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Effect of glutathione and/or selenium levels on growth, yield, and some biochemical constituents of some wheat cultivars grown under sandy soil conditions

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Abstract

Background: Two field experiments were carried out at the Agricultural Production and Research Station, National Research Centre (NRC), El-Nubaria Province, Behaira Governorate, Egypt, during two successive winter seasons to study the effect of glutathione (100, 200, and 300 mg/l) and/or selenium (5 and 10 mg/l) on growth, yield, and yield components of three wheat cultivars (Egypt-2; Shandaweel-1; Gemmeiza-11).

Results: The results indicate that the Gemmeiza-11 cultivar was the most adapted cultivar to grow in the Nubaria region. Individually, glutathione at 300 mg/l or selenium at 10 mg/l caused the highest significant increases in shoot dry weight/plant of three wheat cultivars relative to other levels. Likewise, glutathione treatment at 300 mg/l was the optimum treatment in increasing photosynthetic pigments in three wheat cultivars. Selenium treatment at 10 mg/l was better than selenium treatment at 5 mg/l. Interaction between glutathione at 300 mg/l and selenium at 10 mg/l caused the highest significance increases in total photosynthetic pigments. It is obvious that glutathione at 300 mg/l or selenium at 10 mg/l as individual treatment showed the highest significant increase in grain yield (ton/fed).

Conclusion: Glutathione treatments at 200 or 300 mg/l interacted with selenium treatment at 10 mg/l showed the highest significant increases in grain yield and its components as compared with other treatments in three wheat cultivars. Moreover, It is noted that the highest increases in IAA and phenolic content in the leaves as well as the content of carbohydrate, flavonoid, and phenolic in the yielded grains appeared by the interaction between glutathione at 300 mg/l and selenium at 10 mg/l in the three wheat cultivars under investigation.

Keywords: Wheat cultivars, Antioxidant, Quality, Quantity, Selenium, Glutathione

Background

Wheat (*Triticum aestivum* L.) is one of the most popular cultivated cereals. The wheat grain has three groups of main constituents, starch, protein, and cell wall polysaccharides (dietary fiber), and a group of minor components which can bring benefits to human health. Wheat provides about one-fifth of the human daily calories. It is an essential source of vegetable protein and nutrients for a large proportion of the world's population. This is used by urban and rural communities as a proper food and as the largest source of straw for animal feeding. In Egypt, there is an extreme shortage in wheat production. Therefore, extending wheat growing in sandy soils is the first attempt to overcome wheat problems. Sandy soils in the Nubaria region are subject to a variety of environmental stress conditions including low water availability, high irradiances, temperature fluctuations, soil salinity,

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and nutrients deprivation. In this regard, great efforts must be paid to increase plant tolerance to these conditions by selecting tolerant genotypes and applying the optimum cultural practices and/or treating the seeds (before sowing) or plants (at different growth stages) with some regulating substances as antioxidants. Selecting tolerant wheat cultivar is one of the most important factors for increasing wheat production, where they differ in grain yield and its components (Sultan et al. 2000).

Antioxidants have an important effect on plants to overcome partially the unfavorable conditions and alleviate their reduced effects on yield quantity and quality. Since, antioxidants prevent the damage of important cellular constituents resulted by reactive oxygen species such as free radicals and peroxides that are produced under unfavorable conditions and caused damage to the cell (Kumar et al. 2013).

Glutathione is identified as tripeptide γ-Lglutamyl-L-cysteinyl-glycine and an important pool of reduced sulfur (Rennenberg 1982). Glutathione is a strong antioxidant that has a critical role in preserving a normal balance between oxidation and antioxidation; regulates the number of cell vital functions such as synthesis and repair of DNA, synthesis of proteins, and activation and regulation of enzymes in plants; affects on expression of defense gene (Wingate et al. 1988); maintains the integrity of cell structures and the proper functions of different metabolic pathways; and could be used in redox control of cell (Sanchez-Fernandez et al. 1997).

Glutathione also is used as a substrate in other enzymes such as glutaredoxin; these small oxidoreductases are involved in flower development and plant defense signaling (Rouhier et al. 2008). Also, glutathione is critical for biotic and abiotic stress management. Glutathione protects cells from free radicals and peroxides (Pompella et al. 2003). It is a pivotal constituent of glutathione—ascorbate cycle, a system which decreases toxic hydrogen peroxide (Noctor and Foyer 1998). Foyer and Noctor (2005) added that the higher water solubility and stability of GSH make it an ideal antioxidant that helps plants against reactive oxygen species (ROS).

Selenium has importance as a microelement and has a role in the antioxidative system in plants (Ekelund and Danilov 2001). Accumulation of selenium in plants differs in relation to plant species and is affected by soil selenium concentration, soil properties, and the chemical form of selenium (Zhu et al. 2009). Selenium is biologically active at low concentrations for normal growth and development and at moderate concentrations for homeostatic function. However, at high concentrations, selenium can induce toxicity (Hamilton 2004). The margin between the nutritional requirement and toxicity is quite small, and outside this range, deficiency or toxicity can occur.

Sulfur and selenium have very similar chemical properties, and their absorption and assimilation occur via common pathways (Eapen and D'Souza 2005). So, the toxicity happens at high concentrations due to replacement of sulfur with selenium in amino acids resulting in incorrect folding of the protein and consequently non-functional proteins and enzymes (Nowak et al. 2004). Increased, selenium acts as a pro-oxidant, inhibiting growth and germination of seeds and reducing yields (Carvalho et al. 2003). Selenium levels lower than 1 mg kg^{-1} in the soil can enhance the plant growth because selenium acts as an antioxidant to reduce lipid peroxidation and increase GPx activity (Hartikainen et al. 2000). Low content of selenate under 20 μM may be beneficial to the overall growth and metabolism in wheat seedlings (Ghosh et al. 2013).

Selenium has a positive influence on changes in the activity and permeability of the cellular membrane (Filek et al. 2008) and acts as a cofactor of the enzyme glutathione peroxidase that catalyzes the reduction of peroxides (Cartes et al. 2005). Selenium protects plants from several abiotic stresses and counteracts oxidative stress by inhibiting lipid peroxidation (Djanaguiraman et al. 2005). Selenium was able to promote the growth and development of rice plants and increased the antioxidant capacity of plants subjected to stresses (Peng et al. 2002). It has the ability to increase plant tolerance to oxidative stress, delay senescence, and promotes the growth of aging seedlings (Xue et al. 2001; Pennanen et al. 2002).

This work aimed to study the promotive effect of glutathione (100, 200, 300 mg/l) and/or selenium (5, 10 mg/l) on the growth, quality, and quantity of three wheat cultivars grown under the environmental conditions of the Nubaria region.

Methods

Two field experiments were carried out at the experimental station of Agricultural Production and Research Station, National Research Centre, El Nubaria Province, El Behaira Governorate, Egypt, during two successive winter seasons 2016/2017 and 2017/2018. The soil texture of the experimental site was sandy soil and having the following characteristics: sand 85.3%, silt 10.7%, clay 4%, pH 7.84%, $CaCO_3$, 1.0%, EC and 3.95ds/m and the available total N, P, and K were 8.0, 3.0, and 19.8 ppm, respectively, at 30 cm depth according to the method described by Chapman and Pratt (1978).

The experimental design was split-split plot design with three replicates. The three wheat cultivars (Egypt-2, Shadaweel-1, and Gemmiza-11) occupy the main plots, and the treatments of selenium levels (0.0, 5.0, and 10.0 mg/l) were allocated at random in the sub-plots while the glutathione foliar treatments at rates of 0.0, 100, 200, and 300 mg/l were distributed randomly in sub-sub plots.

Three wheat cultivars (Egypt-2; Shandaweel-1; Gemmiza-11) were obtained from Egyptian Ministry of Agriculture. Soil was plowed twice, ridged, and divided into plots during seed preparation. The area of each plot was 10.5 m^2 (15 rows; 3.5 m long and 20 cm apart between rows). The normal agronomic practices of growing wheat were carried out from sowing till harvest as recommended by wheat research Department Egyptian Ministry of Agriculture. During sowing150 kg calcium super phosphate/fed (15.5% P_2O_5) was used as a general application. Fifty kilograms potassium sulfate (48% K_2O)/fed was added after 30 days from sowing. One hundred twenty kilograms N/fed as ammonium sulfate (20.6% N) was added in six equal doses after complete germination and every 2 weeks till the beginning spike emergence stage. Wheat grains were drilled at a seed rate of 60 kg/fed, during the first week of December for two successive growing seasons. The plants were sprayed on both surfaces of the leaves with different concentrations of glutathione at 100, 200, and 300 mg/l and selenium at 5 and 10 mg/l twice at 30 and 45 days from planting. The experimental design was a randomized complete block design with four replicates.

Growth parameters

Samples of ten guarded plants were taken at random from each plot of the four replications for determination of vegetative growth parameters at 60 days after sowing. The following characteristics were determined: shoot height, leaves number/teller, and fresh and dry weight of shoot. Dry weight was determined after drying in a forced oven at 70 °C till constant weight.

Yield and yield components

At harvest, 1 m^2 from each plot was counted to determine shoot height, number of spikes/m^2, spike length, number of spikelets per spike, grain and straw yield/teller, biological yield/teller, grain index, biological yield (ton/fed), and grain yield (ton/fed). The collected grains were cleaned and dried then ground to a fine powder for determination of some biochemical constituents.

Biochemical constituents

Photosynthetic pigments (chlorophyll a, chlorophyll b, and carotenoids) and indole acetic acid were determined in fresh wheat leaves at 60 days after sowing spectrophotometrically as method recommended by Moran (1982) and Larsen et al. (1962), respectively. Total carbohydrates were determined in fine powdered wheat grains according to Dubois et al. (1956). Phenolic compounds were estimated in dry leaf (at 60 days after sowing) and yielded grains according to Zhang and Wang (2001) by using Folin and Ciocalteu phenol reagent. Total flavonoid contents were measured by the aluminum chloride colorimetric assay as described by Ordoñez et al. (2006).

Statistical analysis

Combined analysis of variance of RCPD using split-split plot design system for the wheat cultivars, substances, and their concentrations across the two seasons were performed using SAS ® (Littell et al. 1996). Least significant differences (LSD) were calculated according to Steel et al. (1997).

Results

Vegetative growth parameters

Table 1 present the role of foliar treatment of glutathione levels and/or selenium on vegetative growth parameters of three wheat cultivars (Egypt-2, Shandaweel-1, Gemmiza-11). Different concentrations of selenium (5 and 10 mg/l) and/or glutathione (100, 200, and 300 mg/l) caused significant increases in different vegetative growth parameters as compared with their corresponding controls of the three wheat cultivars. Glutathione foliar treatment at 300 mg/l or selenium at 10 mg/l caused the highest significant increases in shoot dry weight/plant of three wheat cultivars relative to other levels. Moreover, glutathione at 300 mg/l was more effective than selenium at 10 mg/l in increasing shoot dry weight of three cultivars. Regarding the interaction effect between two antioxidants on three wheat cultivars, data clearly show that interaction between glutathione and selenium with different levels caused significant increases in most of the studied parameters. The most significant increase in shoot dry weight of three cultivars was appeared by interaction between glutathione at 300 mg/l and selenium at 10 mg/l followed by interaction between glutathione at 300 mg/l and selenium at 5 mg/l. Interaction between glutathione at 300 mg/l and selenium at 10 mg/l increased shoot dry weight of Egypt-2 by 37.83%, Shandaweel-1 by 77.77%, and Gemmiza-11 by 51.28% relative to corresponding controls.

Photosynthetic pigments

Data presented in Table 2 show the effect of foliar treatment of different levels of glutathione and/or selenium on different components of photosynthetic pigments of three wheat cultivars (Egypt-2, Shandaweel-1, Gemmiza-11). It is obvious that selenium and glutathione treatments individually with different concentrations caused significant increases in photosynthetic pigment constituents as compared with untreated controls of the three cultivars. Glutathione at 300 mg/l was the optimum treatment in increasing total photosynthetic pigments as compared to glutathione treatment at 100 and 200 mg/l in three wheat cultivars. Meanwhile, selenium treatment

Table 1 Effect of glutathione and/or selenium on vegetative growth parameters of three wheat cultivars grown under conditions of the Nubaria region

Cultivars	Selenium (mg/l)	Glutathione (mg/l)	Shoot height (cm)	Number of leaves/teller	Fresh weight of shoot (g)	Dry weight of shoot (g)
Egypt-2	**0**	**0**	**39.33**	**4.00**	**4.44**	**1.48**
		100	**45.67**	**4.33**	**6.31**	**1.53**
		200	**50.67**	**5.00**	**6.52**	**1.64**
		300	**74.0**	**6.00**	**9.12**	**1.89**
	5	**0**	**55.00**	**4.33**	**6.92**	**1.69**
		100	**57.67**	**5.00**	**8.33**	**1.93**
		200	**71.33**	**5.00**	**8.75**	**1.95**
		300	**71.67**	**6.00**	**8.84**	**1.99**
	10	**0**	**56.67**	**4.33**	**7.70**	**1.73**
		100	**67.33**	**4.57**	**8.74**	**1.82**
		200	**73.67**	**4.67**	**8.81**	**1.92**
		300	**74.67**	**5.67**	**9.34**	**2.04**
Shandaweel-1	**0**	**0**	**47.33**	**4.33**	**5.19**	**1.62**
		100	**71.0**	**5.00**	**6.00**	**1.89**
		200	**76.33**	**5.33**	**8.59**	**1.90**
		300	**81.0**	**5.67**	**10.16**	**2.01**
	5	**0**	**51.67**	**5.00**	**6.73**	**1.73**
		100	**68.00**	**5.33**	**8.35**	**1.95**
		200	**78.33**	**5.67**	**10.51**	**2.48**
		300	**91.33**	**6.00**	**18.38**	**2.84**
	10	**0**	**53.33**	**5.00**	**6.76**	**1.84**
		100	**78.00**	**5.00**	**8.65**	**1.90**
		200	**78.67**	**5.33**	**10.96**	**2.31**
		300	**95.33**	**6.33**	**16.58**	**2.88**
Gemmiza-11	**0**	**0**	**78.33**	**4.67**	**9.55**	**3.12**
		100	**83.00**	**5.67**	**12.66**	**3.45**
		200	**89.00**	**5.67**	**14.51**	**3.75**
		300	**93.00**	**5.67**	**17.11**	**3.95**
	5	**0**	**87.00**	**5.00**	**11.32**	**3.27**
		100	**86.00**	**5.33**	**14.22**	**3.22**
		200	**90.00**	**5.67**	**15.68**	**3.45**
		300	**89.67**	**6.0**	**16.48**	**4.64**
	10	**0**	**76.00**	**5.00**	**11.94**	**3.43**
		100	**80.00**	**5.67**	**12.47**	**3.66**
		200	**90.00**	**6.0**	**14.15**	**3.86**
		300	**94.00**	**6.0**	**17.55**	**4.72**
$LSD_{0.05}$			**3.20**	**0.61**	**1.01**	**0.33**

at 10 mg/l was better than selenium treatment at 5 mg/l in increasing total photosynthetic pigments. It is clear that glutathione treatment at 300 mg/l was more effective than 10 mg/l selenium in increasing total photosynthetic pigments of three cultivars. Regarding the interaction effect between two antioxidants on three wheat cultivars, it was clear that interaction between glutathione at 300 mg/l and selenium at 10 mg/l significantly increased total photosynthetic pigments as compared with other interaction treatments in three wheat cultivars. Interaction between glutathione at 300 mg/l and selenium at 10 mg/l increased the total

Table 2 Effect of glutathione and/or selenium on photosynthetic pigments (mg/g fresh leaf) of three wheat cultivars grown under conditions of the Nubaria region

Cultivars	Selenium (mg/l)	Glutathione (mg/l)	Chlorophyll a	Chlorophyll b	Carotenoid	Total photosynthetic pigments
Egypt-2	**0**	**0**	**0.93**	**0.48**	**0.24**	**1.65**
		100	**1.06**	**0.53**	**0.27**	**1.86**
		200	**1.12**	**0.60**	**0.28**	**2.00**
		300	**1.16**	**0.73**	**0.30**	**2.19**
	5	**0**	**1.02**	**0.54**	**0.24**	**1.80**
		100	**1.23**	**0.64**	**0.32**	**2.19**
		200	**1.28**	**0.66**	**0.34**	**2.28**
		300	**1.33**	**0.72**	**0.35**	**2.43**
	10	**0**	**1.19**	**0.65**	**0.29**	**2.13**
		100	**1.23**	**0.69**	**0.31**	**2.23**
		200	**1.31**	**0.73**	**0.32**	**2.36**
		300	**1.36**	**0.73**	**0.42**	**2.48**
Shadaweel-1	**0**	**0**	**0.98**	**0.54**	**0.30**	**1.82**
		100	**1.21**	**0.61**	**0.36**	**2.18**
		200	**1.23**	**0.65**	**0.36**	**2.24**
		300	**1.40**	**0.68**	**0.40**	**2.48**
	5	**0**	**1.39**	**0.68**	**0.38**	**2.45**
		100	**1.43**	**0.69**	**0.38**	**2.50**
		200	**1.44**	**0.70**	**0.42**	**2.56**
		300	**1.46**	**0.76**	**0.49**	**2.71**
	10	**0**	**1.50**	**0.70**	**0.29**	**2.49**
		100	**1.51**	**0.73**	**0.36**	**2.60**
		200	**1.54**	**0.77**	**0.39**	**2.70**
		300	**1.54**	**0.79**	**0.45**	**2.78**
Gemmiza-11	**0**	**0**	**1.32**	**0.63**	**0.34**	**2.29**
		100	**1.41**	**0.68**	**0.41**	**2.50**
		200	**1.44**	**0.76**	**0.45**	**2.65**
		300	**1.50**	**0.77**	**0.46**	**2.79**
	5	**0**	**1.40**	**0.66**	**0.33**	**2.39**
		100	**1.47**	**0.74**	**0.37**	**2.58**
		200	**1.62**	**0.63**	**0.40**	**2.65**
		300	**1.73**	**0.69**	**0.40**	**2.82**
	10	**0**	**1.45**	**0.69**	**0.33**	**2.47**
		100	**1.48**	**0.73**	**0.37**	**2.58**
		200	**1.73**	**0.77**	**0.39**	**2.89**
		300	**1.86**	**0.83**	**0.43**	**3.06**
$LSD_{0.05}$			**0.18**	**0.21**	**0.08**	**0.22**

photosynthetic pigments of Egypt-2 by 50.30%, Shandaweel-1 by 52.74%, and Gemmiza-11 by 33.62% relative to corresponding controls. It is worthy to mention that the results of photosynthetic pigments (Table 2) are in harmony with the vegetative growth parameters (Table 1).

Yield and its components

Data presented in Table 3 show that foliar treatment of different concentrations of glutathione and/or selenium significantly increased wheat grain yield and most of its components (shoot height, spike length, number of spikelets/spike, biological yield/teller, grain yield/teller,

Table 3 Effect of glutathione and/or selenium on grain yield and yield components of three wheat cultivars grown under conditions of the Nubaria region

Cultivars	Selenium (mg/l)	Glutathione (mg/l)	Shoot height (cm)	Number spikes/ m^2	Spike length (cm)	Number of spikelets /spike	Biological yield/teller (g)	Grain yield/ teller (g)	Straw yield/ teller (g)	Grains index (g)	Biological yield (ton/ fed)	Grain yield (ton/fed)
Egypt-2	0	0	71.00	1.00	9.83	16.33	5.37	1.70	3.67	3.60	1.87	0.899
		100	81.67	1.67	11.33	17.33	6.63	2.00	4.63	3.70	2.17	0.974
		200	86.00	1.67	11.50	18.33	6.86	2.03	4.83	4.10	2.27	0.987
		300	86.33	2.00	13.33	18.67	7.47	2.07	5.40	4.20	2.4	1.095
	5	0	85.00	1.67	12.67	18.33	7.70	2.93	4.77	3.75	1.97	1.003
		100	88.67	1.67	14.00	20.00	11.13	3.23	7.90	4.30	2.97	1.129
		200	91.00	2.00	14.33	20.67	12.33	3.40	8.93	4.30	3.40	1.366
		300	91.67	2.00	14.67	23.00	14.47	4.10	10.37	4.40	4.13	1.603
	10	0	90.00	2.00	8.67	12.17	8.50	3.53	4.97	4.10	3.07	1.290
		100	91.00	2.00	10.67	18.67	9.47	4.17	5.30	4.40	3.81	1.695
		200	92.00	1.67	13.00	19.67	12.83	4.30	8.53	4.50	4.02	1.802
		300	96.00	2.00	13.67	20.33	14.07	5.00	9.07	4.57	4.09	2.039
Shadaweel-1	0	0	61.33	1.00	10.33	17.00	7.10	2.77	4.33	3.80	1.93	0.940
		100	73.67	1.33	12.33	17.33	8.87	3.50	5.37	4.10	2.03	1.056
		200	74.67	2.00	12.67	19.33	9.97	3.60	6.37	4.40	2.23	1.323
		300	81.33	1.67	13.00	20.33	12.60	4.30	8.30	4.70	2.55	1.538
	5	0	81.00	1.67	13.00	19.33	9.27	3.50	5.77	3.80	2.25	1.118
		100	90.33	1.67	13.17	20.67	10.97	3.77	7.20	3.90	2.73	1.284
		200	94.33	2.00	14.00	22.00	12.74	4.37	8.37	4.00	2.97	1.642
		300	95.67	2.00	14.00	22.00	14.16	4.63	9.53	4.50	4.33	1.684
	10	0	82.67	2.00	12.00	18.33	9.90	4.07	5.83	3.80	2.47	1.364
		100	84.00	1.33	12.50	19.67	11.30	4.23	7.07	3.90	2.93	1.665
		200	89.67	1.67	13.67	20.67	11.97	4.37	7.60	4.30	3.41	2.097
		300	98.33	2.33	13.00	21.67	13.51	4.78	8.73	4.60	4.07	2.214
Gemmiza-11	0	0	70.00	1.00	11.33	16.33	9.70	3.80	5.90	5.00	1.98	0.99
		100	83.00	2.00	13.00	17.33	11.67	4.80	6.87	5.10	2.23	1.280
		200	86.67	2.00	13.00	19.33	14.50	5.10	9.40	5.70	2.50	1.388
		300	94.67	2.00	16.50	22.33	15.34	5.17	10.17	6.00	2.85	1.803
	5	0	82.00	2.00	12.00	16.67	9.60	3.87	5.73	5.00	2.08	1.264
		100	89.00	2.00	14.00	17.33	12.67	3.90	8.77	5.30	2.57	1.381
		200	91.33	2.00	18.17	18.67	15.70	4.87	10.83	5.60	3.27	1.657
		300	97.00	2.33	18.83	21.33	18.63	6.93	11.70	6.10	3.83	1.899
	10	0	86.00	2.00	13.00	17.33	14.26	4.83	9.43	5.50	2.47	1.383
		100	94.00	2.00	14.03	17.67	15.60	5.30	10.30	5.90	3.83	2.089
		200	84.67	2.00	14.33	21.00	20.63	6.73	13.90	6.00	4.15	2.119
		300	95.00	2.00	17.00	24.67	22.80	7.07	15.73	6.00	4.41	2.235
$LSD_{0.05}$			2.13	n.s	0.23	1.08	1.01	0.15	0.21	0.11	0.18	0.088

straw yield/teller, grains index, biological yield (ton/fed), and grain yield (ton/fed) of three wheat cultivars (Egypt-2, Shandaweel-1, Gemmiza-11)). Data obviously show that three cultivars showed variations in grain yield and its components where the grain yield of Gemmeiza-11 (0.99 ton/fed) > grain yield of Shandaweel-1 (0.94 ton/fed) > grain yield of Egypt-2 (0.89 ton/fed). It was noted that glutathione treatment at 300 mg/l or selenium treatment at 10 mg/l individually showed the highest significant increase in grain yield (ton/fed) as compared to the other individual treatments. Regarding the interaction effect between two antioxidants on three wheat cultivars, glutathione treatments at 200 or 300 mg/l which interacted with selenium treatment at 10 mg/l showed significant increases in grain yield and its components as compared with individual or combined treatments in three wheat cultivars. Interaction between glutathione at 300 mg/l and selenium at 10 mg/l increased grain yield (ton/fed) of Egypt-2 by 126.81%, Shandaweel-1 by 135.53%, and Gemmiza-11 by 137.37% relative to corresponding controls.

Biochemical constituents

Data presented in Table 4 show that foliar treatment of different concentrations of glutathione and/or selenium increased IAA and phenolic content (in fresh and dry leaf at 60 days after sowing) as well as the contents of carbohydrate, flavonoid, and total phenolic in the yielded grains of three wheat cultivars under investigation. Data showed that different concentrations of selenium and/or glutathione increased IAA, carbohydrate content, flavonoid, and phenolic content as compared to the corresponding controls of each wheat cultivar. Moreover, data show that either glutathione at 300 mg/l or selenium at 10 mg/l significantly increased the value of IAA, carbohydrate content, flavonoid, and phenolic content as compared to the corresponding controls. Regarding interaction effect between two antioxidants on three wheat cultivars, it is obvious that the highest increases in IAA, phenolic content in the leaves, and the content of carbohydrate, flavonoid, and phenolic content in the yielded grains appeared by the interaction between glutathione at 300 mg/l and selenium at 10 mg/l in the three wheat cultivars under investigation.

Discussions

Vegetative growth parameters

The three wheat cultivars showed significant variations in vegetative growth parameters (Table 1). These variations may be attributed to the differences in genetic structure as reported by Clark et al. (1997). The significant increases in vegetative growth parameters due to glutathione treatments are in agreement with those reported by Ghoname et al. (2010) on hot pepper under newly reclaimed sandy soil and Abd Elhamid et al. (2018) on chickpea plant under salinity stress. Sanchez-Fernandez et al. (1997) mentioned that this increased growth by glutathione can be attributed to the improved cell division. Noctor et al. (2012) reflected that plants cannot survive without glutathione which affects plant development, not by other thiols or antioxidants.

Selenium treatments individually or in combination with glutathione increased vegetative growth parameters of three wheat cultivars. Similarly, Djanaguiraman et al. (2005) stated that selenium promotes the growth and development of soybean plants by improving tolerance and antioxidant capacity of plants. Moreover, plant growth promotion by selenium application might be due to the increase in starch accumulation in chloroplasts and protected cell content (Xue et al. 2001). Moreover, Fernandez et al. (2013) mentioned that selenium has a positive impact on the activity and permeability of the cellular membrane and improved cell growth. Hawrylak et al. (2010) stated that cucumber plants treated with selenium and subjected to low temperature grew better than plants grown without the addition of selenium. Selenium addition is preferable for the growth of wheat seedlings under drought conditions; however, growth and physiological responses of seedlings were different depending on the selenium content (Yao et al. 2009).

Photosynthetic pigments

The obtained results showed that all applied treatments had a promoting influence on the photosynthetic pigment, and this effect depends on the levels of glutathione and selenium (Table 2). Generally an increase in chlorophyll content may be the result of the increase in carotenoids which protects chlorophyll from photooxidative destruction (Singh 1996). Glutathione enhances the biosynthesis of photosynthetic pigments or retard chlorophyll degradation and integrated into primary metabolism (Khattab 2007).

The promoting effect of selenium on the content of photosynthetic pigments may be attributed to the role of selenium in stimulating the respiration rates and flow of electrons in the respiratory chain and accelerating the chlorophyll biosynthesis (Germ et al. 2005). Also, an increase in chlorophyll contents of wheat seedlings may be resulted by selenium effect on the protection of chloroplast enzymes and, thus, increasing the biosynthesis of photosynthetic pigments (Pennanen et al. 2002).

Yield and its components

Selecting tolerant wheat cultivar is one of the most important factors for increasing wheat production, where they differ in grain yield and its components (Sultan et al. 2000).

The obtained results showed that all applied treatments had a promoting effect on the grain yield and its components (Table 3). The stimulative effect of glutathione could be explained by Buwalda et al. (1990) who indicated that the promotion effect of glutathione might be due to its effect as a reservoir of reduced sulfur as the amino acid cysteine which is a component of the antioxidant glutathione. The greatest number of spikes/plant and the number of grains/plant by glutathione treatments may be a cause of their higher yield and as such spikes are a more efficient sink for the carbohydrate

Table 4 Effect of glutathione and/or selenium on some biochemical constituents of three wheat cultivars grown under conditions of the Nubaria region

Cultivars	Selenium (mg/l)	Glutathione (mg/l)	IAA (Ug/100 g)	Phenolic content (mg/g)	Carbohydrate content (%)	Flavonoids (mg/100 g)	Phenolic content (mg/100 g)
			In leaves		In grains		
Egypt-2	**0**	**0**	**12.95**	**12.26**	**64.10**	**42.50**	**95.20**
		100	**27.17**	**14.37**	**64.31**	**48.99**	**109.73**
		200	**32.26**	**16.43**	**65.00**	**53.58**	**120.02**
		300	**35.24**	**18.31**	**65.86**	**65.60**	**146.94**
	5	**0**	**17.07**	**17.42**	**64.33**	**46.10**	**103.26**
		100	**30.39**	**24.42**	**64.60**	**57.45**	**128.69**
		200	**48.79**	**39.87**	**65.60**	**63.44**	**142.09**
		300	**57.93**	**41.82**	**66.10**	**68.97**	**154.48**
	10	**0**	**19.52**	**21.43**	**65.77**	**59.59**	**133.47**
		100	**31.31**	**30.96**	**66.59**	**73.45**	**164.52**
		200	**44.56**	**40.98**	**66.92**	**81.30**	**182.11**
		300	**62.85**	**43.32**	**67.64**	**89.65**	**200.82**
Shadaweel-1	**0**	**0**	**25.23**	**35.37**	**70.83**	**34.72**	**77.76**
		100	**35.37**	**41.43**	**73.03**	**42.45**	**95.08**
		200	**43.37**	**41.76**	**73.60**	**51.40**	**115.12**
		300	**48.74**	**44.43**	**73.98**	**59.61**	**133.53**
	5	**0**	**30.76**	**31.48**	**71.53**	**48.55**	**108.75**
		100	**45.93**	**52.32**	**74.10**	**56.75**	**127.12**
		200	**65.93**	**60.93**	**75.29**	**62.60**	**140.22**
		300	**66.37**	**66.37**	**75.77**	**69.70**	**156.13**
	10	**0**	**43.26**	**53.37**	**72.47**	**63.15**	**141.46**
		100	**47.37**	**55.93**	**75.56**	**68.72**	**153.92**
		200	**61.98**	**59.32**	**76.66**	**75.65**	**169.46**
		300	**63.98**	**67.43**	**77.60**	**81.78**	**183.19**
Gemmiza-11	**0**	**0**	**25.32**	**25.26**	**73.06**	**42.42**	**95.02**
		100	**31.82**	**29.37**	**74.32**	**48.70**	**109.09**
		200	**32.82**	**34.87**	**75.08**	**52.50**	**117.60**
		300	**35.87**	**35.98**	**75.41**	**56.95**	**127.57**
	5	**0**	**31.15**	**32.87**	**75.02**	**51.92**	**116.30**
		100	**32.87**	**34.32**	**75.38**	**56.75**	**127.12**
		200	**38.93**	**35.26**	**76.84**	**61.80**	**138.43**
		300	**40.87**	**43.43**	**77.45**	**68.55**	**153.55**
	10	**0**	**34.21**	**35.26**	**77.05**	**59.65**	**133.62**
		100	**40.76**	**42.32**	**76.53**	**63.44**	**142.09**
		200	**44.76**	**50.76**	**77.20**	**69.25**	**155.12**
		300	**49.26**	**54.82**	**78.03**	**75.75**	**169.68**
$LSD_{0.05}$			**1.15**	**1.22**	**2.33**	**2.18**	**5.070**

synthesized in the grains (Ahmed 1985). Moreover, Glutathione enhances the chlorophyll biosynthesis or decreases its degradation and integrated into primary metabolism, and it can affect the functioning of the signal transduction pathway by modulating cellular redox state (Khattab 2007) and thus return in increasing crop yield.

Regarding selenium effect, similar results were previously reported by Faraj (2016) who reported that selenium treatments increased 1000 grain weight by 20%, grain number per spike by 30%, and spike number per square meter by 11%. These trends may attribute to improve root system absorption ability and then encourage cell division which increased tillers per plant and spike number per square meter. It is known that selenium improves the viability of germ cells which increased fertilization probability and then increased grain number per spike. Also, available selenium in plant tissues improves the absorption of minerals and accumulation later in grain (Marja et al. 2004). Moreover, Teimouri et al. (2014) demonstrated that selenium foliar spraying on wheat could increase physiological growth indices and flowering stages that reflected on yield. The application of selenium improved dry matter and grain yield in two wheat genotypes under well-watered and drought conditions (Hajiboland et al. 2015). Due to its ability to increase the antioxidant defense of plants (Hasanuzzaman and Fujita 2011), selenium has been found to delay plant senescence (Hartikainen et al. 2000) and fruit ripening (Zhu et al. 2016; Zhu et al. 2017) in several horticultural species, which could lead to a decreased postharvest loss.

It is obviously clear that there is a close relationship between the enhancement effects of different treatments on growth parameters (Table 1) and total photosynthetic pigments (Table 2) that reflect on the increase in wheat yield (Table 3). These enhancements might be attributed to the physiological roles of such substances such as antioxidants and having the power to increase the amount of assimilates and increasing their translocations from leaves to grains.

Chemical constituents

The obtained results showed that all applied treatments had a promoting effect on the content of IAA, carbohydrate, flavonoid, and total phenolic of three wheat cultivars as shown in Table 4. The importance of glutathione comes from its role in different biosynthetic pathways, detoxification process, antioxidant biochemistry, and redox homeostasis (Noctor et al. 2012). Graham and Graham (1996) found that applying glutathione led to an increase in the phenolic polymer content in the soybean plant. Khattab (2007) reported that priming of canola seeds by soaking in glutathione stimulates the accumulation of phenolics under stress conditions. Moreover, Sadak et al. (2017) showed that treated chickpea plants with glutathione improved phenolic contents. Tallat and Aziz (2005) mentioned that foliar application of glutathione to chamomile plants significantly increased total sugars as well as total nitrogen in the herb.

Selenium is a cofactor of glutathione peroxidase and may play an important role against oxidative tissue damage (Ferrarese et al. 2012) and plays a role in the activation of fructose 1,6 bisphosphatase in alfalfa (Owusu-Sekyere et al. 2013) and a concomitant activation of NO_3 and CO_2 assimilation rate in wheat (Hajiboland and Sadeghzadeh 2014). Gul et al. (2017) suggested that selenium applied at 10 mM showed better performance on different biochemical attributes in both saline and non-saline conditions. Additionally, selenium treatments significantly increased the contents of flavonoids and phenolic compounds of wheat seedlings subjected to cold stress which have the ability to scavenge free radicals and inhibit membrane lipid peroxidation of seedlings (Chu et al. 2010). Poldmai et al. (2013) showed an increase in total phenolics in onion bulbs with selenium treatment. At an optimal level, selenium appears to promote expanding leaves in lettuce that act as strong sinks for carbohydrates (Xue et al. 2001).

Conclusion

Finally, we can conclude that Gemmeiza-11 cultivar was superior over Shandaweel-1 and Egypt-2 cultivars. It is obvious that the grain yield of Gemmeiza-11 gave the highest grain yield under Nubaria conditions. Glutathione treatments at 200 or 300 mg/l which interacted with selenium treatment at 10 mg/l showed the highest significant increases in grain yield and its components.

Abbreviations

IAA: Indole acetic acid; DNA: Deoxyribonucleic acid; GSH: Reduced glutathione; ROS: Reactive oxygen species

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Authors' contributions

MGD designed and performed the experiment and was responsible for all the physiological and biochemical analyses. MShS designed and performed the experiment and was responsible for all the physiological and biochemical analyses. BAB and HHK designed and farmed the plants and contributed to the statistical analysis. All authors wrote and reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

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Ethics approval and consent to participate

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Consent for publication

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Competing interests

The authors declare that they have no competing interests.

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