Foliar application of potassium silicate and glycine betaine: Alleviating water deficit on soil properties, vegetative growth and yield attributes of *Abelmoschus esculentus* L (Okra) and *Solanum melongena* (Eggplant)

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The main problems that agricultural production faces are the shortage of irrigation water. The damage caused by water stress is one of the most critical environmental stresses that cause heavy loss to agriculture worldwide. Two field experiments were performed at a private agricultural farm in Nagalapuram, Theni district, Tamil Nadu, India in 2019 to study the response of physicochemical analysis of soil, vegetative growth and yield attributes of Okra plants (*Abelmoschus esculentus* L) and eggplants (Solanum melongena). The experiment was done with a Randomized complete block design with four replicates. These experiments included seven treatments which were the combination of 3 irrigation intervals and 5 foliar applications of anti transpirants such as Potassium silicate and Glycine betaine. Increasing the irrigation water to 100% improved plant growth, nutrient uptake, and biological yield. The yield of okra irrigated with 75% and 50% was lower by about 7.8% and 13.8% that received 100% water requirements. Likewise, the yield of eggplant with 75% and 50% of irrigation was lower by about 14.5% and 21.7% than that of 100% irrigation. Foliar application of potassium silicate and glycine betaine with 75% irrigation of okra and eggplant reached 97.5% and 96.95% respectively and 50% of irrigation reached around 89.5% and 86.6% of the yield of 100% irrigation. The results obtained from the present investigation show that spaying of potassium silicate and glycine betaine at 2.5 ml/L under water deficit areas increased the growth rate and yield of the okra and eggplant and also these treatments (T4-T7) lets plants resistance to drought stress.

Key Words: *Stress; Antitranspirants; Potassium silicate; Glycine betaine; Irrigation*

INTRODUCTION

Vegetables play an important part in guarding food security, particularly in a country marked by malnutrition and under nutrition, and furnishing a good regular source of income to the growers. The main problems that agrarian product faces are the deficit of irrigation water. Water stress is abiotic stress which harms the growth and productivity of shops [1]. The damage caused by water stress is one of the most critical environmental stresses that beget heavy losses to husbandry worldwide [2]. The relationship between crop yield and water stress can be shown from irrigation trials in which a major range of irrigation perpetration [3]. Agriculture needs a large quantum of irrigation water and this volume will be increased in the future because of the increase in population the available quantum of water for husbandry is declining worldwide because of the lesser prevalence of failure caused by climate change and different mortal conditioning in recent times [4].

In this nation, okra (*Abelmoschus esculentus* L.) is a staple summer vegetable. Okra's green pods are consumed fresh, frozen, or pickled. It is a well-liked vegetable for backyard gardens and provides the body with healthy energy. It offers iodine, protein, amino acids, minerals, vitamins A, B and C [5]. The vegetable is quite delectable and is enjoyed by both wealthy and poor people. Okra can withstand droughts quite well, but it still needs a lot of water to grow, and this has a negative impact on the yield. The greatest yield loss occurred when there was a continuous lack of water up until the first harvest [6]. One of the most crucial methods for boosting okra productivity is the use of antitranspirant compounds under both normal irrigation and drought stress. These substances ought to be cheap and safe for people.

One of the Solanaceae species, eggplant (*Solanum melongena* L.), is farmed as a major vegetable crop in many parts of the world, including tropical areas like India, China and the Middle East [7]. The fruits of the eggplant plant are rich in proteins, carbohydrates and the minerals N, P, K and Fe [8]. According to Byari and Rabighis [9] many researchers found that increasing the frequency of irrigation led to an increase in the vegetative development of eggplant. Moreover, increasing the frequency of irrigation led to an increase in the amount of certain minerals in plant organs [10]. The foliar spray of some antitranspirants, on the other hand, is one of the most crucial instruments for achieving more and better fruits in vegetables. While antiperspirants cut down on water loss during vegetative development and either before or after fruit harvest [11].

Potassium silicate acts as a healing agent because it reduces the negative effects of sodium chloride (NaCl) when potassium ions compete with sodium ions in the root zone [12]; silicate has been shown to have adverse effects of water, mineral deficiency [13] and mitigate the effects of biotic stresses such as salt stress, metal toxicity and nutrient imbalance [14]. Potassium silicate promotes vegetative growth, concentration of crops and mineral nutrients such as nitrogen, phosphorus and potassium elements in potato crop [15]. Foliar spray with potassium silicate increased the growth, yield and quality of strawberry [16], artichoke [17], garlic [18] pumpkin [19] and sweet potato [20].

Glycine betaine is an amino acid that is quickly distributed throughout the plant's components and is regarded as an essential tonic. Glycine betaine, when administered exogenously, can be utilized to boost plant height, chlorophyll (a and b), yield, and yield components both under and without drought stress [21]. According to Dawood and Sadak [22] glycine betaine is essential for both accumulating and non-accumulating plants to withstand drought. In both normal and drought-stressed plant conditions, glycine betaine can be utilized to increase plant height, yield, and yield components [21]. Varieties of plants develop and survive better when exogenous GB is applied under various abiotic stress situations [23-25].

The purpose of this study was to determine how potassium silicate and glycine betaine treatments applied as foliar sprays on okra plants (*Abelmoschus esculentus* L. Moench) and eggplants (*Solanum melongena* L.) vegetative growth and yield.

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MATERIALS AND METHODS

Field experiments

Two field experiments were performed in sand-mixed loamy soil at a private agricultural farm located in Nagalapuram, Theni district, Tamil Nadu, India in 2019 using Okra plants (*Abelmoschus esculentus* L) cv. Lakshmi and Brinjal plants (*Solanum melongena*) cv. Simran to achieve the study objectives. The physical and chemical properties of the experimental soil used were done and shown in Table 1, which had been determined according to Buurman et al., (Table 1) [26].

The experimental design and treatments

The experimental setup consisted of a randomized complete block design with four replicates. In these studies, there were seven different treatments made up of three irrigation intervals and five foliar sprays of antiperspirants like potassium silicate and glycine betaine. Based on the field capacity, three surface irrigation regimes (every 6, 9 and 12 days intervals starting after 1st application of antitranspirants). The total number of irrigations was 9, 6 and 3, respectively. At 45 days following plant emergence, potassium silicate and glycine betaine were applied topically five times every seven days. Potassium silicate (K_2SiO_3) at 2.5 ml/L, glycine betaine at 2.5 ml/L, and control (sprayed with tap water). There was a 3 m^2 plot. Okra seeds were manually planted on March 23, 2019, at a depth of 1-2 cm, and covered with moist and dry soil. The plants were spaced 30 cm apart. On March 15, 2019, brinjal seeds were sown in cork trays using peat moss that had previously been moistened as the substrate. On May 5, 2019, seedlings that had attained the three true leaf stages were planted in a field 45 cm apart. All other suggested agro-managements, such as weed control and disease pest control, were carried out throughout the growing seasons as needed.

The treatments were arranged as follow

T1-Positive Control 1 (normal irrigation)

T2-Negative Control 2 (75% irrigation)

T3-Negative Control 3 (50% irrigation)

T4-75% Irrigation with Potassium Silicate-2.5 ml/ L

T5-75% Irrigation with Glycine betaine-2.5 ml/ L

T6-50% Irrigation with Potassium Silicate-2.5 ml/ L

T7-50% Irrigation with Glycine betaine-2.5 ml/ L

Data recorded were as follows

Vegetative growth parameters: After 60 days of seeding, five plants from each plot were marked at random to record the following information: the number of branches per plant and the height of the plant [27].

Yield and its attributes: Fruit could not be harvested on a specific day because of differences between fruit start and maturation in plants. To assess the yield characteristics of the tested crops, five randomly chosen plants were tagged. The fruits of Bhendi were initially fully maturely gathered on June 18, 2019 and continued until July 8, 2019, yielding a total of 8 pickings spaced two days apart. The initial Brinjal fruit harvest took place on June 18th, 2019 and continued through July 2019 with a total of 4 pickings spaced 7 days apart for the duration of this experiment.

Data analysis: Data on growth and yield parameters such as no. of branches, Height of the plant (in cm), no of fruits and weight of fruits (in grams) were recorded. All of the data were expressed as the mean ± SE for the number of experiments using SPSS *version* 11.5 (SPSS Inc., Cary, NC, USA). Values were considered statistically significant at $p<0.05$.

RESULTS AND DISCUSSION

Analysis of soil

Before and after the experiments were finished, soil samples were randomly taken from the experimental field area at a depth of 0 to 30 cm to be estimated for some mechanical and chemical examination of the employed soil. The results were reported in Table 1. These traits were examined in line with [26]. According to the results, drought stress combined with foliar potassium silicate and glycine betaine application (T4–T7) has the sustained level of nutrients in the soil samples when compared to the stress given negative control treatments like T2 and T3.

Vegetative growth parameters

Effect of irrigation intervals: According to Table 2, the highest significant values on growth parameters, such as the number of branches and height of the Okra plants, were recorded in T1 (40.2 0.58 and 13 0.44) with 100% irrigation, T4 (40 1.14 and 12 0.31) with 75% irrigation, and T6 (39.1 0.64 and 11 0.54) with 75% irrigation, while less significant values were recorded in T2 (36.6 0.4 and 11 ± 0.31) with 75% irrigation, T3 (35.8 ± 0.37 and 11 ± 0.44) with 50% irrigation, T5 (38.9 ± 0.50 and 11 ± 0.54) with 50% irrigation and T7 (37.5 ± 0.5 and 11 ± 0.44) with 50% irrigation. Table 3 shows that the highest significant values on growth parameters such as number of branches and height of the Eggplants were recorded in T1 (53.2 ± 0.167 and 9 ± 0.31) with100% irrigation, T4 (50 ± 0.2 and 9 ± 0.31) with75% irrigation, T2 (49.4 ± 0.10 and 8 ± 0.31) with 75% irrigation, and T6 (46.4 ± 0.33 and 8 ± 0.31) with 75% irrigation and less value were recorded in T3 (47.3 ± 0.16 and 8 ± 0.31) with50% irrigation, T5 (47.6 ± 0.22 and 8 ± 0.31) with50% irrigation and T7 (40.6 ± 0.30 and 8 ± 0.31) with 50% irrigation. In this regard, the highest average values for vegetative growth were found in Tables 2 and 3, followed by values of 75%, while the lowest average values were found in irrigation at 50% (Tables 2 and 3).

TABLE 1
Physico-chemical analysis of tested soil samples

Parameters	Initial	Okra							Eggplant						
		T1	T2	T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7
PH	8.08	7.9	7.95	7.83	7.96	8.03	7.94	7.92	7.5	7.64	8.06	7.7	8.01	7.75	7.68
EC (dSm-1)	0.18	0.24	0.26	0.28	0.26	0.34	0.28	0.34	0.24	0.28	0.29	0.31	0.23	0.32	0.27
Nitrogen (%)	73	69	64	71	66	60	69	66	69	71	66	69	71	66	57
Phosphorous (%)	6	5	8	18	16	4	4	9	11	19	8	9	5	8	9
Potassium (%)	75	540	389	306	425	408	383	367	433	333	367	408	294	333	408
Iron (ppm)	4.6	5	3.9	4	4.3	5	4.4	3.9	4.8	3.9	4.3	3.8	4.2	5.2	4.3
Zinc (ppm)	0.52	0.43	0.4	0.32	0.31	0.43	0.5	0.43	0.42	0.38	0.31	0.48	0.34	0.3	0.29
Copper (ppm)	0.68	0.48	0.34	0.5	0.31	0.48	0.72	0.48	0.31	0.34	1	0.98	0.71	0.48	0.32
Manganese (ppm)	1.9	3.1	2.9	2.2	3.1	2.8	2.4	2.8	3.2	2.4	3.1	2.6	2.4	3.1	2.8

TABLE 2

Growth and yield attributes of Okra

Treatments	Plant ht in cm	No of branches	No of fruits	Weight of fruits
T1	40.2 ± 0.58	13 ± 0.44	40.125 ± 1.95	948.75 ± 101.58
T2	36.6 ± 0.4	11 ± 0.31	39.25 ± 4.22	874.375 ± 58.34
T3	35.8 ± 0.37	11 ± 0.44	38.875 ± 4.39	817.75 ± 72.67
T4	40 ± 1.14	12 ± 0.31	40 ± 4.71	926.875 ± 67.83
T5	38.9 ± 0.50	11 ± 0.54	39.875 ± 4.84	919.5 ± 60.46
T6	39.1 ± 0.64	11 ± 0.54	40.5 ± 4.55	849.75 ± 76.05
T7	37.5 ± 0.5	11 ± 0.44	37.875 ± 4.21	821.75 ± 61.75

TABLE 3

Growth and yield attributes of Eggplant Okra

Treatments	Plant ht in cm	No of branches	No of fruits	Weight of fruits
T1	53.2 ± 0.167	9 ± 0.31	135.75 ± 31.50	4715 ± 728.46
T2	49.4 ± 0.10	8 ± 0.31	136.75 ± 31.86	4027.75 ± 777.37
T3	47.3 ± 0.16	8 ± 0.31	141.75 ± 34.53	3689.5 ± 666.9
T4	50 ± 0.2	9 ± 0.31	139.75 ± 28.23	4734.5 ± 1094.25
T5	47.6 ± 0.22	8 ± 0.31	146.25 ± 30.19	4702 ± 881.17
T6	46.4 ± 0.33	8 ± 0.31	149.5 ± 36.64	4393.75 ± 1762.35
T7	40.6 ± 0.30	8 ± 0.31	148.75 ± 34.06	4288 ± 793.48

These outcomes could be explained by a shortage of water absorbed and a reduction in photosynthetic efficiency in the presence of insufficient water [28]. The variations in irrigation intervals may indicate that as more water is provided to a plant, more moisture is retained in the soil, which in turn may affect plant metabolism and result in increased plant growth characteristics and higher dry matter production. This outcome is consistent with Saied's findings from 2000 on sugar beet [29]. These findings concur with those of Romaisa et al., [30] for okra. When there is a water shortage, the majority of morphological, physiological, and biochemical plant growth processes are affected, which can lead to subpar photosynthesis, respiration, and nutrition metabolism [31,32]. Crops grown in drought-prone regions would benefit from greater growth under limited water availability and efficient use of limited water resources. Plants respond to drought and reduce its negative effects by utilizing one or more of the following strategies: early emergence or escape, drought avoidance, drought tolerance and drought recovery [33,34].

Effect of foliar application of antitranspirants

Table 2 demonstrates that the highest significant values of vegetative growth parameters, including plant height and number, were recorded with spraying plants with potassium silicate with 75% irrigation in T4 (40 1.14 and 12 0.31) followed by T6 (39.1 0.64 and 11 0.54). In contrast, the negative control T2 had the lowest values of the aforementioned growth parameters in Okra plants. According to Table 3, T5 (38.9 0.50 and 11 0.54) and T7 (39.1 0.64 and 11 0.54), which used Glycine betaine spraying with 50% irrigation, had the greatest significant values of the aforementioned vegetative development parameters in eggplants, while T3 (35.8 0.37 and 11 0.44) had the lowest values. These findings concur with those of Abbas et al., [35] for silicon and with those of El-Sherbini [36] and Ragab et al., [37] for glycine betaine. Since silicon boosts defense against infections and promotes development, it may have a stimulating effect on vegetative growth [38]. Increased plant tolerance to several abiotic stressors, such as salt, drought, and severe temperatures, is facilitated by glycine betaine [39]. The maximum plant lengths, number of leaves, and fresh and dry weights/plant of garlic were obtained by foliar application of 4000 ppm potassium silicate compared to the control, according to Abdel-Latif et al., [40]. Moreover, glycine betaine has significantly increased alfalfa and cowpea growth characteristics [41].

<u>Effect of the interactions:</u> Tables 2 and 3 shows that the highest significant values of height of the plant and number of branches/plant of okra and eggplants were obtained with irrigation every 9 days × foliar sprayed by 2.5 ml/L of potassium silicate (T4) and 2.5 ml/L of Glysine betaine (T6) followed by (irrigation every 12 days × foliar sprayed by 2.5 ml/L Potassium silicate (T5) and 2.5ml/L of glycine betaine (T7) and the lowest results observed with irrigation every 12 days (T3) followed by 9 days (T2). The given results of Table 2 and 3 indicated that the given interactions exerted significant effect ($p \leq 0.05$) on plants vegetative growth parameters of the tested crops okra and eggplant. Similar results were harmonious with Farouk and Farouk et al., [42], Rakha [43] and Raza et al., [44].

Yield parameters

<u>Effect of irrigation intervals:</u> Data in Tables 2 and 3 shows that irrigation intervals at 6 days (T1) had the highest number of fruits and weight followed by 9 days (T4 and T6) and 12 days (T5 and T6) interval. Lowest yielding were recorded in irrigation interval of 12 days (T3) followed by 9 days of interval (T2) on both the experimental crops okra and eggplant respectively. Table 2

shows that the highest significant values on yield parameters such as number of fruits and weight of the Okra fruits in grams were recorded, in T1 (40.125 ± 1.95 and 948.75 ± 101.58) with100% irrigation, T4 (40 ± 4.71 and 926.875 ± 67.83) with75% irrigation and T6 (40.5 ± 4.55 and 849.75 ± 76.05) with 75% irrigation and less value were recorded in T2 (39.25 ± 4.22 and 874.375 ± 58.34) with75% irrigation, T3 (38.875 ± 4.39 and 817.75 ± 72.67) with50% irrigation, T5 (39.875 ± 4.84 and 919.5 ± 60.46) with 50% irrigation and T7 (37.875 ± 4.21 and 821.75 ± 61.75) with 50% irrigation. Table 3 shows that the highest significant values on yield parameters on the Eggplants such as T1 (135.75 ± 31.50 and 4715 ± 728.46) with100% irrigation, T4 (139.75 ± 28.23 and 4734.5 ± 1094.25) with75% irrigation, T6 (149.5 ± 36.64 and 4393.75 ± 1762.35) with 75% irrigation and T2 (136.75 ± 31.86 and 4027.75 ± 777.37) with 75% irrigation and less value were recorded in T3 (141.75 ± 34.53 and 3689.5 ± 666.9) with 50% irrigation, T5 (146.25 ± 30.19 and 4702 ± 881.17) with 50% irrigation and T7 (148.75 ± 34.06 and 4288 ± 793.48) with 50% irrigation. In this respect, the highest average values were recorded from Table 3 and 4 for yield attributes were at 100% followed by 75%, while the lowest average values were recorded at 50% irrigation.

Okra plants experienced water stress due to irrigation intervals of 20 days, which is thought to be one of the most significant barriers to photosynthesis and plant productivity [45]. Similar results were obtained by Hussein et al., [46] on okra. Total yield per plant (gms) was the only character that affected significantly ($p \leq 0.05$) by irrigations levels in both Okra and eggplants. These outcomes could be explained by a shortage of water absorbed and a reduction in photosynthetic efficiency in the presence of insufficient water [27]. Smittle et al., [47] and Abd El-Aal [48] found somewhat comparable results with sweet potatoes.

Effect of foliar application of antitranspirants

The data in Tables 2 and 3 make it clear that all foliar sprays improve all measured parameters when compared to the control. Okra and eggplants sprayed with Potassium Silicate (T4 and T6) and Glycine Betaine (T5 and T7) produced the most fruits and weight of fruits, while negative control yields were the lowest (T2 and T3). Results obtained from Table 2 and 3 indicate that the foliar applicants besides exhibited significant positive effects ($p \leq 0.05$) on increasing number of fruits increase the weight of the fruits in tested okra plants. But eggplant exhibited insignificant effect ($p \geq 0.05$) that the Number of fruits doesn't affect the weight of the fruits. Potassium silicate and glycine betaine applied topically significantly reduced drought stress in both crops. These findings are consistent with El-Sherbini [36] findings regarding silicon and Ragab et al., [37] findings regarding glycine betaine.

Regarding silicon, the deposition of the element under the leaf epidermis caused a production of phenols, a physical defence mechanism, which reduced lodging, stimulated the production of phytoalexin, reduced transpiration losses, and increased crop plants' capacity for photosynthesis, leading to an increase in yield from silicon-treated plants Korndorfer et al., [49] and Ahmad et al., [50]. Regarding glycine betaine, improvements in yield and yield components are anticipated to significantly increase plants' ability to withstand abiotic stresses such salt, drought, and severe temperatures (Figures 1-4) [39].

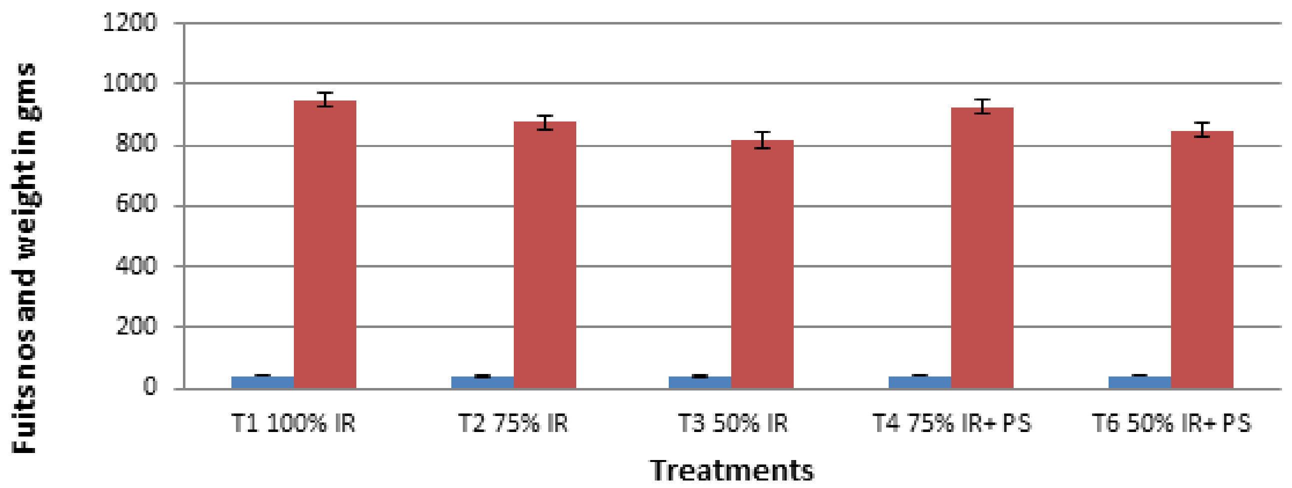

Figure 1) *Effect of Potassium Silicate on yield of Okra at different irrigation level.* **Note:** (■) *Avg No of fruits,* (■) *Avg Weight in gms.*

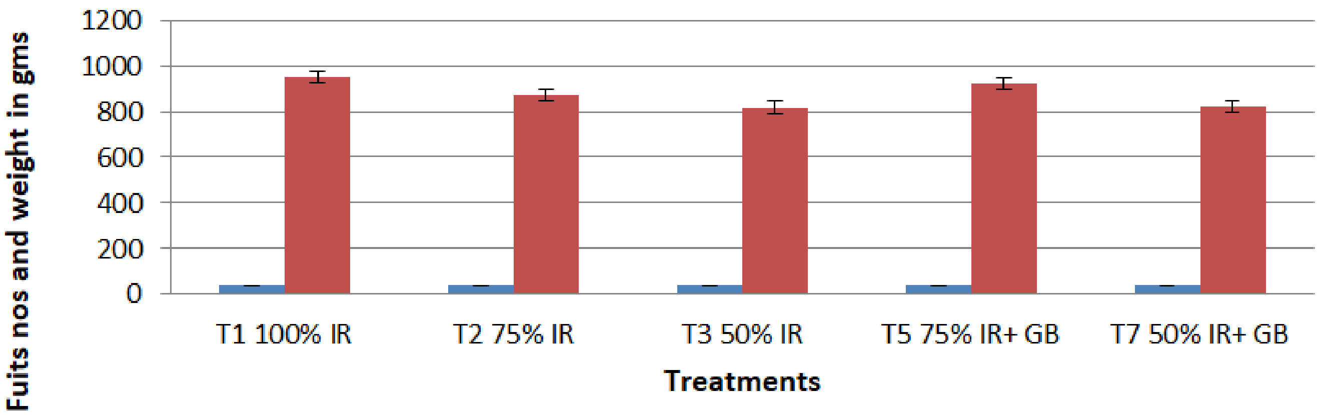

Figure 2) *Effect of Glycine betaine on yield of Okra at different irrigation level.* **Note:** (■) *Avg No of fruits,* (■) *Avg Weight in gms.*

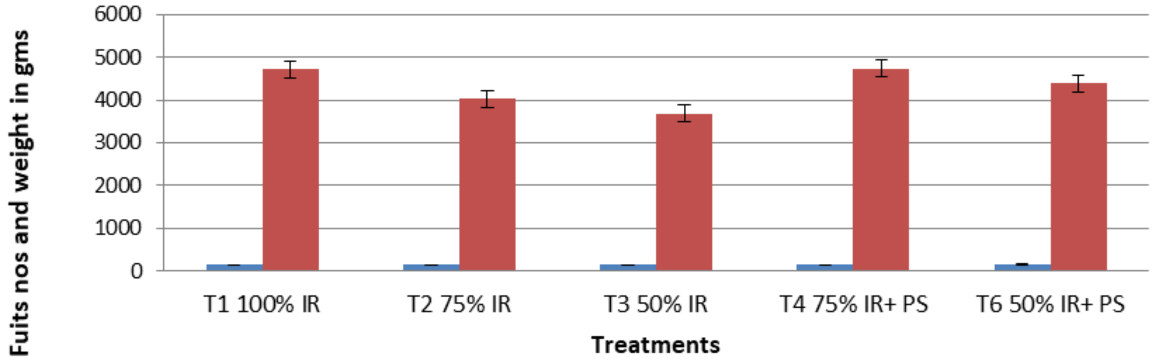

Figure 3) *Effect of Potassium Silicate on yield of eggplant at different irrigation level.* **Note:** (■) *Avg No of fruits*, (■) *Avg Weight in gms.*

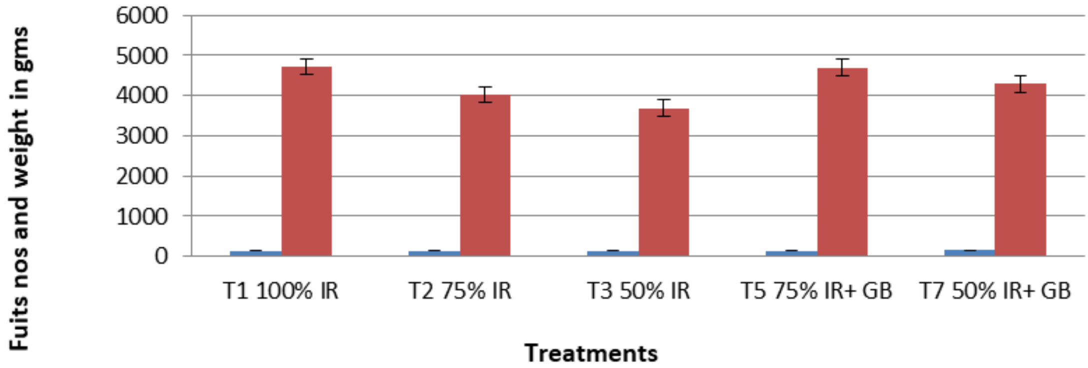

Figure 4) *Effect of glycine betaine on yield of eggplant at different irrigation level.* **Note:** (■) *Avg No of fruits*, (■) *Avg Weight in gms.*

Effect of the interactions

Tables 2 and 3 shows the highest significant growth and yield of okra and eggplants were obtained with the interaction between (irrigation every 9 days × foliar sprayed with 2.5 ml/L of Pottassium silicate) followed by (irrigation every 9 days × foliar sprayed with 2.5 ml/L of glycine betaine) and the lowest one was the interaction between (drought stress irrigation every 12 days followed by interaction between 9 days of negative control). Figures 1 and 2 represent the effect of Potassium Silicate and Glysine betaine on yield of okra respectively at different irrigation level. Figures 3 and 4 represent the effect of Potassium Silicate and Glysine betaine on yield of eggplant respectively at different irrigation level. Similar results were obtained by Farouk and Abd EL Mohsen [42], Rakha [43] and Noreen et al., [51].

CONCLUSION

Water deficit is a limiting factor affecting crop production and quality. With increasing population, urbanization, and industrialization, competition for water is increasing worldwide. Since agriculture is the major consumer of fresh water resources, efforts toward improving water use efficiency will be worthwhile. Increasing the irrigation water to 100% increased the plant growth, nutrients uptake, and biological yield of plants. The yield of okra irrigated with 75% and 50% was lower by about 7.8% and 13.8% that received 100% water requirements. Likewise yield of eggplant with 75% and 50% of irrigation was lower by about 14.5% and 21.7% that of 100% irrigation. But foliar application of potassium silicate and glycine betaine with 75% irrigation of okra and eggplant reached 97.5% and 96.95% respectively and 50% of irrigation reached around 89.5% and 86.6% of the yield of 100% irrigation. The results obtained from the present investigation shows that spaying of potassium silicate and glycine betaine at 2.5 ml/L under water deficit areas increased the growth rate and yield of the okra and eggplant and also these treatments (T4-T7) lets plants resistance to drought stress.

REFERENCES

1. Parkash V, Singh S. A review on potential plant-based water stress indicators for vegetable crops. Sustainability. 2020,12; 12(10):3945.
2. Kumar R, Solankey SS, Singh M. Breeding for drought tolerance in vegetables. Veg Sci. 2012; 39(1):1-5.
3. Raza A, Razzaq A, Mehmood SS, et al. Impact of climate change on crops adaptation and strategies to tackle its outcome: A review. Plants. 2019, 30; 8(2):34.
4. World Bank. Reengaging in agricultural water management: Challenges and options. The World Bank; 2006, 23.
5. Raw P. Composition of foods raw, processed, prepared usda national nutrient database for standard reference, release 25. United States Department of Agriculture (USDA). 2012.
6. El-Kader A, Shaaban SM, El-Fattah M. Effect of irrigation levels and organic compost on okra plants (*Abelmoschus esculentus* L.) grown in sandy calcareous soil. Agric Biol JN Am. 2010;1(3):225-231.
7. Sarhan TZ, Mohammad GH, Teli JA. Effects of humic acid and bread yeast on growth and yield of eggplant (*Solanum melongena* L.). J Agric Sci Technol. 2011; 1:1091-1096.
8. Mahmoud H. Effect of sulphur and phosphorus on some eggplant cultivars under calcareous soil conditions. EJAS. 2000; 51(2):209-226.
9. Byari SH, Al-Rabighi SM. Yield and growth responses of eggplant cultivars to water deficit. EJOH. 1996.
10. Sawan OM, Amer AH, El-Desuki M. Effect of irrigation and organic fertilizer on sugar pea (*Pisum sativum* L.) under Shark El-Owinat condition. Ann of Agric Sci Moshtohor. 2001; 39(2):1251-1264.
11. Yadav NR, Dashora LK. Shelflife of swat pepper (*Capsicum annuum* L.) cv. California wonder as influenced by benzyl adenine and vapor grad. Adv Hortic. 2003; 9:215-221.
12. Chen Z, Zhou M, Newman IA, et al. Potassium and sodium relations in salinised barley tissues as a basis of differential salt tolerance. Funct Plant Biol. 2007; 34(2):150-162.
13. Ma JF, Miyake Y, Takahashi E. Silicon as a beneficial element for crop plants. Plant Sci. 2001; 8:17-39.

14. Ma JF. Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses. Soil Sci Plant Nutr. 2004; 50(1):11-18.

15. Salim BB, Abd El-Gawad HG, Abou El-Yazied A. Effect of foliar spray of different potassium sources on growth, yield and mineral composition of potato (*Solanum tuberosum* L.). J Appl Sci. 2014; 4(4):1197-1204.

16. Zydlik Z, Pacholak E, Rutkowski K. Effect of Actisil preparation on the growth of strawberries grown in the soil depleted by a long monoculture. Zesz Probl Post􏰀p Nauk Rol. 2009(536).

17. Abou El-Khair E.E, Mohsen AAM. Effect of natural sources of potassium on growth, mineral uptake and productivity of Jerusalem artichoke grown in new reclaimed soil conditions. Middle East J Agric Res. (2016); 5 (3): 367-377.

18. Mohamed YA, El-Ghamriny EA, Ahmed A, et al. Effect of planting date and foliar spray with potassium silicate on growth and yield of some garlic cultivars. Zagazig J Agric Res. 2019; 46(2):295-308.

19. Alkharpotly AA, Yosury MM, Abido AI. Effect of foliar application with salicylic acid and potassium silicate on squash plants (*Cucurbita pepo* L.) yield and quality. FJARD. 2019; 33(1):1-24.

20. El-Nagy M, El-Salehein A, Fekry W, et al. Effect of foliar spray with different potassium sources and zinc rates on growth and yield of sweet potato (*Ipomoea batatas* L.). J Product Dev. 2020; 25(2):231-246.

21. Miri HR, Armin M. The interaction effect of drought and exogenous application of glycine betaine on corn (*Zea mays* L.). Eur J Exp Biol. 2013; 3:197-206.

22. Dawood MG, Sadak MS. Physiological role of glycinebetaine in alleviating the deleterious effects of drought stress on canola plants (*Brassica napus* L.). Middle East J Agric Res. 2014; 3(4):943-954.

23. Ashraf MF, Foolad MR. Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environ Exp Bot. 2007; 59(2):206-216.

24. Hoque MA, Okuma E, Banu MN, et al. Exogenous proline mitigates the detrimental effects of salt stress more than exogenous betaine by increasing antioxidant enzyme activities. J Plant Physiol. 2007; 164(5):553-561.

25. Chen TH, Murata N. Glycinebetaine: an effective protectant against abiotic stress in plants. Trends Plant Sci. 2008; 13(9):499-505.

26. Buurman P, Van Lagen B, Velthorst EJ. Manual for soil and water analysis. Backhuys; 1996.

27. Koller HR. Leaf Area􏰀Leaf Weight Relationships in the Soybean Canopy 1. Crop Sci. 1972; 12(2):180-183.

28. Magda AH, Nashwa IA, Zahra AA. Effect of soil moisture and potassium fertilization on the growth and chemical constituents of Jerusalem artichoke (*Helianthus tuberosus* L.) tubers grown on a lacustrine soil. In7th African Potato Association Conference Potato, sweet potato and tuber crops improvement for facing property and hunger in Africa 2007; 22-26.

29. Saied M. Effect of irrigation intervals, furrow irrigation system and nitrogen fertilizer levels on sugar beet yield and its water relations at north delta. J Soil Sci Agric Eng. 2000; 25(7):4737-4745.

30. Romaisa A, Khalid H, Ujala M, et al. Effect of different levels of drought on growth, morphology and photosynthetic pigments of lady finger (*Abelmoschus esculentus*). World J Agric Sci. 2015; 11(4):198-201.

31. Al-Ubaydi RM, Al-Shakry EF, Al-Samara MA, et al. Effect of irrigation intervals on growth, flowering and fruits quality of okra *Abelmoschus esculentus* (L.) Monech. Afr J Agric Res. 2017; 12(23):2036-2040.

32. Hamdi GJ. Effect of perlite in reducing water stress for three genotypes of tomato (Doctoral dissertation, M. Sc. Thesis. College of Agriculture. University of Diyala. Iraq).

33. Al-Shammari AM, Abood MA, Hamdi GJ. Perlite affects some plant indicators and reduces water deficit in tomato. Int J Veg Sci. 2018; 24(5):490-500.

34. Sam-Amoah LK, Willie WK, Owusu-Sekyere JD. Effects of deficit irrigation and chicken manure interactions on the growth and yield of okra in a pot experiment.

35. Abbas T, Sattar A, Ijaz M, et al. Exogenous silicon application alleviates salt stress in okra. Hortic Environ Biotechnol. 2017; 58:342-349.

36. El-Sherbini MA. Physiological studies on sugar pea (*Pisum sativum* L.) (Doctoral dissertation, ph. D., Thesis, fac. Agric., Mans. univ., Egypt. 107).

37. Ragab ME, Helal NA, Sawan OM, et al. Foliar application of glycine betaine for alleviating water stress of tomato plants grown under sandy soil conditions. Int J Chemtech Res. 2015; 8(12):52-67.

38. Greger M, Landberg T, Vaculik M, et al. Silicon influences nutrient status in plants. InProceedings of the 5th International Conference on Silicon in Agriculture, Beijing, China 2011; 57-58.

39. Quan R, Shang M, Zhang H, et al. Improved chilling tolerance by transformation with betA gene for the enhancement of glycinebetaine synthesis in maize. Plant Sci. 2004; 166(1):141-149.

40. Abdel-Latif AA, Ibrahim NM, Ismail SA. Effect of foliar application of potassium silicate and some postharvest treatments on growth, productivity and storability of Garlic. Arab Univ J Agric Sci. 2019; 27(1):761-773.

41. Khadouri HK. Effects of glycine betaine on plant growth and performance of alfalfa (*Medicago sativa* l.) & cowpea (*Vigna unguiculata* l. Walp.) within water deficit conditions.

42. Farouk S, Mohsen AE, Amany R. Improving growth and yield of cowpea plant by foliar application of chitosan under water stress. J Plant Prod. 2011; 2(10):1341-1358.

43. Rakha MK. Growth, yield and fruit quality of eggplant (*Solanum melongena* l.) As affected by irrigation intervals and foliar application of some antitranspirants. J Plant Prod. 2014; 5(12):2069-2083.

44. Raza MA, Saleem MF, Shah GM, et al. Exogenous application of glycinebetaine and potassium for improving water relations and grain yield of wheat under drought. J Soil Sci Plant Nutr. 2014; 14(2):348-364.

45. Tezara W, Marín O, Rengifo E, et al. Photosynthesis and photoinhibition in two xerophytic shrubs during drought. Photosynthetica. 2005; 43:37-45.

46. Hussein HA, Metwally AK, Farghaly KA, et al. Effect of irrigation interval (water stress) on vegetative growth and yield in two genotypes of okra. Aust J Basic Appl Sci. 2011; 5(12):3024-3032.

47. Smittle DA, Hall MR, Stansell JR. Effects of irrigation regimes on yield and water use by sweetpotato. J Am Soc Hortic Sci. 1990; 115(5):712-714.

48. Ahmed AE, Ahmed H. Effect of Folicote Antitranspirant and Irrigation Water Regime on Growth Characters of Sweet Potato (*Ipomoea batatas* L.) Plants Grown In Sandy Soil. Alex Sci Exch J. 2011; 32:363-371.

49. Berthelsen S, Kordorfer GH. Methods for Silicon Analysis in Soil, Plant, and Fertilizers. InProceedings of the third International Conference on Silicon in Agriculture 2005; 85-91.

50. Ahmad A, Tahir M, Ullah E, et al. Effect of silicon and boron foliar application on yield and quality of rice. Pak J Life Soc Sci. 2012; 10(2):161-165.

51. Noreen S, Zafar ZU, Hussain K, et al. Assessment of economic benefits of foliarly applied osmoprotectants in alleviating the adverse effects of water stress on growth and yield of cotton (*Gossypium hirsutum* L.). Pak J Bot. 2015; 47(6):2223-2230.