the control licorice extract 0 g per liter with 100% ETc of water irrigation. Moreover, the water productivity get the highest values with the interaction between licorice extract 10 g per liter with 75% ETc of water irrigation.

According to the results shown in Table (6), when the irrigation water volume was reduced from 100% to 50% of ETc, N, P, K and chlorophyll showed a significant decline; conversely, when irrigation water levels were decreased to 75% and 50% ETc for irrigation water amounts factor, proline was the largest. In addition, the best results in terms of spray factor were obtained by spraying 10 g of licorice extract per liter, but proline achieved a different trend, as the greatest results were with spraying 0 g of licorice extract per liter. In addition, for the interaction between the two factors, spraying 10 g of licorice extract per liter with ETc 100% of water irrigation had the best results in terms of the spray factor; however, licorice extract 10 g per liter with 75% ETc of water irrigation outperformed the control licorice extract 0 g per liter with 100% ETc of water irrigation. Moreover, the proline gets the highest values with the interaction between licorice extract 0 g per liter with 50% ETc of water irrigation.

In this respect, our results are in agreement with those obtained by other researchers Farouk *et al.,* 2011, Sheikha and Al-Malki, 2011; Malekpoor *et al.,* 2016; Mustafa *et al.,* 2017; Astaneh *et al.,* 2018; Rouphael and Colla, 2018; Taha *et al.,* 2019; Rouphael and Colla, 2020; El-Gohary *et al.,* 2021 and Younes *et al.,* 2021.

When compared to the control, licorice root extract often showed the highest significant results. Accordingly, the licorice extract has roughly 100 different chemicals, some of which are concentrated in high concentrations. The most important of these are phenolic, flavonoid, and triterpene saponins, including glycyrrhizin (Shibata, 2000; Shabani *et al.,* 2009 and El-Gohary *et al.,* 2021). Protein, amino acid (asparagine), monosaccharide, tannins, lignins, starch, phytosterols, choline, various vitamins (particularly B1, B2, B3, B6, C, and E), biotin, folic acid, pantothenic acid, numerous minerals (Al, Ca, Fe, Mg, Co, Zn, P, Na, Si, K, and Sn), and bitter principles are also present in licorice extract (Arystanova *et al.,* 2001 and El-Gohary *et al.,* 2021). Furthermore, Sabry *et al.* (2009) discovered that licorice root extract has a variety of minerals, amino acids, vitamins, carbohydrates, and nitrogen, as well as certain chemicals that function similarly to growth promoters. Mevalonic acid, which is used in the manufacture of gibberellin, is also present.

Conclusion

Finally, the results clearly confirm through studying the quantities of water added to the feddan during the season that, the best results were always in favor of the highest irrigation levels ever, 100% of ETc, except for the water productivity trait, which was in favor of the lowest irrigation quantities, 50% and 75% of ETc. spraying application with licorice extract 10 grams per liter, the values of wheat growth indicators and crop quantity increased in addition to water productivity. By studying the interaction between the two factors (irrigation water quantities and spraying concentrations with licorice extract), it was found that the best results were always in favor of the interaction between 100% of evapotranspiration and spraying with 10 grams of licorice extract, except for the water productivity trait, where the best results were with irrigation with 75% of ETc and spraying application with 10 grams of licorice extract. Therefore, we recommend irrigation with 75% of evapotranspiration and spraying with 10 grams of licorice extract, as it achieves economic productivity while saving 25% of irrigation water, this is very important and necessary because of the scarcity of water nowadays.

Consent for publication

All authors declare their consent for publication.

Author contribution

The manuscript was edited and revised by all authors.

Conflicts of Interest

The author declares no conflict of interest.

References

Aldesuquy, H. S., Baka, Z. A., El-Shehaby, O. A., Ghanem, H.E. (2012). Varietal differences in growth vigor, water relations, protein and nucleic acids content of two wheat varieties grown under seawater stress. *Journal of Stress Physiology & Biochemistry*, 8: 24-47.

Anonymous (2000). Approved Methods of American Association of Cereal Chemists. *The American Association of Cereal Chemists. Inc., St. Paul. MN.*

AOAC. (1985). Official Methods of Analysis of the Association of Official Agric. *Chemists. 13th Ed. Benjamin Franklin Station, Washington*, D. C., B. O. Box450, USA.

Arystanova, T., Irismetov, M., Sophekova, A. (2001). Chromatographic determination of glycyrrhizinic acid in Glycyrrhiza glabra preparation. *Chemistry of Natural Compounds*, 37:89–91.

Astaneh, R. K., Bolandnazar, S., Nahandi, F.Z., Oustan, S. (2018). The effects of selenium on some physiological traits and K, Na concentration of garlic (*Allium sativum* L.) under NaCl stress. *Information Processing in Agriculture*, 5: 156-161.

Bates, L.S., Walren, R.R., Tears, I. D. (1973). Rapid determination of proline for water stress studies. Plant and Soil, 39:205-207.

Brown, J.D., Lilliland, O. (1964). Rapid determination of potassium and sodium in plant material and soil extracts by flame-photometry. Proc. *Amer. Soc. Hort. Sci*., 48: 341-346.

Duncan, D.B. (1955). Multiple range and multiple "F" test. Biometrics, 11: 1- 42.

El-Gohary, A.E., Wahba, Hend E., Hendawy, S.F., Hussein, M.S. (2021). Effect of licorice root and cabbage leaf extracts as a natural fertilizer on growth and productivity of *Cynara cardunculus* L. *Egyptian Pharmaceutical Journal*, 20:17–22.

Farouk, S., Mosa, A.A., Taha, A.A., Ibrahim, Heba M., El-Gahmery, A.M. (2011). Protective effect of humic acid and chitosan on radish (*Raphanus sativus* L. var. sativus) plants subjected to cadmium stress. *J. Stress Physiol. Biochem*. 7: 99-116.

Ghazi, Dina A. (2017). Impact of Drought Stress on Maize (*Zea mays*) Plant in Presence or Absence of Salicylic

Acid Spraying. *Journal Soil Science. and Agricultural Engineering, Mansoura University*, 8 (6): 223– 229.

Hassan, W.Z., El-Farghal, W.M., Khalil, F.A.F., EL-Etr, Wafaa M., (2017). Effect of some soil amendments and irrigation treatments on wheat crop productivity in middle Egypt. *Journal Soil Science and Agriculture Engineering, Mansoura Univ*., 8 (10): 553 – 563 .

Jensen M.E. (1983). Design and operation of farm irrigation systems. *American Society Agriculture Engineers, Michigan*.

Kahlown, M.A. Asraf, M., Roof, A., Haq, Z.U. (2003). Determination of crop water requ,irement of major crops under shallow water-table conditions. *Pakistan Council of Research in Water Resources*, Islamabad.

Mahmoud, T. A., Youssef, Ebtessam A., Abo Eid, Manal M. A. (2024). Surface and Sub-Surface Irrigation Techniques Effects on Water Use Efficiency of Valencia Orange Trees. *The Future Journal of Horticulture*, 1 (1): 26 – 37.

Malekpoor, Fatemeh, Pirbalouti, A.G., Salimi, A. (2016). Effect of foliar application of chitosan on morphological and physiological characteristics of basil under reduced irrigation. *Res. on Crops* 17 (2): 354-359.

Mustafa, M.M.I., Wally, M.A., Refaie, K.M., Abd-Elwahed, A.H.M. (2017). Effect of different irrigation levels and salicylic acid applications on growth, yield and quality of garlic (*Allium sativum L*.). *Journal of Biological Chemistry and Environmental Sciences*, 12: 301-323.

Naguib, M.L. (1969). Colorimetric determination of nitrogen components of plant tissues. *Bull. Fac. Agriculture Science*, Cairo University, 43:1.

Ndulue, E., Ramanathan, S. R. (2021). Performance of the FAO Penman–Monteith equation under limiting conditions and fourteen reference evapotranspiration models in southern Manitoba. *Theoretical and Applied Climatology*, 143:1285–1298.

Rouphael, Y., Colla, G. (2018). Synergistic biostimulatory action: Designing the next generation of plant biostimulants for sustainable agriculture. *Frontiers in Plant Science*, 9, 1655 .

Rouphael, Y., Colla, G. (2020). Biostimulants in agriculture. *Frontiers in Plant Science*, 11, 40.

Youssef, Ebtessam A. (2023). Effect potassium silicate foliar application and water stress by using different amounts of irrigation water supply on potato plants (*Solanum tuberosum* L.). *Egyptian Journal of Chemistry*, 66(11):317-326.

Youssef, Ebtessam A., Abdelaal H.K. (2023). Influence of water stress and ortho salicylic acid on sweet potato plants (*Ipomoea batatas* L.) under environment and climate changes. *Egyptian Journal of Chemistry*, 66(SI):99-106.

Youssef, Ebtessam A., Mahmoud, T.A., Abo Eid, Manal A. M. (2023). Effect of some irrigation systems on water stress levels of Washington navel orange trees. *Bulletin of the National Research Centre*, 47(163):1-12.

Sabry G. H., Mervat, S., Abd EL-Wahba, M.A. (2009). Influence of effective micro-organism, seaweed extract and amino acids application on growth, yield and bunch quality of Red Globe grapevines, *Journal of Agricultural Science - Mansoura University*, 34:5901–5921.

Shabani, L., Ehsanpour, A.A., Asghari, G., Emami, J. (2009). Glycyrrhizin production by in vitro cultured Glycyrrhiza glabra elicited by Methyl Jasmonate and salicylic acid. *Russian Journal of Plant Physiology*, 56:621–626.

Sheikha, S.A., Al-Malki, F.M. (2011). Growth and chlorophyll responses of bean plants to chitosan applications. *Eur. J. Sci. Res*. 50: 124-34.

Shibata, S. A. (2000). Drug over the millennia: pharmacognosy, chemistry, and pharmacology of licorice, Yakugaku Zasshi. *Journal of the Pharmaceutical Society of Japa*n, 120:849–862.

Snedecor, G.W., Corchran, W.G. (1980). Statistical Methods. Oxford and J. B. H. Publishing Co. 7th Ed. *lowa State University, Press, Am., Lowa, USA*.

Soroori, Sophia, Danaee, Elham. (2023). Effects of foliar application of citric acid on morphological and phytochemical traits of *calendula officinalis* L. under drought stress conditions. *International Journal of Horticultural Science and Technology*, 10(3): 361-374.

Taha, Noura M., Abd-Elrahman, Shaimaa H., Hashem, F.A. (2019). Improving yield and quality of garlic (*Allium sativum* L.) under water stress conditions. *Middle East Journal of Agriculture*, 8(1): 330-346.

Younes, N. A., Rahman, M.M., Wardany, A. A., Dawood, Mona F.A., Mostofa, M.G., Keya, S.S., Abdel Latef, A.A., Tran, L. P. (2021). Antioxidants and bioactive compounds in licorice root extract potentially contribute to improving growth, bulb quality and yield of onion (*Allium cepa*). *Molecules*, 26: (2633)1-16. https://www.mdpi.com/1420-3049/26/9/2633.

Youssef, Ebtessam A., Hozayen, A.M.A. (2019a). The effect of drought stress condition combined with kaolin spraying application on growth and yield parameters of maize (*Zea mays*). *Plant Archives*, 19(1): 674-683.

Youssef, Ebtessam A., Hozayen, A.M.A. (2019b). Study the effect of chitosan on some growth and yield parameters in wheat grown under water stress condition. *Plant Archives*, 19(1): 684-694.

Zagier, S., Fadhal, F. A., Alisawi, O. (2021). Control Fig Mosaic Virus By plant extracts with salicylic acid. Earth and Environmental Science, 970: 1-7.

Zareian, A. Abad, H.H.S., Hamidi, A. (2014). Yield, yield components and some physiological traits of three wheat (Triticum aestivum L.) cultivars under drought stress and potassium foliar application treatments. International Journal of Biosciences. 4:168-175 .

Zeng, D., Luo, X. (2012). Physiological effects of chitosan coating on wheat growth and activities of protective enzyme with drought tolerance. Open Journal of Soil Science, 2: 282-288, (http://dx.doi.org/10.4236/ojss.2012.23034).