Research Article

# Selenium Supplementation Affects Vegetative and Yield Attributes to Escalate Drought Tolerance in Okra

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**Abstract** | Drought stress restricts the vegetative and yield attributes of okra (*Abelmoschus esculentus* L) primarily by disrupting its biochemical and physiological functions. The current study was conducted to appraise the Selenium (Se) role in improving the drought tolerance in okra. Drought stress (three days (control), six days (mild stress) and nine days (severe stress)) and four doses of Se (0, 1, 2, and 3 mg $L^{-1}$) were imposed after 30 days of sowing. Our outcomes showed that drought stress decreases the number of leaves, plant height, number of branches, stem dry weight, root dry weight, fruit diameter, number of fruit per plant and 1000 seed weight. Visually reduction in vegetative and yield parametric quality okra plant okra were significantly alleviated by the foliar application of Se under drought stress. Se application of 3 mg $L^{-1}$ significantly increased the number of leaves, plant height, number of branches, stem dry weight, root dry weight, fruit diameter, number of fruit per plant and 1000 seed weight. Se regulated processes, improved the vegetative and yield attributes of okra under water deficit conditions as well in control. The current investigation proved beneficial in improving the growth performance of okra, suggesting that foliar supplementation of Se may result in the development of drought mitigation in okra.

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## Introduction

A hostile circumstance often damages the plant drastically that hinder its growth and yield severely. Among the adverse environment drought is one of the most hostile factor that inhibits the plant yield across the world. (Tardieu et al., 2014). Drought restricts the genetic potential of a crop species throughout its life cycle and (Mitra, 2001) reported that drought stress damages drought-sensitive plant at not only at vegetative level but also limits the reproductive development of the drought-resistant plant.

The inhibition of photosynthesis takes place due to the closure of stomata irregularly that is the initial response of plant under drought stress ultimately decreases the dry weight (Chaves et al., 2009; Farooq et al., 2009). Demonstrated that Photosynthetic activity degeneration is also associated with the decline of the activities of enzymes (Chaves et al., 2009).

The extra excitation energy and reactive oxygen species that accountable for the devastation in the photo systems is because of down-regulation photosynthetic carbon metabolism leads (Hajibolandand and Sadeghzadeh, 2014). The respective response of stomatic and non-stomatic restriction in of crop photosynthesis is dependent on the intensity of drought stress and propensity of a plant to dry (Chaves et al., 2009).

Plants accumulates osmolytes and proteins particularly attentive stress resilience under water deficit condition and inhibits the damage. (Krasensky and Jonak, 2012). Besides the restraint in osmotic equilibrium of plant, that acts as a scavenging radicals and reduces the harmful injury of a cell under abiotic stresses (Krasensky and Jonak, 2012). these osmolytes and osmoprotectants generation consists of amino acids like, Proline that help in the adaptation of to drought conditions (Verbruggen and Hermans, 2008). The morphological attributes like root thickness and its development such as the capability of root to break the compact layer of soil, its mass and depth minimize stress resistance (Valliyodan and Nguyen, 2006).

To improve assemble potential of plants facing water shortage circumstances, development of elevated opposing genotypes using breeding advance are necessary (Mitra, 2001; Valliyodan and Nguyen, 2006). Besides, the exogenous appliance of various growth promoters like salicylate and jasmonate and some osmoprotectants like glycine, betaine has been evaluated across the globe to boost drought alleviation at vegetative stages (Farooq et al., 2009). Regarding the use of mineral supplements for drought resistance of plant use of selenium (Se) (Feng et al., 2013) and silicon are more prominent.

In improvement of plant ability in opposition to different abiotic stresses the use of Selenium in low concentration has been evaluated for plant species. (Feng et al., 2013; Hajiboland, 2012). The reduction of harmful influence of abiotic stress through the Se supplementation mainly focuses on Se-mediated antioxidative defense (Wang, 2011; Hasanuzzaman and Fujita, 2011; Hajiboland, 2012; Feng et al., 2013). Proline raise and it accumulation has been noted in the Se-mediated plant. (Yao et al., 2009) Beside the foliar application of Se doses not effects water uptake capability (Yao et al., 2009; Habibi, 2013). Se enhances the plant growth and yield by regulating it water status under water shortage circumstances (Sajedi et al., 2011), Se application mainly promotes the antioxidant enzymes and proline accumulation that ultimately increase the growth and yield of plant under drought condition (Shen et al., 2008). Se foliar application rehabilitates photosynthetic apparatus by reducing the activity of ROS under drought condition (Kumar et al., 2012). It significantly improves the yield component of crop under drought stress and bring plants in homeostasis by changeable the osmotic balance and equilibrium of ion (Kuznetsov et al., 2003).

Okra is one the important vegetable of sub-content belongs to family Malvaceae scientifically called *Abelmoschus esculentus* L. It is native to Ethiopia and Sudan but its comes first in rank India while cultivation. In many countries being an older crop, it is a very important medicinal crop has been bred in Africa, America, Asia, and Europe (Ariyo, 1993; Oyenuga, 1969; Oyelade et al., 2003; Hamon, 1991). It is vulnerable to abiotic stresses (drought stress, chilling temperature, frost, and water-logged condition), and the cultivars have adopted certain behaviors based on the climate of the country where it grows (Siemonsma, 1982).

The current experiment was conducted with an objective find out the function of Se on the Vegetative growth and yield production of the okra plant under drought. Some vegetative and yield parametric attributes of this crop was studied in pots.

## Materials and Methods

An experiment was carried out at Agricultural Research Station Swabi in pots in 2017. An okra drought vulnerable Cultivar super green was sown in pots that were crammed with an equivalent quantity of garden soil and FYM. In order to encourage the seed germination, seeds were soaked for overnight. Ten seeds were sown in each pots in spring season. The depth of seed sowing was ½ inches and sown by hand drill. Thinning was done by uprooting unhealthy and stunted plants while leaving five healthy and uniform okra plants per pot at the time plants produce two true leaves. All cultural practices including weeding were carried out at appropriate time, every pot were treated with the optimized doses of N-P-K. Plants were subjected to treatments after thirty days of Sowing that protected from rain and harsh conditions in plastic tunnel. Drought stress was maintained by subjecting the plants of okra to different irrigation intervals (3, 6 and 9 days). Pots were irrigated at 100% field Capacity by surface irrigation classification. Plants irrigated after three days were measured as control while plants irrigated at the gap of six days were taken as mild stress and plants irrigated at the period of nine days were labeled as severe stress. At the time of subjecting plants to water deficit levels, Se with three different doses (1 mg $L^{-1}$, 2 mg $L^{-1}$, and

3 mg $L^{-1}$) were exogenously applied. An okra plant response to Se under water-deficit levels was assessed using vegetative and yield parametric quality such as number of leaves, plant height, number of branches, stem dry weight, root dry weight, fruit diameter, number of fruit per plant and 1000 seed weight.

*Plant height (cm)*

The average height of the plant was detected with the help of a meter from to the peak of central stem.

*Number of branches plant$^{-1}$*

The number of branches per plant was added up in chosen plants and their standard was observed.

*Number of leaves plant$^{-1}$*

The number of leaves per plant was added up in the preferred plant and standard value was calculated.

*Number of fruits plant$^{-1}$*

The number of pods plant$^{-1}$ was counted in the chosen plant and their average was taken.

*Fruit diameter (cm)*

Pod diameter was recorded in the middle part of the pod in the selected plant and their average was taken.

*1000 Seeds weight (g)*

The weight of 1000 seeds was measured by using the electric balance.

*Stem and root dry weight (g)*

Stem and root dry weight were calculated with the help of electronic balance.

## Results and Discussion

*Number of leaves*

The number of leaves of the okra plant were significantly affected by drought stress, Selenium levels, and their interaction clearly noted in Table 1. The most leaves (28.667) was recorded under well-watered plants while a smallest amount was recorded (17.500) in plants under severe water deficit conditions. Nonetheless, the foliar appliance of Se significantly amplified the Number of leaves under water deficit as well as under well water. The high number of leaves (25.333) was recorded in plants exposed to the high dose of Se at 3 μgmL$^{-1}$ while the lowest (19.444) was noted in plants treated without selenium. Similarly, in case of interaction maximum Number of leaves content (30.333) was noted in plants treated with Se at 3 μgmL$^{-1}$ under well-watered condition while the lowest was observed in plants under severe stress without selenium shown in Figure 1. Overall Se application at 3 mgL$^{-1}$under control and stress conditions produced the maximum number of leaves with respect to treatments where Se was not added.

**Table 1:** *Effect of selenium on number of leaves, plant height, number of branches, stem dry weight, of Okra under water deficit conditions.*

| Treatments | Number of leaves | Plant height | Number of branches | Stem dry weight |
|---|---|---|---|---|
| **Selenium (SE) (mgL$^{-1}$)** | | | | |
| Control | 19.444 d | 88.11 d | 3.2400 d | 3.2844 d |
| 1 | 21.222 c | 103.87 c | 4.2178 c | 4.1044 c |
| 2 | 23.000 b | 124.34 b | 4.9667 b | 5.0656 b |
| 3 | 25.333 a | 147.68 a | 5.8722 a | 5.9944 a |
| LSD | 0.9593* | 6.0194* | 0.3461* | 0.3435* |
| **Drought Stress (DS)** | | | | |
| Control | 28.667 a | 140.69 a | 5.6342 a | 5.7733 a |
| Mild stress | 20.583 b | 114.55 b | 4.5442 b | 4.5267 b |
| Severe stress | 17.500 c | 192.75 c | 3.5442 c | 3.5367 c |
| LSD | 0.8308* | 5.2129* | 0.2997* | 0.2975* |
| SE × DS | 1.6616* | 10.426* | 0.5994* | 0.5950* |

*Means followed by different letters are significant at 5% level of probability by LSD test; NS= non-significant; *=significant at $p < 0.05$.*

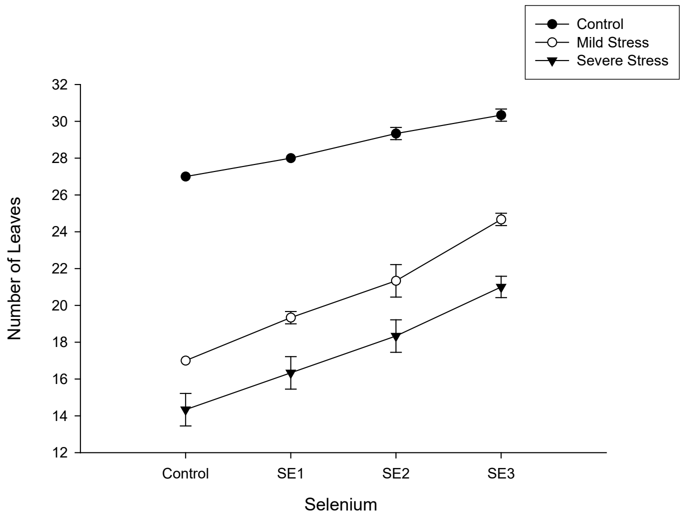


**Figure 1:** *Shows the interaction drought stress and selenium on number of leaves.*

*Plant height*

Drought stresses, Selenium levels, and their interaction significantly affect the plant height as compared to control conditions of okra plants clearly noted in the table.1 plant height (140.69 cm) was observed under well-watered plants while the minimum was observed (92.75 cm) in plants under severe water deficit conditions. However, the exogenous application of selenium significantly enhanced the plant height under water deficit as well as under well water. Maximum Plant height (147.68 cm) was recorded in plants exposed to the high dose of selenium at 3 $mgL^{-1}$ while the lowest (88.11 cm) noted in plants treated without selenium. Similarly, in case of interaction utmost plant height (173.29 cm) was noted in plants treated with selenium at 3 $mg^{-1}$ under control while the lowest (66.95 cm) was observed in plants under severe stress without selenium shown in Figure 2. Overall selenium application at 3$mgL^{-1}$ under control (well-watered) and stress conditions produced maximum plant height with respect to treatments where selenium was not added.

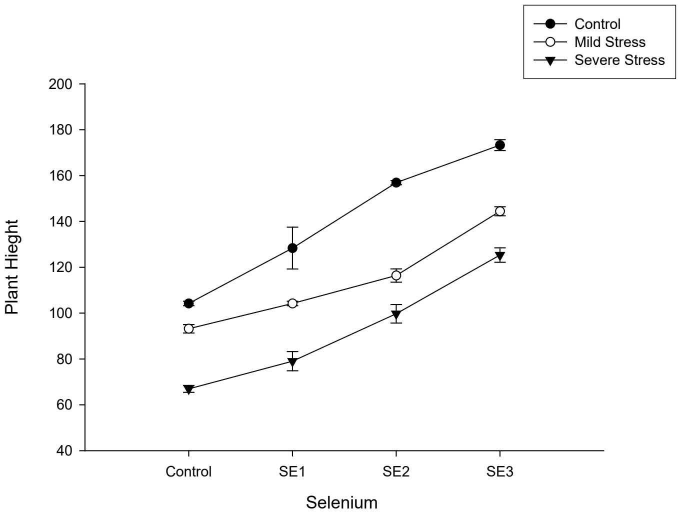


**Figure 2:** *Shows the interaction drought and selenium on plant height.*

## *Number of branches plant$^{-1}$*

Water deficit conditions, Selenium levels, and their interaction significantly affect the number of branches plant$^{-1}$ as measured up to control conditions of okra plants shown in Table 1. The greatest number of branches (5.6342) was noted under well-watered plants while the minimum was observed (3.5442) in plants under severe water deficit conditions. However, the foliar selenium treatment significantly improved the number of branches per plant under water deficit as well as under well water. The utmost number of branches (5.8722) were recorded in plants exposed to the high dose of selenium at 3 $mgL^{-1}$ while lowest (3.2400) noted in plants treated without selenium. Similarly, in case of interaction maximum number of branches (7.2833) was evaluated in plants subjected to selenium at 3 $mgL^{-1}$ under control while lowest (2.4433) was observed in plants under severe stress without selenium shown in Figure 3. Overall selenium application at 3 $mgL^{-1}$under control (well-watered) and stress conditions produced the high number of branches with respect to treatments where selenium was not added.

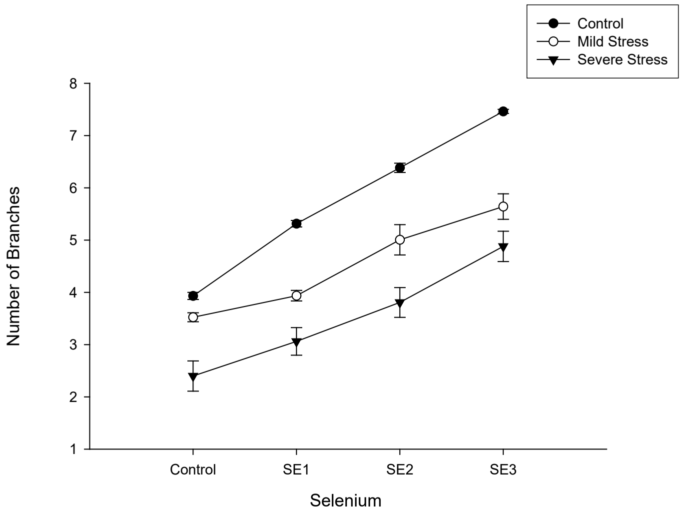


**Figure 3:** *Shows the interaction of drought and selenium on number of branches plant$^{-1}$.*

## *Stem dry weight*

Drought stresses, Selenium levels, and their interaction significantly effects the stem dry weight of the plant as compared to untreated plant clearly demonstrated in Table 1. Maximum stem dry weight (5.7733 g) was observed under well-watered plants while the minimum was observed (3.5367 g) in plants under severe water deficit conditions. However, the exogenous application of selenium significantly enhanced the stem dry weight content under water deficit as well as under well water. High stem dry weight (5.9944 g) was recorded in plants exposed to the high dose of selenium at 3 $mgL^{-1}$ While lowest (3.2844 g) noted in plants treated without selenium. Similarly, in case of interaction maximum (7.4633 g) was recorded in plants treated with selenium at 3 $mgL^{-1}$ under control while the lowest (2.3967 g) was observed in plants under severe stress without selenium shown in Figure 4. Overall selenium application at 3 $mgL^{-1}$ under control (well-watered) and stress conditions produced high stem dry weight with respect to treatments where selenium was not added.

## *Root dry weight*

Drought stresses, Selenium levels, and their interaction significantly affect the dry weight of root as compared to untreated conditions clearly demonstrated in Table 2. Maximum root dry weight (4.3358 g) was observed under well-watered plants while the minimum was observed (2.7583 g) in plants under severe water deficit conditions. However, the foliar application of selenium significantly enhanced the root dry weight content under water deficit as well as under well water. High root dry weight (4.5033 g) was recorded in plants exposed to the high dose of selenium at 3 mgL$^{-1}$ while lowest (2.4667 g) noted in plants treated without selenium. Similarly, in case of interaction maximum (5.6067 g) was recorded in plants treated with selenium at 3gmL$^{-1}$under control while lowest (1.8033 g) was observed in plants under severe stress without selenium shown in Figure 5. Overall selenium application at 3 mgL$^{-1}$ under control (well-watered) and stress conditions produced high root dry weight with respect to treatments where selenium was not added.

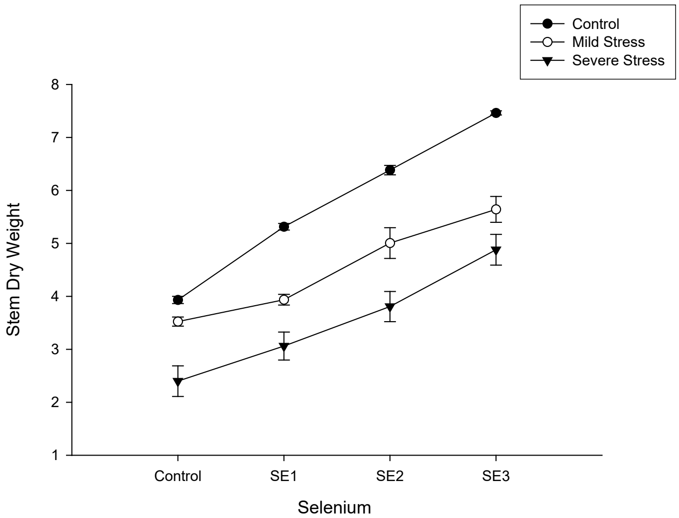


**Figure 4:** *Shows the interaction of drought stress and selenium on stem dry weight.*

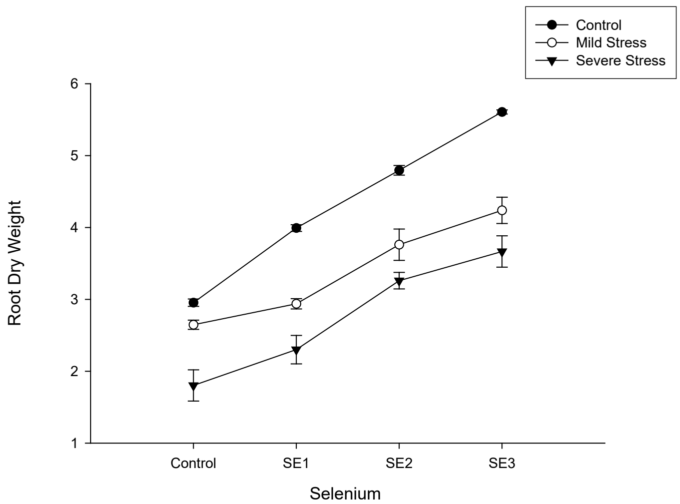


**Figure 5:** *Shows the interaction of drought stress and selenium on root dry weight.*

### *Fruit diameter*

Drought stresses, Selenium levels, and their interaction significantly affect the fruit diameter as evaluated to control conditions in okra plant clearly demonstrated in Table 2. Maximum fruit diameter (2.8150 cm) was observed under well-watered plants while the minimum was observed (1.7358 cm) in plants under severe water deficit conditions. However, the foliar application of Se significantly enhanced the fruit diameter under water deficit as well as under well water. High fruit diameter (2.9244 cm) was recorded in plants exposed to the high dose of selenium at 3 mgL$^{-1}$While lowest (1.6156 cm) noted in plants treated without selenium. Similarly, in case of interaction maximum (3.6400 cm) was recorded in plants treated with selenium at 3gmL$^{-1}$under control while lowest (1.2133 cm) was observed in plants under severe stress without selenium shown in Figure 6. Overall selenium application at 3 mgL$^{-1}$ under control (well-watered) and stress conditions produced high fruit diameter with respect to treatments where selenium was not added.

**Table 2:** *Effect of Selenium on root dry weight, fruit diameter, number of fruit per plant and 1000 seed weight.*

| Treatments | Root dry weight | Fruit diameter | Number of fruit plant$^{-1}$ | 1000 Seed weight |
|---|---|---|---|---|
| **Selenium (SE) (mgL$^{-1}$)** | | | | |
| Control | 2.4667 d | 1.6156 d | 12.076 d | 33.812 d |
| 1 | 3.0767 c | 2.0000 c | 13.803 c | 38.650 c |
| 2 | 3.9389 b | 2.4700 b | 15.502b | 43.406 b |
| 3 | 4.5033 a | 2.9244a | 18.013a | 50.439 a |
| LSD | 0.2423* | 0.1597* | 0.9678* | 2.7091* |
| **Drought stress (DS)** | | | | |
| Control | 4.3358 c | 2.8150 c | 21.345 c | 59.767c |
| Mild stress | 3.3950 b | 2.2067 b | 13.141 b | 36.795 b |
| Severe stress | 2.7583 a | 1.7358 a | 10.060 a | 28.168 a |
| LSD | 0.2098* | 0.1383* | 0.8381* | 2.3461* |
| SE × DS | 0.4197* | 0.2766* | 1.6762* | 4.6922* |

*Means followed by different letters are significant at 5% level of probability by LSD test; NS= non-significant; *=significant at $p < 0.05$.*

### *Number of fruits plant$^{-1}$*

Number of fruit per plant were significantly affected by Drought stresses, Selenium levels, and their interaction clearly demonstrated in Table 2. Highest number of fruits plant$^{-1}$ (21.345) was observed under well-watered plants while the minimum was observed (10.060) in plants under severe water deficit conditions. However, the foliar application of Se significantly improved the number of fruits plant$^{-1}$ under water deficit as well as under well water. The elevated number of fruit plant$^{-1}$ (18.013) was recorded in plants exposed to the high dose of selenium at 3 mgL$^{-1}$ while lowest (12.076) noted in plants treated without selenium. Similarly, in case of interaction maximum (22.997) was recorded in plants treated with selenium at 3gmL$^{-1}$under control while the lowest (6.810) was observed in plants under severe stress without selenium shown in Figure 7. Overall selenium application at 3 mgL$^{-1}$ under control (well-watered) and stress conditions enhanced the fruit numbers per plant with respect to treatments where selenium was not added.

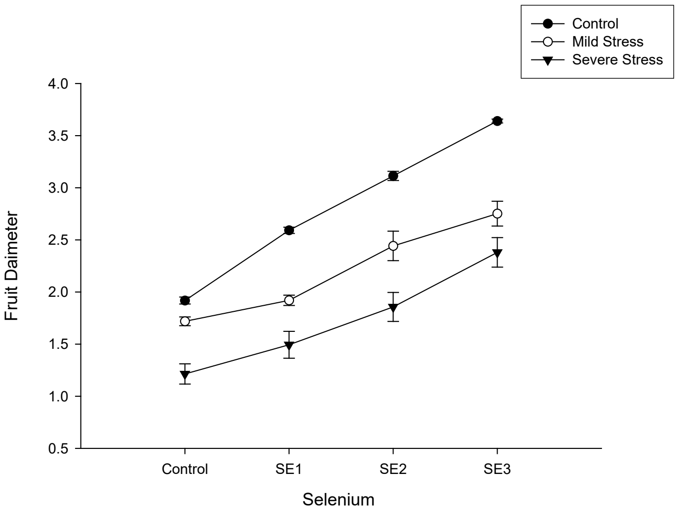


**Figure 6:** *Shows the interaction of drought stress and selenium on fruit diameter.*

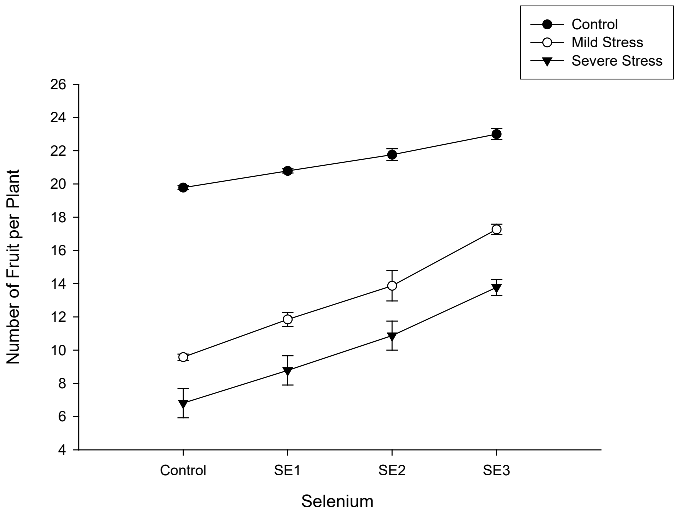


**Figure 7:** *Shows the interaction drought stress and selenium on number of fruit plant$^{-1}$.*

### *1000 seed weight*

Drought stresses, Selenium levels, and their interaction significantly affect 1000 seed weight as compared to control conditions in okra plant clearly demonstrated in Table 2. Maximum 1000 seed weight (59.767 g) was observed under well-watered plants while the minimum was observed (28.168 g) in plants under severe water deficit conditions. However, the foliar application of Se significantly enhanced the 1000 seed weight under water deficit as well as under well water. High 1000 seed weight (50.439 g) was recorded in plants exposed to the high dose of selenium at 3 mgL$^{-1}$ while lowest (33.812 g) noted in plants treated without selenium. Similarly, in case of interaction maximum (64.393 g) was recorded in plants treated with selenium at 3gmL$^{-1}$under control while lowest (19.070 g) was observed in plants under severe stress without selenium shown in Figure 8. Overall selenium application at 3 mgL$^{-1}$ under control (well-watered) and stress conditions produced high 1000 seed weight with respect to treatments where selenium was not added.

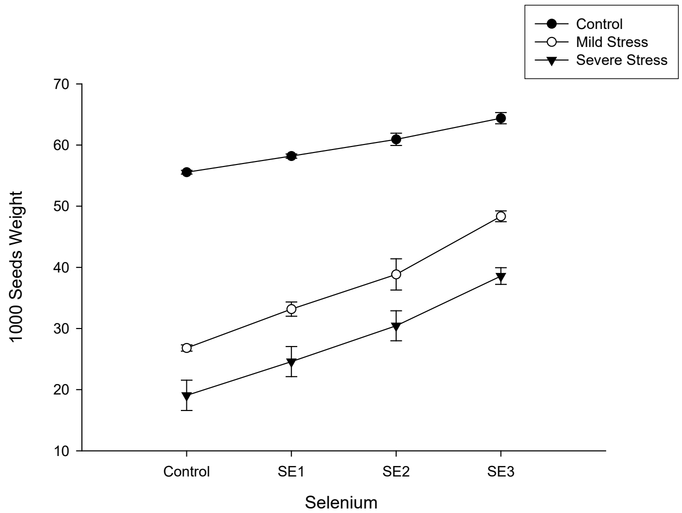


**Figure 8:** *Shows the interaction drought stress and selenium on 1000 seed weight.*

The number of leaves significantly reduced in water deficit conditions could be due to the inhibition of photosynthetic pigments (Farooq et al., 2009). The decrease of photosynthetic apparatus is produced by the reduction of the chlorophyll content under water shortage to a plant (Rensburg et al., 1994). The decline in photosynthetic apparatus and Chlorophyll content is caused by the exessive production of ROS activity under water stress (Kyparissia et al., 1995; Jagtap, 1998). Foliar Se application significantly increased number of leaves may be due to the detrimental effects of Se effect on the chloroplast and helps sustain photosynthetic pigments under harsh conditions of abiotic stress (Khan et al., 2015; Zahedi et al., 2013) which ultimately increased number of leaves (Rezai et al., 2018). The results were further supported by (Kápolna et al., 2012), who clearly mentioned that the Se application increases the photosynthetic apparatus which ultimately increases the vegetative growth of a plant. The height of plant significantly delayed might be due the inhibition of photosynthesis by the ROS. (Bray et al., 2000), because ROS production dramatically damages the chlorophyll and carotenoid component (Blumwald et al., 2000) Application of Se retarded the ROS action (Ashraf et al., 2005) by the raise in antioxidant activity that ultimately boosts the vegetative attributes (Nawaz et al., 2013; Yao et al., 2009; Hasanuzzaman and Fujita, 2011). The reduction in number of branches might be due the irregular closing and opening of stomata under water deficit conditions (Hellens et al., 2000) which reduces the transpiration and inhibits photosynthetic activity (Hare et al., 1998), Se foliar application significantly increased number of branches might be the beneficial effect of Se on chloroplast and photosynthesis (Habibi, 2013; Balal et al., 2016; Dong et al., 2013) underwater deficit condition that is responsible for vegetative growth like number of branches (Rezai et al., 2018; Nawaz et al., 2013). The diameter of fruit has decreased significantly could be due the lesser accumulation of proline and decrease in antioxidant activity (Saleem, 2003) Plant after with foliar application of Se significantly the increase in the diameter of the fruit could be due to stimulated increase of water ratio pigments and TSS, TFA, proline and antioxidant activity (Kuznestov et al. 2003) under drought stress. (Yao et al., 2013) recorded a significant increase in length and diameter of a peak in grain for foliar application. The decrease in fruit number under drought condition might be due the disturbance in the plant equilibrium by the decline in the phenolic compounds and stomata opening. (Stonas et al., 2001) that ultimately reduces the transpiration. The number of fruits has increased significantly due the foliar application of Se can be due to diffusion of Se ions from the surface of leaves to epidermal cells which increases its effectiveness to increase fruit yield (Wójcik, 2004), that is supported by Curtin et al. (2006) who investigated se was more effective in increasing the yield of wheat. Water deficit conditions has delayed in stem and root dry weight might be due the lesser accumulation of anthocyanins and inhibition in photosynthetic activity (Xue et al., 2010). It was found that the dry weight of stem and root was higher in the plant treated with se under drought stress may be the increase of phenolic compound and photosynthesis under drought condition (Bai et al., 1994) the increase in root and stem dry weight was also observed in Se-mediated plant by (Carlson et al., 1989; Yao et al., 2009) Se foliar application increases the growth of root that becomes the cause of high stem dry weight (Okçu et al., 2005), further the results was supported by (Valadabadi et al., 2010) observed a significant increase in total dry weight of rapeseed cultivars sprayed with Se under water stress, together with the increase in weight of dry stem (Yamur and Kaydan, 2006). Less accumulation in proline level and inhibition in protein synthesis by drastic damage of photosynthesis caused severe decreased in the 1000 seed weight of okra plant (Arora et al., 2002) by ROS raise that decline chlorophyll and reduce the cell elongation as well (Hamidou et al., 2007) the Se application raised the 1000 seed weight might be due the increase of chlorophyll, accumulation of proline and the increase of antioxidant under drought condition.

## Conclusions and Recommendations

From the present study it was conclude that the foliar application of selenium has minimized the damaging of drought on okra plant by increasing its vegetative parametric quality such as number of leaves, plant height, number of branches, stem dry weight, root dry weight, fruit diameter, number of fruit plant$^{-1}$ and 1000 seed weight. Therefore, Selenium has observed a beneficial element for mitigation.

## Novelty Statement

Novelty of this study is to evaluate the effect of foliar application of selenium on okra under drought stress for the increasing drought tolerance; Selenium minimized harmful effect of drought stress and increased the yield of okra.

## Author's Contribution

**Jawad Ali**: Conceived the idea, collected the data and conducted the research.
**Ibad Ullah Jan**: Designed the research and edited the final draft.
**Hidayat Ullah**: Helped in analysis.

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