POTENTIAL OF CHITOSAN IN REDUCING GA3 DOSES AND THEIR EFFECT ON GROWTH, YIELD, AND BULB QUALITY IN "GIZA RED" ONION

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ABSTRACT
Tow field experiments were conducted during the seasons of 2020/2021 and 2021/2022 at the experimental farm Etay El-Baroud research station to investigate the effect of foliar application with gibberellic acid (GA3) at 50 and 100 ppm and the chitosan (CS) at of 100 and 200 ppm, in addition, to control for each to Giza Red onion. The results showed significant and positive effects of the examined concentrations of GA3 or CS on all the studied characters except leaves number and shape index, in both seasons. Concerning the interaction effect, all of the studied characters were enhanced significantly in all treatment combinations between GA3 and CS levels. The treatments of GA3 (50 ppm) with CS (200 ppm), GA3 (100 ppm) with CS (100 ppm), and GA3 (100 ppm) with CS (200 ppm) were found to give the highest mean values for all characters, in both seasons without significant differences among them. Also, the results revealed some kind of synergistic effect between GA3 and CS where the combined application was found to be more effective in onion plants performance thane the single ones that gave the ability to reduce the used doses of GA3 by 50%, which, consequently, reduce the expected hazardous of using gibberellins.

Keywords: Gibberellic, chitosan, onion, growth, yield, bulbs quality

إمكانات الشيتوزان في تقليل جرعات GA3 وتأثيرها على النمو والمحصول وجودة الأبصال في بصل "الجيزة الأحمر"

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المستخلص
أجريت تجربتان حقليتان في موسمي الزراعة 2021/2020 و 2022/2021 في المزرعة التجريبية بمحطة أبحاث إيتاي البارود لفحص تأثير الرش الورقي بحمض الجبريليك (GA3) عند 50 و 100 جزء بالمليون والشيتوزان عند 100 و200 جزء بالمليون، بالإضافة إلى ذلك، مقارنة في كل منهما. أظهرت النتائج تأثيراً معنوياً وإيجابياً لتركيزات GA3 أو CS المدروسة على جميع الصفات المدروسة ما عدا عدد الأوراق ودليل الشكل في كلا الموسمين. فيما يتعلق بتأثير التفاعل، تم تحسين جميع الصفات المدروسة بشكل ملحوظ في جميع تركيبات العلاج بين مستويات GA3 و .CS أيضا، تم العثور على أن معاملات (50 جزء بالمليون GA3 مع 200 جزء بالمليون CS)، (100 جزء بالمليون GA3 مع 100 جزء بالمليون CS) و(100 جزء بالمليون GA3 مع 200 جزء بالمليون CS) قد أعطت أعلى متوسطات لجميع الصفات في كلا الموسمين دون وجود فروق معنوية بينهم. كما كشفت النتائج عن إحتمالية وجود نوع من التأثير التآزري بين GA3 وCS حيث وجد أن التطبيق المشترك أكثر فاعلية في أداء نباتات البصل من تلك المنفردة التي تعطي القدرة على تقليل الجرعات المستعملة من GA3 بنسبة 50٪، وبالتالي، تقليل المخاطر المتوقعة من استخدام الجبرلين.

الكلمات المفتاحية: جبريلين، شيتوزان، بصل، النمو، محصول، جودة الأبصال

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INTRODUCTION

In Egypt, the onion (*Allium cepa* L.) crop is one of the most important vegetable crops that have been cultivated and consumed thousands of years ago. Also, onions are one of Egypt's most important vegetable crops in terms of local consumption as well as exportation occupies the third most important export crop after oranges and potatoes. The latest statistics indicate that Egypt is one of the top ten onion-producing countries, with a total cultivated area of 89018 hectares and a total production of 3,155,649 tones. In addition, the exports of Egyptian onions, at end of 2019, recorded 550,000 tons, compared to 310,000 tons in 2018 (FAOSTAT). Globally; onions are the center of attention of researchers because of its strategic and economic importance (6, 7) Gibberellic acid (GA_3) is one of the most common active forms of the gibberellins family that functions as a natural plant growth hormone that regulates a variety of developmental processes and is gaining great attention all over the world due to its usefulness in agriculture, nurseries, tissue culture, etc. (17). Exogenous application of such form of gibberellins (GA_3) found to enhance the productivity and quality of several vegetable crops by affecting many of vital physiological processes. The effective concentration of GA_3 is varied depending on the vegetable species, and the suitable growth stage for application (10). In the context of onions, GA_3 is considered as a significant application for improving the growth, productivity, chemical composition, and bulb quality characteristics as found by many researchers (11; 24; 28; 34). Also, these previous research articles found that the suitable GA_3 concentration, for onion plants, was ranged from 50 to 150 ppm depending on the used cultivar and environmental and growth circumstances, and the suitable growing stage for GA_3 foliar application was 7 leaves stage. However, there are recent research papers that pointed out the environmental and human hazards of GA3 intensive use in different agricultural products (18; 22), and it should find ways to reduce the used GA3 doses. Chitosan is a derivative of chitin and is considered the recent agricultural environment-friendly agent for more safe food production (16). Chitosan is a natural low toxic and low input compound that is biodegradable and environmentally friendly with various applications in agriculture. Also, chitosan, recently, has become of interest as a crop bio-stimulant that ensures agro-sustainability in vegetable production (29). The chitosan beneficial influences were clearly found in a wide range of vegetable crops, which could be concluded in increasing mean values of different vegetative growth, photosynthetic pigments concentration, yield, and its components, and quality characters of the treated plants' traits as found with onion (4; 14), garlic (32), strawberry (26), and lettuce (35). These favorable effects may be to chitosan involvement in the signaling pathway for the biosynthesis of phenolics in addition to many plant hormones as found with gibberellins and auxins (3; 19; 31), its significant role in reducing the water use of the treated plants by increasing stomatal closing (12). The aim of this study is to examine the effect of chitosan and/or GA_3 on the onion plants growth, leaves chlorophyll content, leaves chemical composition, yield and its components, and bulbs chemical quality characters, in addition to the possibility of reducing the GA3 used doses for producing more safe onion bulbs for human consumption.

MATERIALS AND METHODS

Two field experiments were conducted in seasons of 2020/2021 and 2021/2022 in the experimental farm Etay El-Baroud research station, El-Beheira Governorate, Egypt (Latitude 30° 53' N, Longitude 30° 38' E) to study the effect of foliar application of gibberellic acid (GA3) in different concentration alone or in combination with different concentration of chitosan (CS) on the performances of onion plants cv. "Giza Red" under field conditions.

Planting and the experimental layout

Onion cv. "Giza Red" was transplanted in 15th and 18th December of 2020/2021 and 2021/2022, respectively. The planting distance was 10 cm between transplants in both sides of the rows. Each plot contains five rows with 70 cm in width and 4 meter in length. Each experimental plot surrounded by gourd row to preventing the treatments interferences. The examined treatments were foliar application with gibberellic acid (GA3) in concentrations of 50 and 100 ppm in addition to control, and the chitosan (CS) in concentrations of 100 and 200 ppm in addition to control. All treatments were applied three times, starting from the seven leaves stage, at intervals of every two weeks. All other agricultural practices (fertilization, pest control, irrigation, … etc.) were doe following the recommendations of commercial production of onion stated from Ministry of Agriculture and Land Reclamation. The experimental layout was Randomized Complete Block Design (RCBD) in split plot arrangement with three replications. The area of each sup-plot was 14 m^2 (5 rows×0.7 m width ×4 m long). The GA3 treatments were allocated randomly in main plots; while the CS treatments were applied randomly in sup-plots. Therefore, the total number of experimental treatments were 27 (3 GA3×3 CS×3 Reps.).

Recorded data

There were four main groups of the recorded data as follow:

Vegetative growth characters

Five onion plants from each sup-plot were taken randomly at 75 days after transplanting to record the vegetative growth parameters such as plant length (cm), number of leaves, shoot fresh weight that was leaves blades with their pseudo stem (g), shoot dry weight (g).

Leaves chemical composition and chlorophyll

The chlorophyll content of onion leaves was determined non-destructively using a SPAD-502 chlorophyll meter (23). Concerning onion leaves' chemical composition i.e., nitrogen, phosphorus, and potassium as % were determined for each one according to the methodology described by Temminghoff and Houba (33).

Bulbs physical quality and yield

At the end of the season and curing of the onion bulbs, other samples were randomly taken to measure bulb physical characteristics such as length (cm), and bulb diameter (cm) using a Vernier caliper. The bulb shape index was calculated by dividing the bulb length over the bulb diameter. Bulbs yield (Ton fad^{-1}) was estimated by recording the yield of each sub-plot in kilograms that was multiplied by the factor of 300, which was the result of dividing the area of one faddan (4200 m^2) by the area of one sub-plot (14 m^2), and then the output converted to tons.

Bulbs chemical quality

Total carbohydrates (%) were determined by colorimetry through phenol-sulfuric acid reaction as illustrated by Nielsen (25). The onion bulbs total soluble solids (TSS as Brix◦) was measured by using a hand refractometer. For total phenols, the folinn-ciocalteu reagent method of Ainsworth and Gillespie (5) was followed using spectrophotometer at 765 nm. The total phenols content mean values were expressed as mg of gallic acid equivalents per gram of fresh weight. Pyruvic acid (μmol g^{-1}) were determined using di-nitrophenyl hydrazine (NDPH) as described by Anthon and Barrett (8).

Statistical analysis

All the recorded data were statistically analyzed using CoStat program. The significance among the treatments was done by using Least Significant Difference (LSD; $p \leq 0.05$) by using the same program.

RESULTS AND DISCUSSION

Vegetative growth characters

The mean values listed in Table 1 illustrate the main effects of GA3, CS, and their interaction on plant height, leaves number, and shoot fresh and dry weights of onion plants cv. "Giza Red" in seasons of 2020/2021 and 2021/2022. Except leaves number, the foliar application of GA3 at 100 ppm or CS at 200 ppm was resulted in significant increase in the mean values of plant height, and shoot fresh and dry weights compared with other used concentrations, in both seasons. Although their little values, the average increasing percentage over control of both seasons for shoot dry weight followed by plant height and shoot fresh weight characters showed response to 200 ppm CS compared to 100 ppm GA3, which were 15.57, 14.84, and 9.91% for GA3, respectively, while they were 9.91, 9.12, and 7.32% for CS, respectively. Concerning the interaction effect, the treatment combinations of GA3 (50 ppm) with CS (200 ppm), GA3 (100 ppm) with CS (100 ppm), and GA3 (100 ppm) with CS (200 ppm) were found to give the highest significant mean values of plant height, and shoot fresh and dry weights without significant differences among them, in both seasons of study. The results revealed that the combined treatments of GA3 with CS were more effective in plant height, and shoot fresh and dry weights comparing to the solo treatment. This is evident by calculating the average percentage increase for the above-mentioned three higher treatments for both seasons, as it was found that they are 25.51% for shoot dry weight, followed by 22.33% for plant height and 13.06% for shoot fresh weight. These results are in harmony with many other former researches that stated the role of GA3 foliar application on enhancing the growth parameters of onion plants (11; 28; 30; 34). In addition to the significant effect of CS on enhancing the vegetative growth of onion plants criteria (4; 14) Also, Jogaiah *et al*. (20) reported that CS could be involved in enhancing plant growth and development through signaling pathway correlated to gibberellins biosynthesis.

Table 1. The effect chitosan and/or GA3 foliar application on plant height, leaves number, shoot fresh weight, and shoot dry weight of onion plants cv. "Giza Red" during 2020/2021 and 2021/2022 seasons

CS	GA3							
	2020/2021				2021/2022			
	Control	50 ppm	100 ppm	Mean	Control	50 ppm	100 ppm	Mean
				Plant height (cm)				
Control	43.66e	47.77cd	50.42b	47.28C	44.87f	49.02de	51.32bc	48.40C
100 ppm	45.82d	48.21c	53.95a	49.32B	47.42e	50.6cd	52.96ab	50.33B
200 ppm	47.55cd	54.83a	54.87a	52.42A	47.72e	53.59a	54.6aa	51.97A
Mean	45.68C	50.27B	53.08A		46.67C	51.07B	52.96A	
				Leaves number				
Control	8.05	8.38	8.10	8.18	7.62	7.50	7.62	7.57
100 ppm	8.29	7.86	7.90	8.02	7.93	7.88	7.97	7.93
200 ppm	8.11	7.56	7.76	7.81	7.86	7.69	7.65	7.93
Mean	8.15	7.93	7.92		7.80	7.69	7.75	
				Shoot fresh weight (gm plant^{-1})				
Control	89.30e	98.28cd	105.25b	97.61C	101.51cd	101.00cd	104.10b	100.58C
100 ppm	97.82d	100.61cd	105.65ab	101.36B	100.53d	103.01bc	104.59ab	102.71B
200 ppm	102.53bc	110.00a	110.04a	107.52A	96.64e	106.87a	106.90a	105.09A
Mean	96.55C	102.96B	106.98A		99.56C	103.63B	105.20A	
				Shoot dry weight (gm plant^{-1})				
Control	17.19e	20.63cd	21.61bc	19.81C	18.63e	19.75cd	20.74b	19.71C
100 ppm	19.19d	21.13bc	22.77ab	21.03B	19.32d	20.11c	21.05ab	20.16B
200 ppm	20.37cd	23.52a	24.56a	22.82A	19.40d	21.36a	21.10ab	20.62A
Mean	18.92C	21.76B	22.98A		19.12C	20.41B	20.97A	

*** The means with the same letter(s) do not differ significantly under 0.05 confidence level**

Leaves chemical composition and chlorophyll

The effect of foliar application of GA3 or CS in addition to their interaction on the mean values of onion leaves content of N%, P%, K%, and chlorophyll content were showed in Table 2. Generally, the application of GA3 or CS were found to affect these characters, significantly, especially when applied at the highest concentrations (100 ppm for GA3, and 200 ppm for CS), in both seasons of study. Also, it found that the application of 100 ppm GA3 were more effective in increasing the onion leaves content of N%, P%, chlorophyll, and K% comparing to 200 ppm CS treatment, which were estimated by 31.36, 21.68, 15.48, and 11.52% for GA3 treatment, respectively, while they were 23.03, 11.78, 9.20, and 7.10% for CS treatment, respectively as a both seasons average. Moreover, the interaction between the different treatment's levels of GA3 and CS was found to be significant for onion leaves content of N%, P%, K%, and chlorophyll content traits, in both seasons of study with superiority of the treatments of GA3 (50 ppm) with CS (200 ppm), GA3 (100 ppm) with CS (100 ppm), and GA3 (100 ppm) with CS (200 ppm), in both seasons of study. In addition, the results revealed that the combined application of GA3 with CS was found to be more effective than single treatments. This finding could be shown clearly by calculating the mean average percentages of increment over control for the three highest treatment combinations in both seasons, which was found to be 61.10% for N%, 38.92% for P%, 25.78%, and 22.52% over control. The GA3 is an effective application for increasing the nutrients uptake and photosynthetic pigments (9; 27). Also, the application of CS was found to be favorable application for increasing the nutrients and chlorophyll contents on onion (4; 14) and other vegetable crops as garlic (32), strawberry (26), and lettuce (35). Moreover, the combined application with GA3 and CS was found to be significant for increasing the chlorophyll and nutrients content in peppermint (1).

Table 2. The effect chitosan and/or GA3 foliar application on leaves content of N%, P%, K%, and chlorophyll of onion plants cv. "Giza Red" during 2020/2021 and 2021/2022 seasons.

CS	GA3							
	2020/2021				2021/2022			
	Control	50 ppm	100 ppm	Mean	Control	50 ppm	100 ppm	Mean
	Leaves N%							
Control	1.44f	1.94de	2.51bc	1.97C	1.86e	1.99d	2.17b	2.00C
100 ppm	1.91e	2.30cd	2.68ab	2.30B	2.07c	2.10c	2.21ab	2.13B
200 ppm	2.05de	3.04a	3.02a	2.70A	2.05c	2.22ab	2.26a	2.18A
Mean	1.80C	2.43B	2.74A		2.00C	2.10B	2.21A	
	Leaves P%							
Control	0.284f	0.326cd	0.346b	0.319C	0.237g	0.317de	0.338bc	0.298C
100 ppm	0.315de	0.328c	0.356ab	0.333B	0.293f	0.330cd	0.351ab	0.325B
200 ppm	0.314e	0.357a	0.366a	0.346A	0.304ef	0.360a	0.364a	0.343A
Mean	0.304C	0.337B	0.356A		0.278C	0.336B	0.351A	
	Leaves K%							
Control	2.25f	2.61c-e	2.73ab	2.53C	2.18f	2.45cd	2.54b	2.39C
100 ppm	2.52e	2.62cd	2.9bc	2.61B	2.36e	2.51bc	2.57ab	2.48B
200 ppm	2.57de	2.78ab	2.80a	2.72A	2.42de	2.62a	2.62a	2.55A
Mean	2.45C	2.67B	2.74A		2.32C	2.53B	2.58A	
	Chlorophyll (SPAD)							
Control	43.95e	49.31cd	50.23bc	47.83C	41.67g	50.12de	52.58bc	48.12C
100 ppm	47.50d	48.81cd	52.87a	49.72B	44.19f	51.70cd	53.78ab	49.89B
200 ppm	49.70c	52.07ab	53.42a	51.73A	48.19e	55.44a	55.10a	53.05A
Mean	47.05C	50.06B	52.17A		44.82C	52.42B	53.82A	

*** The means with the same letter(s) do not differ significantly under 0.05 confidence level**

Bulbs physical quality and yield

The mean values of bulb diameter, bulb length, shape index, average bulb weight, and bulb yield as indicators to the effect of foliar application GA3, CS, and their interaction on onion bulbs physical quality and yield were listed in Table 3 for 2020/2021 and 2021/2022 seasons. The results showed, that although the application of GA3 or CS was significantly affecting the studied characters, the shape index did not exhibit any significant response, in both seasons of study. Also, the concentrations of 100 ppm for GA3 and 200 ppm for CS gave the highest mean values of the studied characters, in both seasons.However, the main effect of 100 ppm GA3 was higher on comparing to 200 ppm CS. This is evidenced by calculating the both seasons average percentage increase over control for GA3 and CS, which were 12.33% and 6.97% for bulb diameter, 10.18% and 6.63% for bulb length, 10.75% and 8.64% for average bulb weight, and 18.34% and 11.15% for bulb yield fad^{-1}, respectively. Moreover, the interaction effect between GA3 and CS levels was found to be significant for all the studied characters except bulb shape index, in both seasons. The treatment combinations of GA3 (50 ppm) with CS (200 ppm), GA3 (100 ppm) with CS (100 ppm), and GA3 (100 ppm) with CS (200 ppm) were the three interactions that gave the highest significant mean values of the studied characters without significant differences among them, in both seasons. In addition, it is noticeable that the resulted effect of the above-mentioned combined applications was more effective in increasing mean values of these characters compared to the single treatments of GA3 and CS. This becomes clear when calculating the average percentage increase over the control for those three treatments in both seasons of study, which was estimated by 29.77% for bulb yield fad^{-1} followed by 19.70% for average bulb weight, 18.05% for bulb diameter, and 13.94% for bulb length. The results of this study are agreed with those of (11; 21; 28; 30) how stated the effect of using GA3 on enhancing the yield of onion bulbs and its physical quality parameters. Concerning the CS treatments, the results of this investigation emphasize the results of Ahmed *et al*. (3) who found a positive retune of foliar application on onion plants yield and its components as well as their physical quality.

Table 3. The effect chitosan and/or GA3 foliar application on bulb diameter, bulb length, shape index, average bulb weight, and bulbs yield of onion plants cv. "Giza Red" during 2020/2021 and 2021/2022 seasons.

CS	GA3							
	2020/2021				2021/2022			
	Control	50 ppm	100 ppm	Mean	Control	50 ppm	100 ppm	Mean
				Bulb diameter (cm)				
Control	7.25f	8.02cd	8.77b	8.02C	7.35f	7.47ef	8.01bc	7.61C
100 ppm	7.71e	8.09c	8.94ab	8.25B	7.66de	7.89cd	8.15ab	7.90B
200 ppm	7.79de	9.06a	8.95ab	8.60A	7.76d	8.30a	8.29a	8.12A
Mean	7.58C	8.39B	8.89A		7.59C	7.89B	8.15A	
				Bulb length (cm)				
Control	6.49f	6.80de	7.29bc	6.86C	6.67f	6.75ef	7.19bc	6.87C
100 ppm	6.62ef	7.17c	7.47ab	7.09B	6.81ef	7.06cd	7.43a	7.10B
200 ppm	6.89d	7.59a	7.61a	7.37A	6.94de	7.33ab	7.54a	7.27A
Mean	6.67C	7.19B	7.46A		6.81C	7.05B	7.39A	
				Shape index				
Control	0.90	0.85	0.85	0.87	0.91	0.90	0.88	0.90
100 ppm	0.86	0.89	0.85	0.87	0.89	0.90	0.93	0.90
200 ppm	0.89	0.84	0.87	0.86	0.89	0.88	0.91	0.90
Mean	0.88	0.86	00.86		0.90	0.89	0.91	
				Average bulb weight (gm bulb^{-1})				
Control	84.04e	91.22d	96.97bc	90.74C	86.21f	95.53cd	99.20b	93.65C
100 ppm	92.92cd	93.76cd	98.92ab	95.20B	90.91e	97.94bc	100.30ab	96.38B
200 ppm	95.20b-d	103.44a	103.28a	100.64A	93.50d	102.87a	102.47a	99.61A
Mean	90.72C	96.14B	99.72A		90.21C	98.78B	100.66A	
				Bulb yield (ton fad^{-1})				
Control	11.43e	13.47cd	14.33bc	13.08C	12.16f	13.55cd	14.45b	13.39C
100 ppm	12.68d	13.48cd	15.03ab	13.73B	13.06e	13.75c	14.75ab	13.85B
200 ppm	12.92d	16.11a	16.15a	15.06A	13.43d	14.86a	14.76a	14.35A
Mean	12.34C	14.35B	15.17A		12.88C	14.05B	14.65A	

*** The means with the same letter(s) do not differ significantly under 0.05 confidence level**

Bulbs chemical quality

The mean values listed in Table 4 showed significant effect of foliar application of GA3 or CS as well as their interaction on chemical quality parameters i.e., total carbohydrates, TSS, total phenols, and pyruvic acid, in both seasons of study. Also, using 100 ppm of GA3 or 200 ppm of CS was found to give the highest mean values of above-mentioned characters comparing with other treatments, in both seasons. The comparison between the both seasons average increasing percentage of these tow treatments over control was revealed that the GA3 was more effective comparing to CS treatment, which was estimated by 34.15% and 17.02% for total carbohydrates, 10.04% and 6.29% for TSS, 25.08 % and 21.22% for total phenols, and 8.72% and 5.71% for pyruvic acid, respectively. Concerning the interaction effect between GA3 with CS levels, it was found that the treatment interactions between GA3 (50 ppm) with CS (200 ppm), GA3 (100 ppm) with CS (100 ppm), and GA3 (100 ppm) with CS (200 ppm) were the most treatments that gave the highest mean values of the studied chemical quality parameters of onion bulbs without significant differences among them, in both seasons of study. As found previously, the general average of increasing percentage over the control for the highest three combined treatments for the bulbs chemical quality traits in both seasons were found to be more pronounced than the corresponding values for the single treatments. The total carbohydrates were given the most increasing percentage as 58.24% followed by total phenols as 52.56%, TSS as 16.15%, and pyruvic acid as 10.58%. The effect of GA3 on onion bulbs chemical quality was published by many authors as reported by (13; 21). Also, the CS application was be a significant application for adjusting the chemical quality of onion bulbs (3). In general, the findings of this investigation could point out the existence of some kind of synergistic effect between GA3 and CS that resulted in such superiority over the single application of each of them. 20) suggested that chitosan may induced a signal to synthesize phytohormones such as gibberellins. Also, It could deduct from the results of Ahmed *et al*. (2) on faba bean and Elsharkawy and Ghoneim (15) on artichoke that there may be a motivational relationship between chitosan and gibberellic. Also, the last research paper stated that the multiple application of GA3 and CS was more effective comparing to one-time application for growth, yield, and quality parameters of artichoke.

Table 4. The effect chitosan and/or GA3 foliar application on bulbs total carbohydrates, TSS, total phenols, and pyruvic acid of onion plants cv. "Giza Red" during 2020/2021 and 2021/2022 seasons.

CS	GA3							
	2020/2021				2021/2022			
	Control	50 ppm	100 ppm	Mean	Control	50 ppm	100 ppm	Mean
	Total carbohydrates (%)							
Control	9.96g	12.84de	14.32bc	12.37C	9.16f	12.37de	13.73bc	11.76C
100 ppm	11.47f	13.51cd	15.51ab	113.50B	11.81e	12.94cd	14.40ab	13.05B
200 ppm	11.76ef	15.83a	15.83a	14.55A	11.87e	14.40ab	14.79a	13.69A
Mean	11.06C	14.14B	15.22A		10.95C	13.24B	14.31A	
	TSS Brix°							
Control	12.39g	13.83de	14.36bc	13.53C	11.85f	12.54de	13.06bc	12.48C
100 ppm	13.20f	13.93cd	14.60ab	13.91B	12.24e	12.71d	13.21ab	12.72B
200 ppm	13.43ef	14.83ab	15.00a	14.42A	12.80cd	13.50a	13.38a	13.23A
Mean	13.01C	14.20B	14.65A		12.30C	12.82B	13.22A	
	Total phenols (mg GA g^{-1} FW)							
Control	4.19f	5.67cd	5.96bc	4.94C	4.46f	5.76cd	6.22bc	5.48C
100 ppm	5.05e	5.73cd	6.38a	5.90B	5.12e	5.78cd	6.78a	5.89B
200 ppm	5.56d	6.30ab	6.47a	6.27A	5.31de	6.67ab	6.99a	6.33A
Mean	5.26C	5.70B	6.11A		4.97C	6.07B	6.66A	
	Pyruvic acid (μmol g^{-1})							
Control	7.00g	7.36ef	7.80bc	7.38C	6.59e	6.94cd	7.21b	6.91C
100 ppm	7.24f	7.54de	7.98ab	7.59B	6.83d	7.03c	7.32ab	7.06B
200 ppm	7.59cd	7.91ab	7.08a	7.86A	6.97cd	7.30ab	7.48a	7.25A
Mean	7.27C	7.60B	7.96A		6.80C	7.09B	7.34A	

*** The means with the same letter(s) do not differ significantly under 0.05 confidence level**

Conclusion

According to the results of this investigation, the three times foliar application of each of GA3 (50 ppm) with CS (200 ppm), GA3 (100 ppm) with CS (100 ppm), and GA3 (100 ppm) with CS (200 ppm) could be effective treatments, with the preference of GA3 (50 ppm) with CS (200 ppm) application because of decreasing the used of synthetic GA3, for enhancing the growth and the quantity and the quality onion bulbs yield cv. "Giza Red" with reducing the expected health and environmental concerns of using GA3.

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