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Biochemical Response of Okra (*Abelmoschus esculentus* L.) to Selenium (Se) under Drought Stress

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Abstract: Drought stress restricts the growth of okra (*Abelmoschus esculentus* L.) by disrupting its biochemical and physiological functions. The current study was conducted to evaluate the role of selenium (0, 1, 2, and 3 mg Se L^{-1} as a foliar application) in improving okra tolerance to drought (control (100% field capacity-FC), mild stress (70% FC), and severe stress (35% FC)) imposed 30 days after sowing (DAS). Drought (severe) markedly decreased chlorophyll (32.21%) and carotenoid (39.6%) contents but increased anthocyanin (40%), proline (46.8%), peroxidase (POD by 12.5%), ascorbate peroxidase (APX by 11.9%), and catalase (CAT by 14%) activities. Overall, Se application significantly alleviated drought stress-related biochemical disturbances in okra. Mainly, 3 mg Se L^{-1} significantly increased chlorophyll (21%) as well as anthocyanin (15.14%), proline (18.16%), and antioxidant activities both under drought and control conditions. Selenium played a beneficial role in reducing damage caused by oxidative stress, enhancing chlorophyll and antioxidants contents, and improved plant tolerance to drought stress. Therefore, crops including okra especially, must be supplemented with 3 mg L^{-1} foliar Se for obtaining optimum yield in arid and semiarid drought-affected areas.

Keywords: abiotic stress; antioxidant activity; micronutrient; photosynthetic pigments; phenols

1. Introduction

Climate change has become a major threat to food security and has created a big problem for economic growth in many countries [1–4]. Additionally, climate change has fashioned the hazard of risky events such as drought [5,6]. Drought causes a decline in crop production worldwide [7,8]. Drought limits a crop species and genetic potential throughout the life cycle [9]. It not only harms drought-sensitive plants at the vegetative level, but also prevents drought-resistant plants from reproducing or reproductive development [8,10]. Active oxygen forms generated under drought stress cause oxidative stress, which ultimately retards photosynthesis, respiration, and plant growth by damaging many cellular constituents such as lipids, carbohydrates, proteins, and nucleic acids [11–15]. Moreover, it alters the developmental process by driving plants to a defensive state where plant productivity is hindered in the long run [16]. Plants can adapt to water stress through osmotic adjustment, desiccation protection, and metabolic changes [17–19]. Under slight stress conditions, osmotic adjustment plays a vital role [20,21]. When more severe stress desiccation occurs, the accumulation of desiccation protectants such as late embryogenesis abundant (LEA) proteins and sugars avoids damage to biomacromolecules, especially membrane systems, to some extent. Long-term mild water stress may change plant metabolic pathways, which is useful for plants to adapt to stress conditions [22,23].

Plants adapt and adjust themselves to the drought condition by protein and osmolyte accumulation [24–26]. These accumulated osmolytes and proteins behave as an osmotic readjustment promoter, which improves the osmotic equilibrium and reduces cell injury during water scarcity [27]. These osmolytes are composed of amino acids such as proline, which help to adapt to drought conditions [28]. Furthermore, morphological features such as thickness, depth, mass, and root development (such as the ability of the root to break the compacted soil layer) have a main role in minimizing stress resistance [29,30]. The exogenous application of various growth promoters has been evaluated across the globe to boost drought alleviation [11]. However, the use of such attributes is usually costly. Recently, much attention has been brought to the use of mineral supplements for stress resistance [31]. Under such conditions, selenium (Se), as an element with toxicological and physiological importance, is of high interest to many biologists [32]. It plays a crucial role in plant growth under various abiotic stressors via the enhancement of the amount of photosynthetic pigments, phenolic compounds, and antioxidant activity and the improvement of plant tolerance during water deficiency by regulating the water status [33,34].

Selenium (Se) used in low concentration has been demonstrated to improve crop productivity under environmental stressors [35]. Studies have shown that Se supplementation under abiotic stress elevates plant defense by the accumulation of plant osmolytes and higher antioxidant activity [36,37]. Nevertheless, Se-mediated alteration in water-related attributes and the collection of osmotic and water absorption competency under water-deficit conditions stay unidentified and the achieved outcomes are also inconsistent. The enhancement in proline accumulation under Se application has also been evaluated [38], while its application does not affect water intake capability [38,39].

Okra (*Abelmoschus esculentus* L.) is a common plant in the subcontinent and belongs to the Malvaceae family [40]. Okra is prone to different abiotic stressors such as water logging, cold temperatures, drought stress, and frost conditions. Okra cultivars have adopted certain behaviors based on the climatic conditions in which they grow [41]. Therefore, the present experiment was conducted to investigate the role of Se in alleviating drought stress in okra.

2. Materials and Methods

This study was conducted to evaluate the role of selenium (0, 1, 2, and 3 mg Se L^{-1} as a foliar application) in improving okra tolerance to drought (control (100% field capacity-FC), mild stress (70% FC), and severe stress (35% FC)) imposed 30 days after sowing (DAS). The okra cultivar Super Green was sown in pots (16 inches in diameter and 26 inches in height) at Agricultural Research Station Swabi (34° N, 72° E) in Khyber Pakhtunkhwa, Pakistan under a plastic tunnel. The soil used in the experiment was non-saline (0.49 d Sm^{-1}), alkaline (pH = 7.87), and clay loam in texture and low in organic matter (0.91%). Garden soil and farmyard manure (1:1) were used as the pot medium in equal amounts. The seeds of the cultivar were bought from Bayer Crop Science Pakistan (Pvt.) Ltd. The experiment was replicated three times using a two-factor completely randomized design.

Ten okra seeds were sown in each pot during spring. Four uniform and healthy okra plants (at the time the plants produced true leaves) were retained per pot after thinning. The pots were randomized periodically to maintain the statistical requirements and eliminate position effects. The mean air temperature and relative humidity during the experiment were 29 °C (maximum air temperature: 32.7 °C, minimum air temperature: 22.3 °C) and 70%, respectively. Recommended doses of N-P-K at rates of 150 kg N, 112 kg P_2O_5, and 75 kg K_2O were applied. Out of these doses, 30% of N and 50% of P and K were applied as the basal dose. The remaining 50% of P, 40% of N, and 25% of K were applied as the first top dressing four weeks after sowing. Drought stress (control (100% FC), mild stress (70% FC), and severe stress (35% FC)) was applied 30 days after sowing to establish the seedlings. The desired moisture stress was achieved by subjecting the plants to various levels of drought stress (70% and 35% of the field capacity). GS3 (Decagon Devices, Inc., USA) was used to determine the moisture content at the appropriate time in the soil. Plants under control conditions were regularly watered to achieve the optimum moisture of 100% of the field capacity during the experiment. The field capacity and permanent wilting point of the potting mixture were estimated as 39% and 20% of the soil's gravimetric moisture. Along with subjecting the plants to water deficit stress levels, they were treated with Se (1, 2, and 3 mg L^{-1}) by foliar application. A transparent polythene sheet (0.03 mm) was used for pot protection from rainfall. The recommended cultural practices as desired for pot experiments were adopted across the experiment.

2.1. Biochemical Attributes

Chlorophyll content was measured according to Yang et al. [42]. The proline content in the okra was determined according to Bates et al. [43]. The activity of APX was measured using the method described by Asada et al. [44] with slight modifications. The activities of CAT and POD were determined according to Chance et al. [45] with slight modifications. Anthocyanin content was extracted and estimated by the method described by Zhang et al. [46].

2.2. Statistical Analysis

The indicated data were subjected to an analysis of variance appropriate for CRD using Statistix 8.1 software packages (Statistix®; Analytical Software Inc., Tallahassee, FL, USA). Significant ($p < 0.05$) results were further subjected to least significant difference (LSD) testing according to Steel et al. [47].

3. Results

3.1. Chlorophyll Content

The analysis of variance indicated that drought stress, Se levels, and their interaction significantly affected total chlorophyll and chlorophyll-*a* and *b* as shown in Table 1. Maximum total chlorophyll content was observed at field capacity, while it was reduced under drought conditions; under mild 22.6% stress, decline occurred in the total chlorophyll content, whereas in plants under severe 32.21% stress, decline was noted. However, the foliar application of Se significantly increased chlorophyll content under both water-deficient and control conditions. Plants exposed to 1 mg Se L^{-1} had a 6.16% enhancement of total chlorophyll content, while plants exposed to 2 and 3 mg Se L^{-1} had increases of 12.48% and 20.98% in total chlorophyll content, respectively. Similarly, in the case of interaction, a 45.71% increase occurred. The maximum total chlorophyll content was observed under control conditions at 3 mg Se L^{-1} (Figure 1), while non-Se-treated plants under severe stress conditions showed the lowest amount of total chlorophyll. Overall, using 3 mg Se L^{-1} under control conditions or even under stress conditions produced a high level of total chlorophyll content with respect to treatments without augmentation.

Table 1. Effects of Se on the chlorophyll *a*, chlorophyll *b*, total chlorophyll, and carotenoid contents of okra under water deficit conditions.

Selenium (Se) (mg L^{-1})	**Total Chlorophyll (µg mL^{-1})**	**Chlorophyll *a* (µg mL^{-1})**	**Chlorophyll *b* (µg mL^{-1})**	**Carotenoid (µg mL^{-1})**
Control	36.263 d	24.076 d	12.188 d	7.630 d
1	38.648 c	25.803 c	12.844 c	8.460 c
2	41.432 b	27.502 b	13.930 b	9.564 b
3	45.883 a	30.013 a	15.870 a	11.360 a
LSD	1.2702 *	0.9678 *	0.4950 *	0.3224 *
Drought Stress (DS)				
Control	49.624 a	33.345 a	16.279 a	11.814 a
Mild stress	38.409 b	25.141 b	13.268 b	8.812 b
Severe stress	33.637 c	22.060 c	11.577 c	7.135 c
LSD	1.1000 *	8.8381 *	0.4290 *	0.2798 *
SE × DS	Figure 1	Figure 2	Figure 3	Figure 4

* Means followed by different letters in each column are significantly different from each other at 5% of the level of probability by the LSD test.

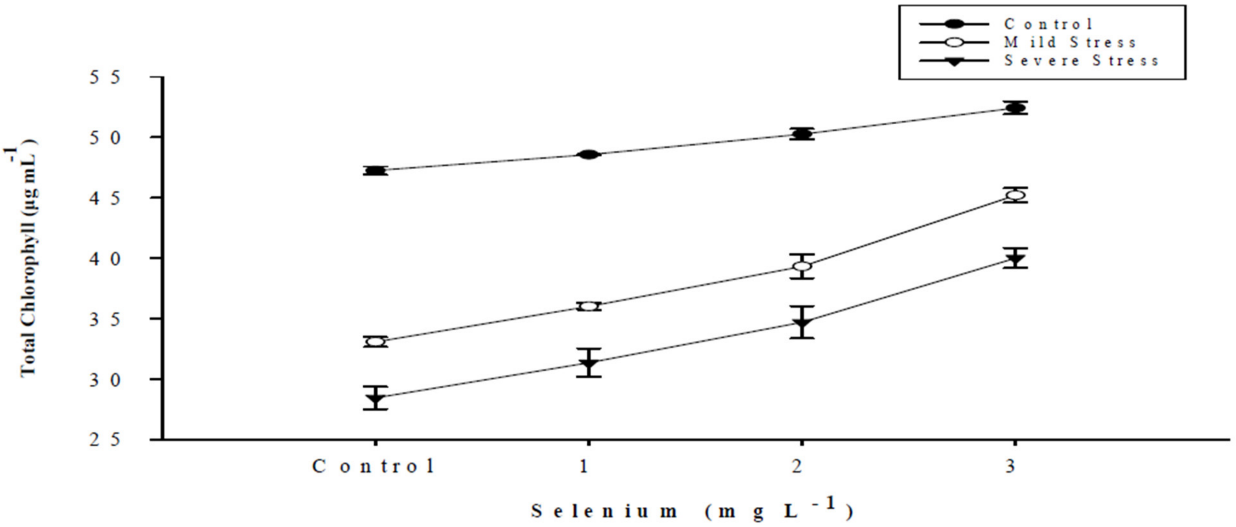

Figure 1. Effect of selenium (Se) on the total chlorophyll content of okra under drought stress.

The highest amount of chlorophyll *a* was observed at 100% FC, while it decreased under drought conditions. The reduction of chlorophyll *a* content under mild and severe stress conditions occurred by 24.60% and 33.84%, respectively, compared to the control. However, plants treated with the Se foliar application significantly increased their chlorophyll *a* content under both drought and control conditions. Plants exposed to 1 mg Se L^{-1} increased their chlorophyll *a* content by 6.96%, while plants treated with 2 and 3 mg Se L^{-1} increased their chlorophyll *a* content by 12.45% and 19.8%, respectively. Similarly, in the case of interaction, a 46.25% increase was observed at 3 mg Se L^{-1} under control conditions, as shown in Figure 2, while the lowest chlorophyll-*a* content was observed under severe stress conditions without Se treatment. In general, the application of 3 mg Se L^{-1} under control and stress conditions produced higher chlorophyll-a content than for the other treatments.

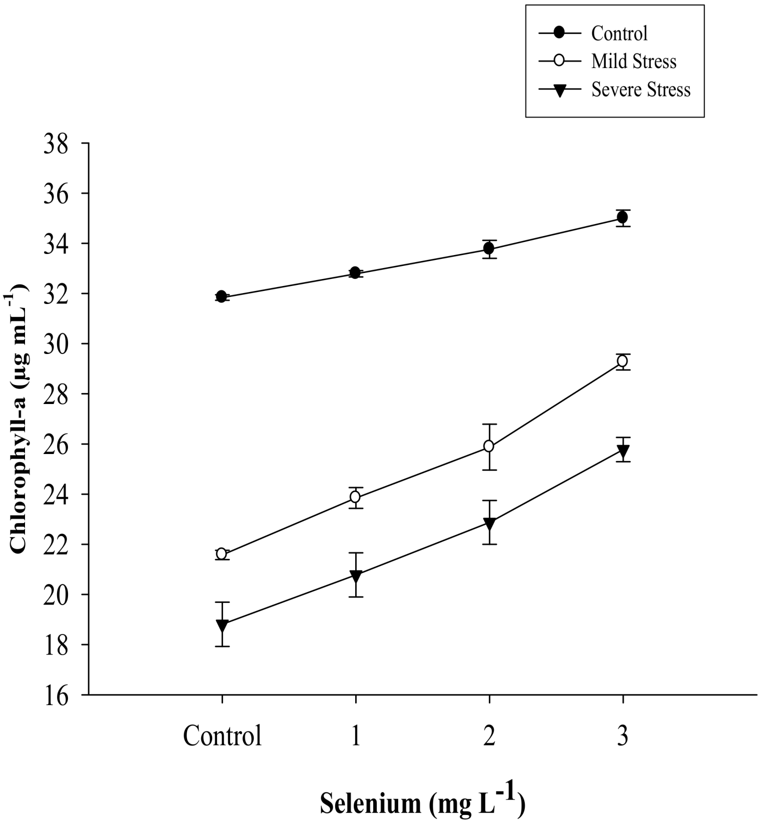

Figure 2. Effect of selenium (Se) on the chlorophyll-*a* content of okra under drought stress.

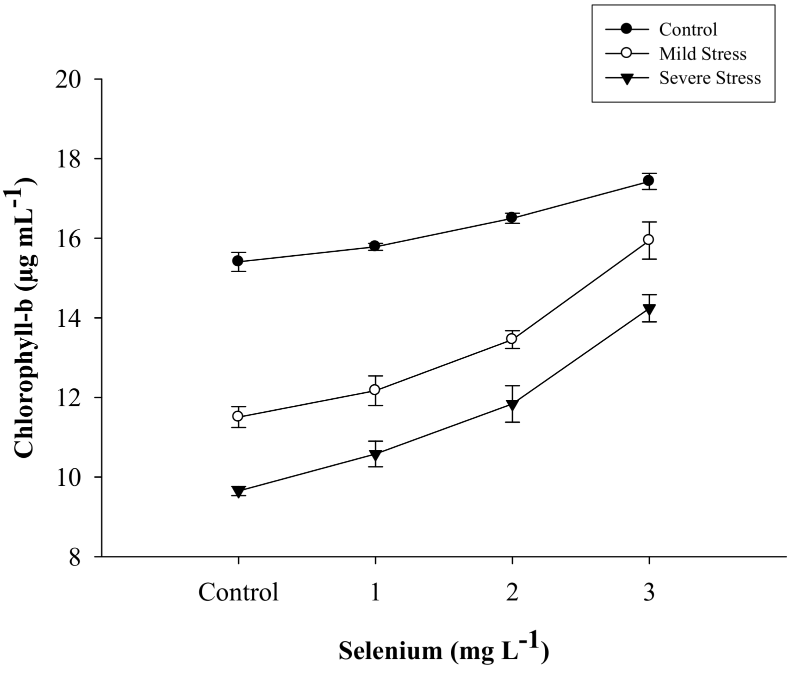

Figure 3. Effect of selenium (Se) on the chlorophyll-*b* content of okra under drought stress.

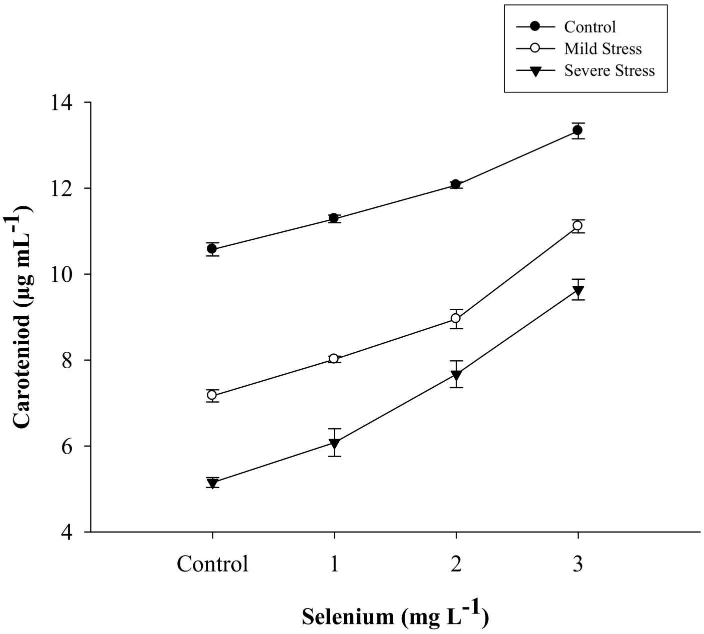

Figure 4. Effect of selenium (Se) on the carotenoid content of okra under drought stress.

Drought stress, Se levels, and their interaction exerted a significant effect on the plant chlorophyll-*b* content as presented in Table 1. Maximum chlorophyll-*b* content was observed in plants at 100% FC, which declined with inducing drought stress. Under mild stress, an 18.5% decline occurred in chlorophyll-*b* content, whereas in plants under severe stress, a 28.9% decline was noted. However, plants treated with Se significantly increased their chlorophyll *b* content under both water-deficient and normal conditions. Plants exposed to 1 mg Se L^{-1} had 5.11% enhanced chlorophyll-*b* content, while plants exposed to 2 and 3 mg Se L^{-1} had improved chlorophyll-b content by 12.5% and 23.2%, respectively. Similarly, in the case of interaction, a 44.62% increase occurred, at 3 mg Se L^{-1} under 100% FC as shown in Figure 3, while the lowest chlorophyll-*b* content was observed in plants without Se treatment under severe stress conditions. Overall, the 3 mg Se L^{-1} foliar application of Se produced a high level of chlorophyll-*b* content under drought stress.

3.2. Carotenoid Content

Carotenoid content was significantly affected by water stress, Se levels, and their interaction (Table 1). Maximum carotenoid content was observed at 100% FC, which was reduced with inducing drought conditions. Under mild stress, carotenoid content declined by 25.41%, while under severe stress, a 39.6% decline in plant carotenoid content was noted. However, plants treated with the Se foliar application significantly increased their carotenoid content irrespective of drought stress. Plants exposed to 1 mg Se L^{-1} improved in their carotenoid content by 9.81. Likewise, plants treated with 2 and 3 mg Se L^{-1} raised their carotenoid content by 20.22% and 32.83% over the control, respectively. Similarly, in the case of interaction, a 61.36% increase in plants treated with 3 mg Se L^{-1} over the control was observed, as shown in Figure 4, while the lowest content was observed in plants under severe stress without Se treatment. Overall, Se application at the rate of 3 mg L^{-1} produced high carotenoid content with respect to treatments without augmentation under both control and stress conditions.

3.3. Anthocyanin Content

Irrigation regimes, Se levels, and their interactions differed significantly for anthocyanin, as shown in Table 2. Anthocyanin content in the plants increased under water deficit conditions as compared to the control. The anthocyanin content was increased by 20.9 and 40% under mild and severe conditions compared to the control. Likewise, the foliar application of Se also significantly increased the anthocyanin levels regardless of drought treatment. Plants exposed to 1 mg Se L^{-1} had a 6.49% enhancement in anthocyanin content, while plants exposed to 2 and 3 mg Se L^{-1} had 9.02% and 15.14% increases in anthocyanin content, respectively. Similarly, in the case of interaction, a 51.01% increase occurred, with maximum anthocyanin content observed in plants treated with 3 mg Se L^{-1} under control conditions (Figure 5), while the lowest was observed in non-Se-treated plants under severe stress conditions. In comparison to the treatments without augmentation, Se application at a 3 mg L^{-1} dosage led to higher anthocyanin content under control and stress conditions.

Table 2. Effects of Se on the anthocyanin (mg g^{-1}), proline (μmole g^{-1}), APX (μg per mg of protein), POD (μg per mg of protein), and CAT (μg per mg of protein) content of okra under water deficit conditions.

Selenium (Se) (mg L^{-1})	**Anthocyanin (mg g^{-1})**	**Proline (μmole g^{-1})**	**APX**	**POD**	**CAT**
			μg per mg of Protein		
Control	0.6544 d	20.523 d	15.879 d	22.586 d	15.755 d
1	0.6999 c	22.296 c	16.677 c	23.785 c	16.711 c
2	0.7193 b	23.054 b	17.614 b	25.192 b	17.837 b
3	0.7712 a	25.078 a	18.521 a	26.552 a	18.925 a
LSD	0.0163 *	0.6361 *	0.3342 *	0.5023 *	0.4018 *
Drought Stress (DS)					
Control	0.5288 c	15.624 c	16.123 c	22.955 c	16.048 c
Mild stress	0.7193 b	23.207 b	17.089 b	24.404 b	17.206 b
Severe stress	0.7712 a	29.382 a	18.306 a	26.227 a	18.667 a
LSD	0.0141 *	0.5500 *	0.2894 *	0.4350 *	0.3480 *
SE × DS	Figure 5	Figure 6	Figure 7	Figure 8	Figure 9

* Means followed by different letters in each column are significantly different from each other at 5% of the level of probability by the LSD test.

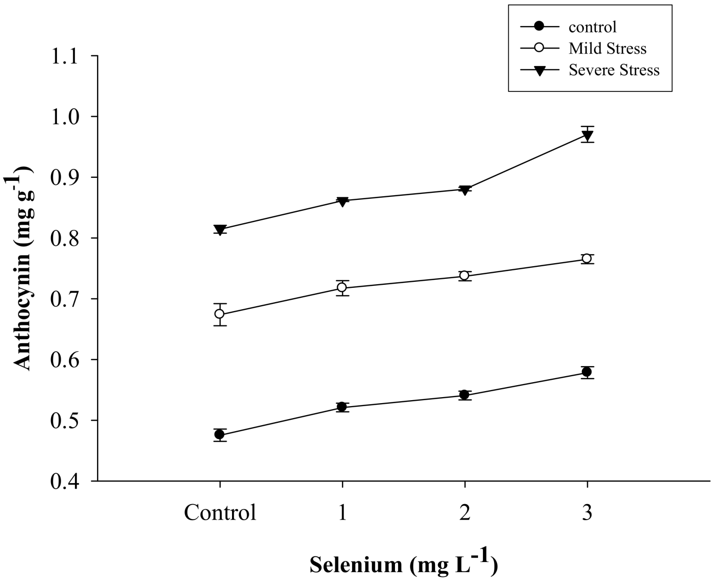

Figure 5. Effect of selenium on the anthocyanin content of okra under drought stress.

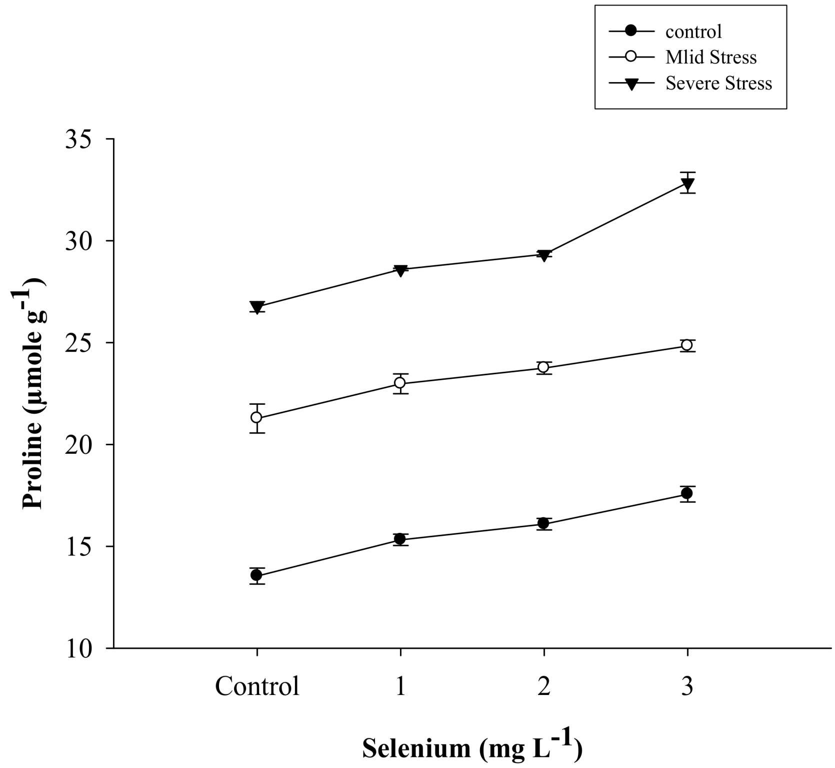

Figure 6. Effect of selenium (Se) on the proline content of okra under drought stress.

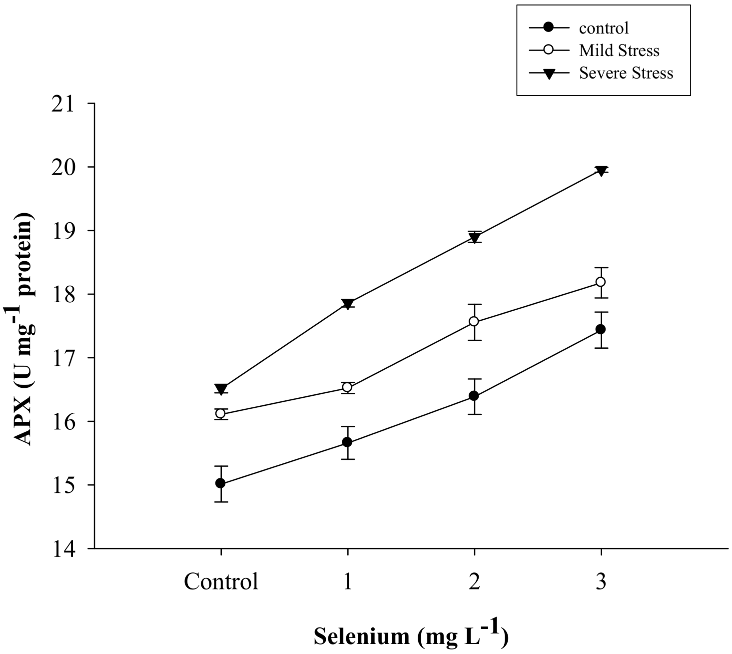

Figure 7. Effect of selenium (Se) on the APX activity of okra under drought stress.

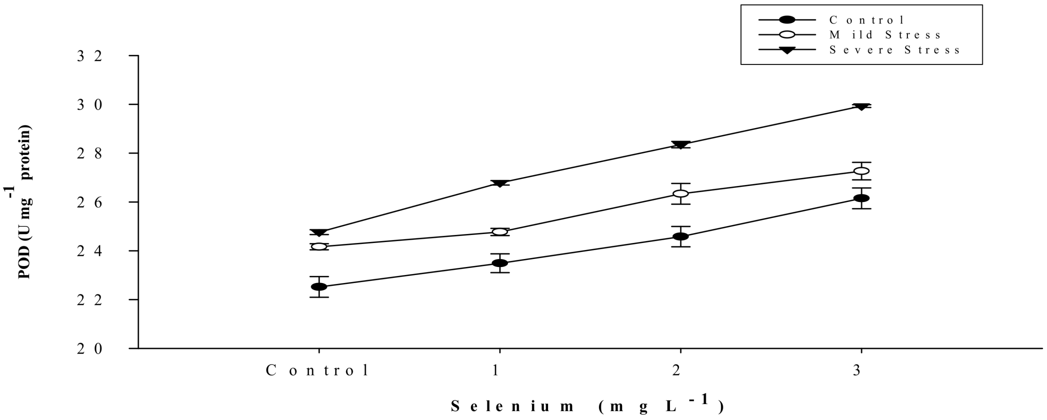

Figure 8. Effect of selenium (Se) on the POD activity of okra under drought stress.

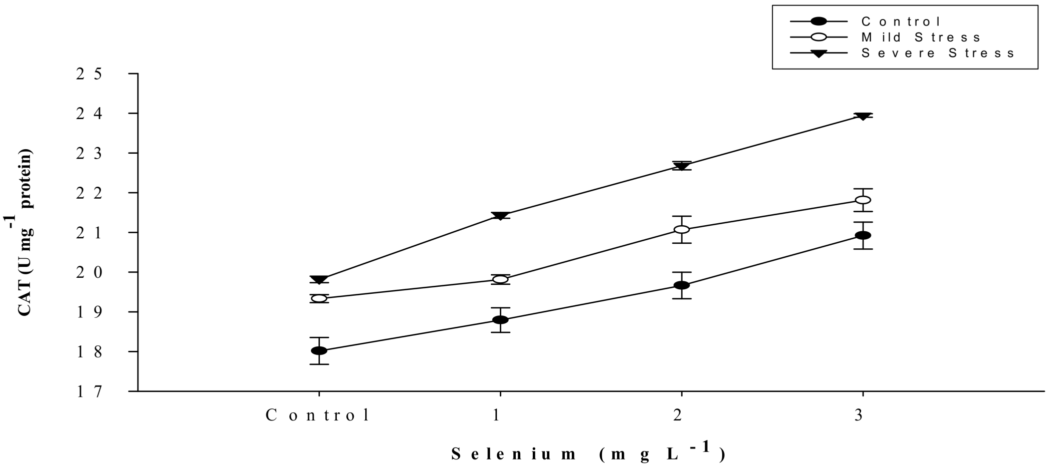

Figure 9. Effect of selenium (Se) on the CAT activity of okra under drought stress.

3.4. Proline Content

Plant proline content significantly responded to drought stress, Se levels, and their interactions (Table 2). Plant proline content increased with increasing drought stress as compared to the control. Under mild stress, a 32.67% increase occurred, while under severe stress, it was enhanced by 46.82% over 100% FC (control). Similarly, the foliar application of Se to the plants significantly enhanced proline levels under both water deficit as well as control conditions. Plants exposed to 1 mg Se L^{-1} had enhanced proline content by 7.94%, while plants exposed to 2 and 3 mg Se L^{-1} had increased proline by 10.97% and 18.16%, respectively. Similarly, in the case of interaction, a 58.78% increase occurred in plants treated with Se (at 3 mg L^{-1}) under the control conditions (Figure 6), while the lowest amount of proline was observed in non-Se-treated plants under the severe stress condition. In comparison to treatments without augmentation, 3 mg Se L^{-1} led to a higher proline content under both the control and stress conditions.

3.5. Antioxidant Activities

Ascorbate peroxidase (APX) responded significantly toward drought, Se levels, and their interactions as shown in Table 2. Plants increased their APX content under water deficit conditions as compared to the control. Under mild stress, a 5.66% increase occurred, while APX was increased by 11.92% under severe stress. Similarly, the foliar application of Se to the plants significantly enhanced their APX levels under both the water deficit as well as in well-watered plants. Plants exposed to Se at 1 mg L^{-1} had enhanced APX content by 4.8%, while plants exposed to Se at 2 and 3 mg L^{-1} had increased APX content by 9.85% and 14.26%, respectively. Similarly, in the case of interaction, a 24.75% increase occurred, where the minimum APX content was observed in non-Se-treated plants under severe stress conditions while the maximum APX content was obtained at 3 mg Se L^{-1} in control plants (Figure 7). In total, under control or stress conditions, the presence of 3 mg Se L^{-1} produced high levels of APX.

Peroxidase activity (POD) significantly responded to drought, Se levels, and their interactions as shown in Table 2. The POD content in plants increased under water deficit conditions as compared to the control. Under mild stress, a 5.93% increase occurred, while okra plants under severe stress enhanced their POD content by 12.47%. Similarly, the exogenous application of Se to plants significantly enhanced POD levels under water deficit conditions as well as in well-watered plants. Plants exposed to Se at 1 mg L^{-1} had 5.04% enhanced POD content, while plants exposed to Se at 2 3 mg L^{-1} had increases of 10.34% and 15% in POD, respectively. Similarly, in the case of interaction, a 25.81% increase occurred, with the minimum amount of POD observed in non-Se-treated plants under severe stress conditions while the maximum POD value was obtained in the presence of Se (3 mg L^{-1}) in control plants (Figure 8). In total, under control and stress conditions in the presence of 3 mg L^{-1} Se, high levels of POD were obtained without augmentation.

The responses of catalase activity (CAT) to drought, Se levels, and their interactions were also found significant (Table 2). The plants' CAT content increased with drought as compared to the control. Under mild stress, a 6.73% increase occurred, while under severe stress, CAT was enhanced by 14.03%. Similarly, the foliar application of Se to plants significantly enhanced CAT content under water deficit as well as in well-watered plants. Plants exposed to Se at 1 mg L^{-1} had enhanced CAT by 5.72%, while plants exposed to Se at 2 and 3 mg L^{-1} had 11.67% and 16.75% increases of CAT, respectively. Similarly, in the case of interaction, a 28.71% increase occurred, with the minimum amount of CAT observed in non-Se-treated plants under severe stress conditions while the maximum CAT was obtained in the presence of Se (3 mg L^{-1}) in control plants (Figure 9). In total, under control and stress conditions in the presence of 3 mg L^{-1} Se, high levels of CAT were obtained without augmentation.

4. Discussion

Climate change has tormented global food security [48,49]. Among the harsh outcomes of climate change, drought stress has an important role in the decline of crop productivity and ultimately, food security. The decline and changes in the patterns of rainfall are causing numerous onsets of droughts across the globe [50]. Drought stress negatively affects plant growth, plant physiology, and reproduction [51,52].

Our results show that drought stress decreased chlorophyll (32.21%) and carotenoid (39.6%) contents but increased anthocyanin (40%), proline (46.8%), peroxidase (POD by 12.5%), ascorbate peroxidase (APX by 11.9%), and catalase (CAT by 14%) levels. Water deficit stress usually leads to a decrease in the chlorophyll content of the plant, damages its photosynthetic apparatus, and disrupts its production [53]. Severe drought stress causes severe damage to photosynthetic machines and chlorophyll in plants [54]. Inadequate water supply results in lower turgor and osmotic pressure in cells that govern the production of reactive oxygen species (ROS) [55] and damages chlorophyll content, resulting in lower photosynthetic activity [56,57]. Such disturbances in the biochemical machinery due to drought could be due to general chlorophyll content composite reduction which is instructed by the CAB gene family [58].

We found that Se significantly alleviated drought stress-related biochemical disturbances in okra. Mainly, 3 mg L^{-1} selenium significantly increased chlorophyll (21%) as well as anthocyanin (15.14%), proline (18.16%), and antioxidant activities both under water deficit and control conditions. Selenium (Se) plays important roles in enhancing crop growth [59], minimizing damage from abiotic stress [60], increasing chlorophyll content and carotenoids in plant leaves [61], enhancing phenolic compounds [62], stimulating antioxidant activity [63], and improving plant tolerance to water deficit conditions [64]. The foliar application of Se reduces harmful effects on chloroplasts and helps with the sustainability of photosynthetic pigments under harsh abiotic stress conditions [65]. In the present study, similar results were observed in Se-treated okra plants under drought conditions. The destruction in photosynthetic activity could be due to the decline in chlorophyll content by a huge generation of ROS [66]. Se foliar application can control antioxidant activities, such as those of POX, CAT, APX, and SOD, which can help sustain their photosynthetic pigments under abiotic stress by minimizing lipid oxidation and modifying the biosynthetic pathway of chlorophyll in plants [39,65,67,68]. Chu et al. [68] reported similar results under abiotic stress in wheat. In this experiment, we observed that the exogenous application of Se increased the carotenoid content in okra under drought stress conditions significantly.

However, the findings of Abbas [69] on *Sorghum bicolor* and Dong et al. [61] on *Lycium* showed that low levels of Se application enhance photosynthetic activity but considerably decrease it when approaching high concentrations because of adverse consequences on porphobilinogen synthase production [70] or the replacement of sulfur (S) atoms through Se in S-including amino acids such as methionine and cysteine [71]. Conversely, Hawrylak-Nowak et al. [72] noticed insignificant consequences from Se application for the carotenoid content in crops. Peng et al. [73] evaluated that the Se application increased carotenoid levels involved in the reliability of membrane maintenance and scavenging of free radicals. Astaneh et al. [74] meanwhile demonstrated that Se enhances the carotenoid levels of a plant under abiotic stress. Anthocyanin increases in plants under drought stress were clearly shown in the findings of Spyropuolos et al. [75] in three oak species (*Quercus* sp.) under water deficit conditions. Furthermore, anthocyanin protects plants from photoinhibition and photodamage to their chloroplasts under high light stress [76]. Anthocyanin also minimizes the harmful effects of abiotic stress [77].

Wahid and Ghazanfar [78] studied the effect of Se on anthocyanins and leaf flavonoids and reported that increasing the concentration of anthocyanin protected the cell (as a scavenger of superoxide radicals) against oxidative damage and reduced the harmful effects of various abiotic stressors such as heavy metal stress, drought stress, UV-B stress, waterlogging stress, salinity stress, cold and heat, and high and low temperature [79,80]. All of the aforementioned abiotic stressors produce ROS which can severely damage plants. Stress activates the antioxidant enzyme defence in plants by altering their APX, POD, and CAT levels [81] to minimize ROS damage [82]. Increased POD and CAT in drought-stressed plants may indicate that the plants are adapting to a severe environment [38].

The increases in POD and CAT in plants under drought stress may adapt plants according to harsh conditions [38]. The improvement in antioxidant enzyme activity under drought stress showed an extreme ROS boost [83,84]. Antioxidant enzymes detoxify O_2 and H_2O_2 levels and facilitate in decreasing extremely lethal HO accumulation [85]. The remarkable enhancements from the antioxidant enzyme-like (APX, POD, and CAT) application of Se shows that Se is responsible for the impetuous inhibition of O_2 into H_2O_2 [84] and can be straightforwardly used for repressing O_2 and OH content in plant cells [86]. Previously, it has been investigated in various crops such as wheat, barley, tomato, and rice [87] that Se application increases antioxidant activity under abiotic stress; the balance between SOD and other enzymes that scavenge ROS is very important in establishing a stable status level of O_2 and H_2O_2 content in plant cells [85]. So, the foliar application of Se with optimized concentrations plays an important role in the enhancement of antioxidant enzymes that scavenge ROS and decline H_2O_2 levels in plants under abiotic stress [88].

5. Conclusions

Selenium (Se) foliar application in okra plants under drought stress resulted in minimizing the damaging effects of stress by improving their biochemical responses such as their chlorophyll, carotenoid, and anthocyanin contents. It has a direct role in increasing proline content and antioxidant activity to scavenge excess ROS produced under drought stress. Further mechanistic research work is necessary to clarify the effect of foliar Se on leaf anatomical structures and the pathway involved in improving overall plant biochemical reactions under abiotic stress.

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