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Effect of different gelatin concentrations on growth and yield of onion plants (*Allium cepa* L.) under water stress

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THIS EXPERIMENTAL investigation examined the effects of different gelatin concentrations on growth and yield of onion plants (*Allium cepa* L.) cv. Giza red seedlings under water stress influence of over the course of two consecutive seasons (2022/2023–2023/2024). Thus, the purpose of this experimental study was to improve the growth process and yield parameters of onion plants in sandy loam soil conditions in the Belbeis region of El Sharkia Governorate, Egypt, by using different concentrations of gelatin (1.0, 1.5, and 2.0%) as well as the control under different levels of water supply (100, 75, and 50% of ETc, i.e., evapotranspiration). Four times was the gelatin foliar spraying procedure applied: once on December 7th, and then every 15 days using a backpack sprayer with a 20-liters capacity till the drop point. Data from this experimental study's two experimental seasons made it clear that, when compared to the control, every treatment greatly accelerated the growth process of the plants and yield characteristics. However, spraying with foliar spraying with gelatin (2%) under water supply of 100 or 75% of ETc achieved economic vegetative growth and yield.

Keywords: Onion Plants, Irrigation, Evapotranspiration, Water Stress, Gelatin.

Introduction

Onion (*Allium cepa* L.) is considered one of the most important vegetable crops in Egypt. The total planted area in year 2022 was 230615 feddans (53223 in new land and 177329 in old land), which produced about 4348259 tones and by average 14.91 ton/fed (M.A.L.R., 2022).

Drought, as an abiotic stress increased mainly in arid and semi-arid regions like Egypt, cause direct decline in crop growth may be across either decrease in cell elongation, cell turgor or cell volume due to covering of xylem and phloem vessels thus obstruction any translocations (Youssef and Taha, 2016; Taha *et al.,* 2019; Youssef, 2023; Youssef and Abdelaal, 2023 and Youssef, 2025 a&b).

Therefore, it has become necessary to search for means that enable the plant to coexist with the low limit conditions of the water quantities needed to produce an economic crop. One of these means is the use of anti-transpiration to reduce the severity of water loss through transpiration and maintain a relative fullness suitable for the growth and erection of the leaves and the performance of various metabolic processes. Anti-transpiration can be described as substances that reduce the plant's loss of water by different means, either by (partial) closing of the stomata or reflecting the radiation falling on the plant and thus reducing its temperature and thus reducing water loss or working to change the internal hormonal balance in favor of increasing ABA (abscisic acid) or ethylene or NO (nitric oxide), which changes the osmotic pressure of the guard cells to eventually close the stomata (Prakash and Ramachandran, 2000 and Abraheem, 2017). There is no doubt that the use of organic materials in food production has become a major concern for researchers looking for an environment free of pollutants. This prompted the researcher to search for alternatives to polymers and chemicals used in the manufacture of anti-transpiration. The choice fell on gelatin, whether pure or raw, after reviewing its physical properties and conducting observations using cut leaves. Gelatin is a peptide that forms collagen, which forms connective tissue in the animal kingdom. It is composed of 1-2% mineral salts and 84-90% protein (Laura *et al*., 2001 and Abraheem, 2017).

Gelatin is a collection of peptides and proteins produced by partial hydrolysis of collagen extracted from the skin, bones, and connective tissues of animals. During hydrolysis, some of the bonds between and within component proteins are broken. Its chemical composition is, in many aspects, closely similar to that of its parent collagen. Gelatin

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is nearly tasteless and odorless with a colorless or slightly yellow appearance. Gelatin consists of 98–99% protein, it contains 19 amino acids, predominantly glycine (Gly) 26–34%, proline (Pro) 10–18%, and hydroxyproline (Hyp) 7–15%, which together represent around 50% of the total amino acid content. Glycine is responsible for close packing of the chains. Presence of proline restricts the conformation. This is important for gelation properties of gelatin. Other amino acids that contribute highly include: alanine (Ala) 8–11%; arginine (Arg) 8–9%; aspartic acid (Asp) 6–7%; and glutamic acid (Glu) 10–12%.

Therefore, this study aimed to enhanced onion plants growth parameters and yield parameters by using different concentrations of gelatin under different levels of water irrigation (100, 75 and 50% of ETc i.e., evapotranspiration) in sandy loam soil conditions.

Material and Methods

Two successive seasons were conducted during 2022/2023 and 2023/2024 to test the action foliar application of different gelatin concentrations on growth and yield of onion plants (Allium cepa L.) cv. Giza red seedlings under water stress. Therefore, this study aimed to enhanced onion plants growth parameters and yield parameters by using different gelatin concentrations (0.0, 1.0, 1.5 and 2.0%) under different levels of water irrigation (100, 75 and 50% of ETc i.e., evapotranspiration) in sandy loam soil conditions at Belbeis region – El Sharkia Governorate, Egypt.

In addition, the tested irrigation levels based on different rates of irrigation water i. e., 1718, 1222, and 859 m3/feddan/ season for the first season and 1819, 1295, and 910 m3/feddan/season for the second season. These values resulted from the CROPWAT, 2012 version 8.0.1.1 computer program by using meteorological data of the region (year 2022/2023 & 2023/2024) and characteristics of the experimental plants. Moreover, this experiment included 12 treatments, which were the interactions between three rates of evapotranspiration (100, 75 and 50% of ETc i.e., evapotranspiration) and three different gelatin concentrations (1.0, 1.5 and 2.0%) as well as the control treatment. The experimental layout was split plot system in a complete randomized block design with five replicates. The main plot (first factor) comprised in three irrigation levels (100, 75 and 50% of ETc) and the sub-plot (second factor) was different gelatin concentrations (0.0, 1.0, 1.5 and 2.0%). Also, the experimental unit area was 12.6 m2. It contained three dripper lines (GR 16mm, 25 cm between the dripper) with 7 m length and 60 cm in width. Healthy seedlings with uniform size of onion plants (Allium cepa L.) were selected from a commercial nursery and transplanted on the 15th of November in both seasons. Then, they were transplanted on both line dripper sides at distance of 25 cm apart. After twenty days from planting, the plants were subject to three levels of water supply [50, 75 and 100 % of evapotranspiration (ETc)]. These treatments reflecting conditions achieved as severe water stress, moderate and optimum level of water supply, respectively. The plants in every treatment were irrigated every 2 days, as it is known that irrigation should be prevented from onion plants during the last 3 weeks of their life to obtain a good onion crop. At last, all the onion plants of this study received the same horticultural practices except experimental treatments.

The foliar spraying process with gelatin was applied four times the first time was at the 7th of December and every 15 days with the addition of a wetting agent (Triton B) to the spraying solution at a concentration of 0.1% by using a backpack sprayer, with the capacity of 20 liters until the drip point.

Based on various rates of irrigation water, the tested irrigation levels, i.e., 1718, 1222, and 859 m3/feddan/ season for the first season and 1819, 1295, and 910 m3/feddan/season for the second season as shown in Tables 1 and 2. These values resulted from the CROPWAT (2012) version 8.0.1.1 computer program using the region meteorological data (2022/2023-2023/2024 seasons). Furthermore, the reference evapotranspiration (ETo) is multiplied by the particular crop coefficient (Kc) to determine the estimated crop water need (ETc), meaning that ETc = ETo × Kc.

The tested treatments were evaluated throw the following parameters:

vegetative growth characters Onions plants were harvested when they reached horticultural mature at the 15th of May (about 180 days after transplanting) and the samples were taken randomly in both seasons at the first of April to record the vegetative growth and yield parameters like plant height (cm), fresh weight (g) and dry weight (g) as well as leaves fresh weight (g) and dry weight (g).

Yield and yield parameters At harvest the bulb diameter (cm), bulb height (cm), bulb fresh weight (g) and bulb dry weight (g) as well as the yield (ton/fed.) were determined and recorded.

Water use efficacy Water use efficiency (WUE) values were calculated according to the following equation (Jensen, 1983). WUE =(Yield (kg per feddan))/(Seasonal ET (m3 per feddan))

Water use returns Water unit returns (WUR) values were calculated according to the following equation

WUR = WUE x price of 1kg onion (11 EGP according to 2024 price).

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

Year	2022		2023					
Month	November	December	January	February	March	April	May	Total
No. of days/month	16	31	31	28	31	21	-	
Crop coefficient	0.75	0.80	0.89	1.01	1.01	1.00	-	
ETo-100%	2.49	1.89	1.93	2.50	3.42	4.82	-	
ETc-100%	1.87	1.51	1.72	2.53	3.45	4.82	-	
W.R (m^3/fed./Day)	7.84	6.35	7.21	10.61	14.51	20.24	-	
W.R (m^3/ fed. Month)	125.50	196.86	223.64	296.94	449.74	425.12	-	1718
ETo-75%	1.40	1.13	1.29	1.89	2.59	3.62	-	
ETc-75%	1.05	0.91	1.15	1.91	2.62	3.62	-	
W.R (m^3/fed./Day)	4.41	3.81	4.82	8.03	10.99	15.18	-	
W.R (m^3/ fed. Month)	70.59	118.12	149.28	224.93	340.68	318.84	-	1222
ETo-50%	1.25	0.95	0.97	1.25	1.71	2.41	-	
ETc-50%	0.93	0.76	0.86	1.26	1.73	2.41	-	
W.R (m^3/fed./Day)	3.92	3.18	3.61	5.30	7.25	10.12	-	
W.R (m^3/ fed. Month)	62.75	98.43	111.82	148.47	224.87	212.56	-	859

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

Year	2023		2024					
Month	November	December	January	February	March	April	May	Total
No. of	16	31	31	28	31	21	-	
Crop	0.75	0.80	0.89	1.01	1.01	1.00	-	
ETo-100%	2.59	2.03	2.03	2.58	3.82	4.91	-	
ETc-100%	1.94	1.62	1.81	2.61	3.86	4.91	-	
W.R	8.16	6.82	7.59	10.94	16.20	20.62	-	
W.R (m^3/ fed.	130.54	211.44	235.23	306.44	502.34	433.06	-	1819
ETo-75%	1.46	1.22	1.36	1.95	2.89	3.68	-	
ETc-75%	1.09	0.97	1.21	1.97	2.92	3.68	-	
W.R	4.59	4.09	5.07	8.29	12.27	15.47	-	
W.R (m^3/ fed.	73.43	126.87	157.02	232.13	380.52	324.80	-	1295
ETo-50%	1.30	1.02	1.02	1.29	1.91	2.46	-	
ETc-50%	0.97	0.81	0.90	1.30	1.93	2.46	-	
W.R	4.08	3.41	3.79	5.47	8.10	10.31	-	
W.R (m^3/ fed.	65.27	105.72	117.62	153.22	251.17	216.53	-	910

Leaf total chlorophyll The photosynthetic pigments contents (mg/ 100 g of fresh weight) were determined in fresh samples of leaf (Von-Wettestein, 1957).

Statistical analysis The experimental design was split plot system in a complete randomized block design with five replicates. The evapotranspiration rates were randomly arranged in the main plots while gelatin concentrations were randomly distributed in the sub plots. This experiment included 12 treatments, which were the interactions between three rates of evapotranspiration (50, 75 and 100 % of ETc) and four different gelatin concentrations (0.0, 1.0, 1.5 and 2.0%). The data obtained were statistically analyzed using the analysis of variance method (Snedecor and Cochran, 1980). The differences between means were differentiated by using Duncan's range test (Duncan, 1955).

Results

Table (3) illustrates the various effects of foliar spraying with different concentrations of gelatin (0, 1, 1.5, 2%) on the characteristics of onion leaves under water stress by irrigation with varying amounts of water calculated on the basis of the reference evapotranspiration (100, 75, 50%) or the interaction between them.

Concerning the water stress treatments through the various irrigation treatments, they had an adverse effect on the characteristics listed in the table. The measurements of these characteristics decreased as the water stress increased, starting at 100% of the reference evapotranspiration and continuing through 75% until reaching 50%, where the plant height recorded a value of 54.74 cm with 100% of evapotranspiration compared to 42.62 cm with 50% of evapotranspiration in the first season, while in the second season this characteristic achieved a value of 54.47 cm with 100% of evapotranspiration compared to 39.06 cm with 50% of evapotranspiration.

Based on an analysis of the data in the table, we can conclude that applying gelatin topically to onion plants has a positive impact on the characteristics listed therein, including plant height (cm), fresh and dry leaf weight (g), and total water content (%). On the other hand, the characteristic of leaves' dry matter percentage (%) was negatively impacted. We note that, when gelatin increasing in concentration of the spraying solution the positive effect on these characteristics is increase. The foliar spray treatment with gelatin at a rate of 2% achieved the highest results for plant height (cm), which reached 53.17 cm in the first season of the experiment and in the second season it reached 52.64 cm.

As for, the interaction between water stress treatments and gelatin foliar spraying, the best treatment that ranked first was gelatin 2% with irrigation at a rate of 100% of evapotranspiration with a value of 62.16 cm and 62.32 cm compared to the treatment of 50% of evapotranspiration without spraying, which decreased to 40.86 cm and 37.55 cm during the first and second seasons, respectively.

As for the effect of water stress treatments, the trait recorded a percentage of 14.45 with 100% evapotranspiration compared to 18.18 with 50% evapotranspiration in the first season, while in the second season this trait achieved a percentage of 12.83% with 100% evapotranspiration compared to 16.53% with 50% evapotranspiration.

As for, the effect of gelatin and different irrigation treatments on the rest of the previously mentioned traits, it took the same trend that was achieved with the plant height trait during the two seasons of the study, except for the trait of the percentage of dry matter in the leaves, which took a different trend, as the higher the concentrations of the spray solution of gelatin, the lower the percentage of dry matter, reaching 14.87, 13.20% with the foliar spraying treatment with gelatin at a rate of 2% during the first and second seasons, respectively.

Onion bulbs and yield under water stress are shown in Table (4) along with the different effects of foliar spraying with different concentrations of gelatin (0, 1, 1.5, 2%) and irrigation with different amounts of water calculated based on the reference evapotranspiration (100, 75, 50%) or the interaction between them.

The features shown in the table were negatively impacted by the different irrigation levels used to alleviate water stress. From 100% of the reference evapotranspiration to 75% of it, these characteristics' readings fell as the water stress grew, eventually reaching 50%., where the yield (ton/fed.) recorded a value of 18.56 (ton/fed.) with 100% of evapotranspiration compared to 12.70 (ton/fed.) with 50% of evapotranspiration in the first season, while in the second season this characteristic achieved a value of 20.75 (ton/fed.) with 100% of evapotranspiration compared to 11.48 (ton/fed.) with 50% of evapotranspiration.

Applying gelatin topically to onion plants positively affects the parameters stated in the table, such as bulb diameter (cm), bulb height (cm), fresh and dried bulb weight (g), and yield (ton/fed.). This conclusion is based on an examination of the data in the table. Conversely, there was a detrimental influence on the dry matter percentage (%) of the bulbs. We note that, these features improve as the concentration of gelatin in the spraying fluid increases. The greatest results for yield (ton/fed.) were obtained with a 2% gelatin foliar spray treatment; in the first season of the trial, yield (ton/fed.) reached 17.93 (ton/fed.), and in the second season, it reached 18.84 (ton/fed.).

As for, the interaction between foliar spraying with gelatin and water stress treatments, the best treatment that ranked first was gelatin 2% with irrigation at a rate of 100% of evapotranspiration with a value of 22.75 (ton/fed.) and 24.76 (ton/fed.) compared to the treatment of 50% of evapotranspiration without spraying, which decreased to 11.34 (ton/fed.) and 10.59 (ton/fed.) during the first and second seasons, respectively.

As for the effect of water stress treatments, the trait recorded a percentage of 15.56 with 100% evapotranspiration compared to 17.06 with 50% evapotranspiration in the first season, while in the second season this trait achieved a percentage of 13.74% with 100% evapotranspiration compared to 20.30% with 50% evapotranspiration.

As for, the effect of gelatin and different irrigation treatments on the rest of the previously mentioned traits, it took the same trend that was achieved with the yield trait during the two seasons of the study, except for the trait of the percentage of dry matter in the bulb, which took a different trend, as the higher the concentrations of the spray solution of gelatin, the lower the percentage of dry matter, reaching 15.56, 15.17% with the foliar spraying treatment with gelatin at a rate of 2% during the first and second seasons, respectively.

Table (5) illustrates the various effects of foliar spraying with different concentrations of gelatin (0, 1, 1.5, 2%) on the characteristics of leaf pigments and carotenoids under water stress by irrigation with varying amounts of water calculated on the basis of the reference evapotranspiration (100, 75, 50%) or the interaction between them.

Table 3. Effect of water stress and foliar application of gelatin concentrations on leaves parameters of onion (2022/2023-2023/2024 seasons).

Treatments	Plant height (cm)	Leaves fresh wight (g)	Leaves dry wight (g)	Leaves dry matter (%)	Leaves water content (%)
			First season		
ETc 100% (control)	54.74A	39.54A	5.54A	14.45C	85.55A
ETc 75%	50.39B	27.06B	4.42B	16.50B	83.51B
ETc 50%	42.62C	14.40C	2.61C	18.18A	81.82C
Gelatin 0% (control)	44.36D	19.78D	3.49C	17.89A	82.11D
Gelatin 1%	48.82C	24.13C	3.99B	16.95B	83.05C
Gelatin 1.5%	50.64B	29.90B	4.53A	15.79C	84.21B
Gelatin 2%	53.17A	34.20A	4.73A	14.87D	85.13A
ETc 100 % X Gelatin 0% (control)	47.64f	29.82f	5.18a	17.37c	82.63d
ETc 100 % X Gelatin 1%	53.57c	35.05c	5.43a	15.48d	84.52c
ETc 100 % X Gelatin 1.5%	55.60b	41.89b	5.68a	13.57e	86.43b
ETc 100 % % X Gelatin 2%	62.16a	51.42a	5.85a	11.38f	88.62a
ETc 75 % X Gelatin 0%	44.60g	19.85h	3.49d	17.60c	82.40d
ETc 75 % X Gelatin 1%	50.98e	24.04g	4.11c	17.09c	82.91d
ETc 75 % X Gelatin 1.5%	52.53d	30.93e	4.84b	15.66d	84.34c
ETc 75 % X Gelatin 2%	53.44 c	33.41d	5.22a	15.63d	84.37c
ETc 50 % X Gelatin 0%	40.86j	9.66k	1.81f	18.69a	81.31e
ETc 50 % X Gelatin 1%	41.92i	13.29j	2.43e	18.28b	81.72e
ETc 50 % X Gelatin 1.5%	43.78h	16.87i	3.06d	18.13b	81.87e
ETc 50 % X Gelatin 2%	43.93h	17.77i	3.13d	17.61c	82.39d
			Second season		
ETc 100% (control)	54.47A	31.83A	3.99A	12.83C	87.17A
ETc 75%	50.64B	22.12B	3.13B	14.38B	85.63B
ETc 50%	39.06C	13.64C	2.24C	16.53A	83.47C
Gelatin 0% (control)	41.04D	16.98D	2.73C	16.41A	83.59D
Gelatin 1%	48.22C	21.63C	3.01B	14.42B	85.58B
Gelatin 1.5%	50.32B	23.29B	3.22B	14.28B	85.72B
Gelatin 2%	52.64A	28.22A	3.51A	13.20D	86.80A
ETc 100 % X Gelatin 0% (control)	43.05f	23.33e	3.60b	15.42c	84.58d
ETc 100 % X Gelatin 1%	55.41c	30.88c	3.88b	12.56e	87.44b
ETc 100 % X Gelatin 1.5%	57.09b	33.13b	4.16a	12.55e	87.45b
ETc 100 % % X Gelatin 2%	62.32a	39.96a	4.31a	10.79f	89.21a
ETc 75 % X Gelatin 0%	42.52g	17.59g	2.81c	15.96b	84.04d
ETc 75 % X Gelatin 1%	50.57e	20.33f	2.95c	14.53d	85.47c
ETc 75 % X Gelatin 1.5%	54.35d	21.48f	3.05c	14.21d	85.79c
ETc 75 % X Gelatin 2%	55.11c	29.09d	3.72b	12.80e	87.20b
ETc 50 % X Gelatin 0%	37.55k	10.01j	1.79f	17.84a	82.16d
ETc 50 % X Gelatin 1%	38.68j	13.68i	2.21e	16.17b	83.83d
ETc 50 % X Gelatin 1.5%	39.53i	15.27h	2.46d	16.09b	83.91d
ETc 50 % X Gelatin 2%	40.49h	15.61h	2.50d	16.01b	83.99d

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

Concerning the water stress treatments through the various irrigation treatments, they had an adverse effect on the characteristics listed in the table. The measurements of these characteristics decreased as the water stress increased, starting at 100% of the reference evapotranspiration and continuing through 75% until reaching 50%, where the chlorophyll a recorded a value of 0.697 (mg/ 100g of F. W.) with 100% of evapotranspiration compared to 0.733 (mg/ 100g of F. W.) with 50%

of evapotranspiration in the first season, while in the second season this characteristic achieved a value of 0.645 (mg/ 100g of F. W.) with 100% of evapotranspiration compared to 0.390 (mg/ 100g of F. W.) with 50% of evapotranspiration.

Table 4. Effect of water stress and foliar application of gelatin concentrations on bulb parameters and yield of onion plants (2022/2023-2023/2024 seasons).

Treatments	Bulb diameter (cm)	Bulb height (cm)	Bulb fresh wight (g)	Bulb dry wight (g)	Bulb dry matter (%)	yield (ton/fed.)
			First season			
ETc 100% (control)	5.41A	7.16A	110.44A	16.86A	15.56B	18.56A
ETc 75%	4.78B	6.83B	99.44B	15.76B	15.85B	16.71B
ETc 50%	3.87C	5.92C	75.57C	12.89C	17.06A	12.70C
Gelatin 0% (control)	5.41A	7.16A	110.44A	16.86A	15.56B	18.56A
Gelatin 1%	4.05C	6.12C	80.56D	13.80D	17.19A	13.53D
Gelatin 1.5%	4.71B	6.63B	93.67C	14.91C	16.00B	15.74C
Gelatin 2%	4.80B	6.75B	99.63B	15.75B	15.89C	16.74B
ETc 100 % X Gelatin 0%	5.20A	7.04A	106.75A	16.22A	15.56D	17.93A
ETc 100 % X Gelatin 1%	4.02c	6.36c	83.55f	15.34d	18.36a	14.04f
ETc 100 % X Gelatin 1.5%	5.47b	7.14b	107.22c	16.57c	15.46d	18.02c
ETc 100 % % X Gelatin 2%	5.67b	7.04b	115.60b	17.51b	15.15d	19.42b
ETc 75 % X Gelatin 0%	6.49a	8.09a	135.39a	18.00a	13.30e	22.75a
ETc 75 % X Gelatin 1%	4.33c	6.36c	90.63e	14.31e	15.78d	15.23e
ETc 75 % X Gelatin 1.5%	4.83c	6.84b	100.01d	15.87d	15.87d	16.80d
ETc 75 % X Gelatin 2%	4.81c	7.17b	103.15d	16.41c	15.91d	17.33d
ETc 50 % X Gelatin 0%	5.17b	6.96b	103.98d	16.45c	15.82d	17.47d
ETc 50 % X Gelatin 1%	3.81d	5.63d	67.48i	11.77h	17.43b	11.34i
ETc 50 % X Gelatin 1.5%	3.82d	5.91d	73.77h	12.29g	16.66c	12.40h
ETc 50 % X Gelatin 2%	3.91d	6.04d	80.14g	13.32f	16.62c	13.46g
ETc 100% (control)	3.92d	6.08d	80.88g	14.19e	17.55b	13.59g
			Second season			
ETc 100% (control)	6.09A	6.80A	123.49A	16.44A	13.74C	20.75A
ETc 75%	5.60B	6.69A	100.68B	15.84B	15.96B	16.91B
ETc 50%	3.83C	6.19B	68.33C	13.85C	20.30A	11.48C
Gelatin 0% (control)	4.30D	5.85D	77.39D	14.58D	19.00A	13.00D
Gelatin 1%	5.08C	6.51C	95.04C	15.24C	16.80B	15.97C
Gelatin 1.5%	5.49B	6.87B	105.45B	15.72B	15.70C	17.72B
Gelatin 2%	5.81A	7.01A	112.11A	15.97A	15.17D	18.84A
ETc 100 % X Gelatin 0%	4.60d	5.25f	88.13g	15.64f	17.75d	14.81g
ETc 100 % X Gelatin 1%	6.05b	6.72d	123.75c	16.52b	13.35g	20.79c
ETc 100 % X Gelatin 1.5%	6.51b	7.29b	134.73b	16.67b	12.37h	22.64b
ETc 100 % % X Gelatin 2%	7.19a	7.93a	147.34a	16.94a	11.49i	24.76a
ETc 75 % X Gelatin 0%	5.00c	6.45e	81.02h	15.10g	18.64c	13.61h
ETc 75 % X Gelatin 1%	5.59c	6.68d	97.05f	15.89e	16.37e	16.31f
ETc 75 % X Gelatin 1.5%	5.86b	6.95c	109.60e	16.03d	14.62f	18.41e
ETc 75 % X Gelatin 2%	5.94b	6.70d	115.04d	16.36c	14.22f	19.33d
ETc 50 % X Gelatin 0%	3.31e	5.86f	63.02j	13.00i	20.62a	10.59j
ETc 50 % X Gelatin 1%	3.61e	6.12e	64.31j	13.30i	20.68a	10.81j
ETc 50 % X Gelatin 1.5%	4.10d	6.37e	72.03i	14.48h	20.11a	12.10i
ETc 50 % X Gelatin 2%	4.30d	6.41e	73.95i	14.63h	19.78b	12.42i

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

Based on an analysis of the data in the table, we can conclude that applying gelatin topically to onion plants has a positive impact on the characteristics listed therein, including chlorophyll a and b (mg/ 100g of F. W.). On the other hand, the characteristic of carotenoids (mg/ 100g of F. W.) was negatively impacted. We note that, when gelatin increasing in concentration of the spraying solution the positive effect on these characteristics is increase. The foliar spray treatment with gelatin at a rate of 2% achieved the highest results for chlorophyll a (mg/ 100g of F. W.), which reached 0.599 (mg/ 100g of F. W.) in the first season of the experiment and in the second season it reached 0.555 (mg/ 100g of F. W.) .

As for, the interaction between water stress treatments and foliar spraying with gelatin, the best treatment that ranked first was gelatin 2% with irrigation at a rate of 100% of evapotranspiration with a value of 0.733 (mg/ 100g of F. W.) and 0.696 (mg/ 100g of F. W.) compared to the treatment of 50% of evapotranspiration without spraying, which decreased to 0.398 (mg/ 100g of F. W.) and 0.358 (mg/ 100g of F. W.) during the first and second seasons, respectively.

As for, the effect of different irrigation treatments and gelatin on the chlorophyll b traits, it took the same trend that was achieved with the chlorophyll b trait during the two seasons of the study, except for the trait of the carotenoids, which took a different trend.

Table 5. Effect of water stress and foliar application of gelatin concentrations on leaf pigments and carotenoids of onion plants (2022/2023-2023/2024 seasons).

Treatments	Chlorophyll A (mg/ 100g of F. W.)	Chlorophyll B (mg/ 100g of F. W.)	Carotenoids (mg/ 100g of F. W.)
		First season	
ETc 100% (control)	0.679A	0.236A	0.449C
ETc 75%	0.547B	0.199B	0.555B
ETc 50%	0.433C	0.160C	0.628A
Gelatin 0% (control)	0.504D	0.180D	0.593A
Gelatin 1%	0.539C	0.195C	0.558B
Gelatin 1.5%	0.572B	0.206B	0.522C
Gelatin 2%	0.599A	0.213A	0.503D
ETc 100 % X Gelatin 0% (control)	0.600c	0.213c	0.526d
ETc 100 % X Gelatin 1%	0.661c	0.237b	0.469e
ETc 100 % X Gelatin 1.5%	0.723b	0.247a	0.405f
ETc 100 % % X Gelatin 2%	0.733a	0.249a	0.398g
ETc 75 % X Gelatin 0%	0.513d	0.184e	0.584d
ETc 75 % X Gelatin 1%	0.528d	0.192d	0.571d
ETc 75 % X Gelatin 1.5%	0.541d	0.201c	0.554d
ETc 75 % X Gelatin 2%	0.605c	0.218c	0.512d
ETc 50 % X Gelatin 0%	0.398g	0.143i	0.669a
ETc 50 % X Gelatin 1%	0.427f	0.158h	0.635b
ETc 50 % X Gelatin 1.5%	0.451e	0.168g	0.608c
ETc 50 % X Gelatin 2%	0.458e	0.171f	0.600c
		Second season	
ETc 100% (control)	0.645A	0.225A	0.427C
ETc 75%	0.503B	0.183B	0.511B
ETc 50%	0.390C	0.144C	0.565A
Gelatin 0% (control)	0.467D	0.167D	0.546A
Gelatin 1%	0.499C	0.181C	0.514B
Gelatin 1.5%	0.530B	0.190B	0.481C
Gelatin 2%	0.555A	0.197A	0.463D
ETc 100 % X Gelatin 0% (control)	0.570d	0.202c	0.500e
ETc 100 % X Gelatin 1%	0.628c	0.225b	0.446g
ETc 100 % X Gelatin 1.5%	0.687a	0.235a	0.385h
ETc 100 % % X Gelatin 2%	0.696a	0.237a	0.378i
ETc 75 % X Gelatin 0%	0.472e	0.169f	0.537c
ETc 75 % X Gelatin 1%	0.486e	0.177e	0.525d
ETc 75 % X Gelatin 1.5%	0.498e	0.185d	0.510e
ETc 75 % X Gelatin 2%	0.557d	0.201c	0.471f
ETc 50 % X Gelatin 0%	0.358h	0.129i	0.602a
ETc 50 % X Gelatin 1%	0.384g	0.142h	0.572b
ETc 50 % X Gelatin 1.5%	0.406f	0.151g	0.547c
ETc 50 % X Gelatin 2%	0.412f	0.154g	0.540c

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

Discussion

Table (3) illustrates the various effects of foliar spraying with different concentrations of gelatin (0, 1, 1.5, 2%) on the characteristics of onion leaves under water stress by irrigation with varying amounts of water calculated on the basis of the reference evapotranspiration (100, 75, 50%) or the interaction between them.

Concerning the water stress treatments through the various irrigation treatments, they had an adverse effect on the characteristics listed in the table. The measurements of these characteristics decreased as the water stress increased, starting at 100% of the reference evapotranspiration and continuing through 75% until reaching 50%.

Based on an analysis of the data in the table, we can conclude that applying gelatin topically to onion plants has a positive impact on the characteristics listed therein, including plant height (cm), fresh and dry leaf weight (g), and total water content (%). On the other hand, the characteristic of leaves' dry matter percentage (%) was negatively impacted. We note that, when gelatin increasing in concentration of the spraying solution the positive effect on these characteristics is increase. The foliar spray treatment with gelatin at a rate of 2% achieved the highest results for plant height (cm) in both seasons.

As for, the interaction between water stress treatments and gelatin foliar spraying, the best treatment that ranked first was gelatin 2% with irrigation at a rate of 100% of evapotranspiration compared to the treatment of 50% of evapotranspiration without spraying, during the first and second seasons, respectively.

As for the effect of water stress treatments, the trait recorded a percentage of 14.45 with 100% evapotranspiration compared to 18.18 with 50% evapotranspiration in the first season, while in the second season this trait achieved a percentage of 12.83% with 100% evapotranspiration compared to 16.53% with 50% evapotranspiration.

As for, the effect of gelatin and different irrigation treatments on the rest of the previously mentioned traits, it took the same trend that was achieved with the plant height trait during the two seasons of the study, except for the trait of the percentage of dry matter in the leaves, which took a different trend, as the higher the concentrations of the spray solution of gelatin, the lower the percentage of dry matter, reaching 14.87, 13.20% with the foliar spraying treatment with gelatin at a rate of 2% during the first and second seasons, respectively .

In response to drought stress, the body produces more growth inhibitors like ethylene and abscisic acid and less growth promoters like cytokinin, auxin, and gibberellin. This results in inhibition of cell division, which lowers plant growth rates and minimizes leaf area .

In this respect, our results are in agreement with those obtained by other researchers (Youssef and Taha, 2016; Mustafa et al., 2017; Astaneh et al., 2018; Rouphael and Colla, 2018; Taha et al., 2019; Rouphael and Colla, 2020; Younes et al., 2021; Youssef, 2023; Youssef and Abdelaal, 2023 and Youssef, 2025 a&b).

By maintaining the water content of plant tissues and thereby boosting the plant's tolerance to drought stress, gelatin may have an anti-transpiration effect on mitigating the effects of moisture stress. Alternatively, because it contains a variety of amino acids, including glutamic acid, glycine, proline, alanine, arginine, aspartic acid, and others, and because of their direct contribution to lowering drought stress and boosting plant activity through cytokinin and gibberellin production as well as lowering levels of ethylene and abscisic acid. This, in turn, results in increased cell division, which raises plant growth rates and leaf area.

In this respect, our results are in agreement with those obtained by other researchers (Abraheem, B. A. 2017).

Onion bulbs and yield under water stress are shown in Table (4) along with the different effects of foliar spraying with different concentrations of gelatin (0, 1, 1.5, 2%) and irrigation with different amounts of water calculated based on the reference evapotranspiration (100, 75, 50%) or the interaction between them.

The features shown in the table were negatively impacted by the different irrigation levels used to alleviate water stress. From 100% of the reference evapotranspiration to 75% of it, these characteristics' readings fell as the water stress grew, eventually reaching 50%., where the yield (ton/fed.) recorded a value of 18.56 (ton/fed.) with 100% of evapotranspiration compared to 12.70 (ton/fed.) with 50% of evapotranspiration in the first season, while in the second season this characteristic achieved a value of 20.75 (ton/fed.) with 100% of evapotranspiration compared to 11.48 (ton/fed.) with 50% of evapotranspiration.

Applying gelatin topically to onion plants positively affects the parameters stated in the table, such as bulb diameter (cm), bulb height (cm), fresh and dried bulb weight (g), and yield (ton/fed.). This conclusion is based on an examination of the data in the table. Conversely, there was a detrimental influence on the dry matter percentage (%) of the bulbs. We note that, these features improve as the concentration of gelatin in the spraying fluid increases. The greatest results for yield (ton/fed.) were obtained with a 2% gelatin foliar spray treatment; in the first season of the trial, yield (ton/fed.) reached 17.93 (ton/fed.), and in the second season, it reached 18.84 (ton/fed.).

As for, the interaction between foliar spraying with gelatin and water stress treatments, the best treatment that ranked first was gelatin 2% with irrigation at a rate of 100% of evapotranspiration with a value of 22.75 (ton/fed.) and 24.76 (ton/fed.) compared to the treatment of 50% of evapotranspiration without spraying, which decreased to 11.34 (ton/fed.) and 10.59 (ton/fed.) during the first and second seasons, respectively.

As for the effect of water stress treatments, the trait recorded a percentage of 15.56 with 100% evapotranspiration compared to 17.06 with 50% evapotranspiration in the first season, while in the second season this trait achieved a percentage of 13.74% with 100% evapotranspiration compared to 20.30% with 50% evapotranspiration.

As for, the effect of gelatin and different irrigation treatments on the rest of the previously mentioned traits, it took the same trend that was achieved with the yield trait during the two seasons of the study, except for the trait of the percentage of dry matter in the bulb, which took a different trend, as the higher the concentrations of the spray solution of gelatin, the lower the percentage of dry matter, reaching 15.56, 15.17% with the foliar spraying treatment with gelatin at a rate of 2% during the first and second seasons, respectively .

The plant produces less growth promoters like cytokinin, auxin, and gibberellin and more growth inhibitors like ethylene and abscisic acid in response to drought stress. As a result, cell division is inhibited, which reduces the leaf area that contains less chlorophyll. This reduces photosynthesis rates and the plant's capacity to synthesise carbohydrates, which ultimately leads to a decrease in bulb weight and the planted area's total yield. Our findings conform to those of other researchers in this regard, as evidenced by the works of other researchers (Metwally, 2011; Youssef and Taha, 2016; Mustafa et al., 2017; Rouphael and Colla, 2018; Taha et al., 2019; Rouphael and Colla, 2020; Younes et al., 2021 and Aku, 2023) .

Gelatin may have an anti-transpiration effect on reducing the effect of moisture stress by preserving the water content of plant tissues and thus increasing the plant's tolerance to drought stress. Or because it contains many amino acids such as glycine, proline, alanine, arginine, aspartic acid and glutamic acid and their direct role in reducing drought stress and increasing plant activity by increasing the production of gibberellins and cytokinins and reducing ethylene and abscisic acid levels, which ultimately leads to increased cell division, which means increased plant growth rates and increased leaf area with increased chlorophyll content of leaves, which leads to increased photosynthesis and thus increased carbohydrate formation rates in the plant, which ultimately leads to increased bulb weight and higher final yield for the cultivated area. Our findings and those of other researchers are comparable in this regard (Abraheem, 2017).

Table (5) illustrates the various effects of foliar spraying with different concentrations of gelatin (0, 1, 1.5, 2%) on the characteristics of leaf pigments and carotenoids under water stress by irrigation with varying amounts of water calculated on the basis of the reference evapotranspiration (100, 75, 50%) or the interaction between them.

Concerning the water stress treatments through the various irrigation treatments, they had an adverse effect on the characteristics listed in the table. The measurements of these characteristics decreased as the water stress increased, starting at 100% of the reference evapotranspiration and continuing through 75% until reaching 50%, where the chlorophyll a recorded a value of 0.697 (mg/ 100g of F. W.) with 100% of evapotranspiration compared to 0.733 (mg/ 100g of F. W.) with 50% of evapotranspiration in the first season, while in the second season this characteristic achieved a value of 0.645 (mg/ 100g of F. W.) with 100% of evapotranspiration compared to 0.390 (mg/ 100g of F. W.) with 50% of evapotranspiration. In this respect, our results are in agreement with those obtained by other researchers (Youssef and Taha, 2016; Mustafa et al., 2017; Rouphael and Colla, 2018; Taha et al., 2019; Rouphael and Colla, 2020 and Younes et al., 2021).

Based on an analysis of the data in the table, we can conclude that applying gelatin topically to onion plants has a positive impact on the characteristics listed therein, including chlorophyll a and b (mg/ 100g of F. W.). On the other hand, the characteristic of carotenoids (mg/ 100g of F. W.) was negatively impacted. We note that, when gelatin increasing in concentration of the spraying solution the positive effect on these characteristics is increase. The foliar spray treatment with gelatin at a rate of 2% achieved the highest results for chlorophyll a (mg/ 100g of F. W.), which reached 0.599 (mg/ 100g of F. W.) in the first season of the experiment and in the second season it reached 0.555 (mg/ 100g of F. W.). Our findings are consistent with those of other investigators (Abraheem, 2017).

As for, the interaction between water stress treatments and foliar spraying with gelatin, the best treatment that ranked first was gelatin 2% with irrigation at a rate of 100% of evapotranspiration with a value of 0.733 (mg/ 100g of F. W.) and 0.696 (mg/ 100g of F. W.) compared to the treatment of 50% of evapotranspiration without spraying, which decreased to 0.398 (mg/ 100g of F. W.) and 0.358 (mg/ 100g of F. W.) during the first and second seasons, respectively.

As for, the effect of different irrigation treatments and gelatin on the chlorophyll b traits, it took the same trend that was achieved with the chlorophyll b trait during the two seasons of the study, except for the trait of the carotenoids, which took a different trend.

Conclusion

By studying the experimental data and verifying the results mentioned in the research after treating onion plants (*Allium cepa* L.) with four concentrations of gelatin (0.0, 1.0, 1.5 and 2.0%) by foliar spraying process, which were applied four times (the first time was at the 7th of December and every 15 days) under water stress conditions (100, 75 and 50% of ETo), it recommend treating the onion plant with foliar spraying by gelatin (2%) under water supply of 100 or 75 of ETc , which achieved economic vegetative growth and yield.

Consent for publication:
The author declares their consent for publication.

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The manuscript was edited and revised by the author.

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The author declares no conflict of interest.

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