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RESEARCH PAPER

Effect of Potassium Silicate, Glycine Betaine and Proline on Fruit Quality of Peaches in Newly Reclaimed Land Exposed to Heat Stress

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Abstract

The current study was performed on a 6-year-old "Florida" peach cultivar (*Prunus persica*) during 2022 and 2023 respectively. Twenty-four peach trees uniformly were selected and sprayed two times at the beginning of pit starts hardening and at the end of phase two of fruit growth with the following treatments: the control, glycine betaine at 400 mg l^{-1}, potassium silicate at 200 mg l^{-1}, potassium silicate at 400 mg l^{-1}, potassium silicate at 200 mg l^{-1} + glycine betaine at 400 mg l^{-1}, potassium silicate at 400 mg l^{-1} + glycine betaine at 400 mg l^{-1}, proline at 400 mg l^{-1} and potassium silicate at 200 mg l^{-1} + proline at 400 mg l^{-1}. The results indicated that both treatments of potassium silicate at 200 mg l^{-1} + proline at 400 mg l^{-1} and potassium silicate at 400 mg l^{-1} + glycine betaine at 400 mg l^{-1} resulted in a significant increase in concentrations of anthocyanin and total carotenoid contents in the skin. Moreover, total soluble solid, vitamin C and total soluble solid / acidity were shown with high concentrations as compared with the control. Overall, the use of potassium silicate at 200 mg l^{-1} + proline at 400 mg l^{-1} or potassium silicate at 400 mg l^{-1} + glycine betaine at 400 mg l^{-1} two times is recommended.

1. Introduction

Peach is one of the important fruit crops in Egypt, with an estimated total fruit production quantity of both peaches and nectarines at about 337,910 tons. (FAO, 2020). Climate change is one of the main challenges in agricultural production which has many negative consequences in agricultural fields. Heat stress, an abiotic stress resulting from climate changes, is caused by high temperatures and leads to numerous adverse effects throughout various developmental stages, such as carbon assimilation, respiration, fertilization, cell differentiation, and fruit maturity. Furthermore, fruit crops such as apples (Austin et al., 1999; Sugiura et al., 2013) are negatively impacted by heat stress, particularly in terms of their maturity and fruit quality characteristics. The typical air temperature throughout the growing season for cultivated peach trees in Egypt ranges between 35 and 40ºC, while nighttime temperatures in the field range between 25ºC and 28ºC. It was recently reported that KU-PP2, a peach cultivar in Japan, has minimal chill requirements. For example, when trees were exposed to 30ºC, various adverse effects were observed, including decreases in fruit size, photosynthesis, stomata density, leaf size, thickness, and chlorophyll content. Additionally, high temperatures accelerated the harvesting season (Sikhandakasmita et al., 2021a,b). Meanwhile, growth and development could be slowed down by heat stress, which is reflected in peach fruit size, weight, and sweetness. Peach trees grown in the newly reclaimed areas in Egypt are exposed to many adverse effects due to heat, which disrupts the balance between plants and water. Problems with water uptake, imbalances in transpiration, stomatal malfunctioning, disruption of sap flow, inhibition of chlorophyll biosynthesis, ultimately leading to a decline in photosynthesis and damage to thylakoid membranes, result in increased membrane leakage (Prasad et al., 2008). The objectives of this study were to investigate the effects of some osmoregulators on peach trees and fruits exposed to heat stress under field conditions, and to assess the impact of potassium silicate, glycine betaine, and proline on fruit quality under such stressful conditions.

2. Material and Methods

The current study was carried out on the "Florida" peach cultivar (*Prunus persica*) during two consecutive seasons in 2022 and 2023. The six-year-old trees, planted in a private orchard in Sadat City, Menoufia Governorate, Egypt, were spaced at 4×5 meters and were irrigated with drips. Throughout the season, trees had been subjected to standard agricultural practices. The soil had a sand-like texture, and drip irrigation was used. The block design for the treatments was fully randomized. Three replications were used for each treatment and one peach tree represented one replication. For this study, twenty-four trees were used in each season. Eight treatments, applied by spraying twice at the beginning of pit hardening and then at the end of phase two from the double sigmoid curve of fruit growth, were randomly assigned to twenty-four standard "Florida" peach trees. The treatments included the following: tap water spray (as the control), glycine betaine at 400 mg l^{-1}, potassium silicate at 200 mg l^{-1}, potassium silicate at 400 mg l^{-1} + glycine betaine at 400 mg l^{-1}, proline at 400 mg l^{-1}, and potassium silicate at 200 mg l^{-1} + proline at 400 mg l^{-1}. To lower the surface tension and raise the contact angle of sprayed droplets, the non-ionic surfactant Top film was added to all treatments at 0.05% (V/V). The average air temperature measured during spray times was between 33ºC and 37ºC, while the nighttime temperature in the field is between 15 and 20ºC. These treatments were set up in a Randomized Complete Block Design (RCBD) Analysis of Variance (ANOVA). Statistical analysis was done according to (Gomez and Gomez,1984), using Costat (Version 6.303, cohort, USA, 1998–2004).

2.1. Physical characteristics

Samples of five fruits per tree (replicate) were collected randomly and the fruit weight was measured by using an electronic balance so as to determine peel and seeds weight percentage, fruits were peeled and the weight of total seeds, peel (g) and juice volume (ml) were calculated. Fruits diameter (mm) were measured by vernier caliper. Fruit firmness was measured by a hand Effigy-Penetrometers attached with a plunger 8 mm diameter was utilized to estimate this parameter as kg cm^{-2} (Southwick et al., 1996).

2.2. Chemical characteristics

Vitamin C was estimated by a 2,6-dichlorophenol indophenol method (Mazumadar and Majumder, 2003). A known amount of edible portion of "Florida prince" peach fruits extracted with 3% metaphosphoric acid by thorough crushing. The filtered extract was made up to a known volume with 3% metaphosphoric acid then titrated with the standard indophenol dye solution to a pink endpoint (persisting for fifteen sec). Electrolyte leakage (EL %) was determined from the following equation by a Conductivity meter (CD-4301) according to Fan and Sokorai (2005).

$$EL = \left(\frac{C_{60} - C_1}{CT}\right) \times 100$$

According to the AOAC (1994), total soluble solids (TSS %) is estimated in fruit juice by using a Carl-Zeiss hand refractometer and total titratable acidity (%) is expressed as g malic acid / 100 ml juice. Soluble solids content (SSC) / acid ratio was calculated from the results recorded for fruit juice SSC and TA. The spectrophotometer (APEL, PD-303S Japan) is used to measure the amount of vitamin C present (Desai and Desai, 2019). When bromine water is added, ascorbic acid oxidizes and becomes dehydroascorbic acid. A coupling reaction occurs when 2, 4 dinitrophenyl hydrazine is heated to 37°C for three hours. After treating the solution with 85% H_2SO_4, which produces a colored complex after three hours, the absorbance was measured at 491 nm.

Total carotenoids were extracted using the method given by Ranganna (1995). A known weight of sample, i.e. 5 g fresh peach fruit was weighed and ground finely with mortar and pestle in acetone till the residue became colorless. The acetone extract was collected in a conical flask. Separating funnel was used for the separation of the carotenoid pigments. The carotenoid extract was transferred to a separating funnel and then added petroleum was added with the addition of 10% Na_2SO_4. The funnel was swirled to separate the carotenoid layer. The isolated carotenoids were collected in a volumetric flask. The process was repeated till remained extract showed no color. The absorbance was read at 452 nm spectrophotometrically. Total carotenoids were estimated using the following formula:

$$Tc = \left(\frac{3.87 \times A \times Vm \times Df \times 100}{Sw \times 1000}\right)$$

Where; Tc: total carotenoids (mg 100 g^{-1} fresh weight^{-1}), A: absorbance (452 nm), Vm: volume make up, Df: dilution factor, and Sw: sample weight (g).

The procedure described by Onayemi et al., (2006) was used to determine the anthocyanin content of the extracts. One gram of fruit skin samples were ground up using a 1.5 M HCl (by volume) solution and 20 ml of 85% ethanol. The samples were stored in the deep freeze for the entire night while covered. After the extracts were finished using 50 milliliters of the solvent, a spectrophotometer (Unico 1200-USA) was used to measure the absorbance of the mixture at 530 nm. The outcome is given in mg 100 g^{-1} of fresh fruit. The following (Lees and Francis,1971) equation was used to calculate total anthocyanin.

$$Ta = \left(\frac{A530 \times V}{98.2 \times W}\right)$$

Where Ta: total anthocyanin (mg 100 g^{-1}), A530 is the rate of absorption of the sample at the wavelength of the subtitle A. For example, A530 is the absorption at a wavelength of 530 nm. V= total volume of extract (ml), W= weight of sample (g).

3. Results and Discussion

3.1. Physical characteristics

3.1.1. Fruit weight

The effect of various applications and the control on some physical characteristics of “Florida” peach fruits during the two study seasons is shown in Table 1. The data revealed that many treatments were effective in increasing fruit weight at harvest time especially the combination of potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1} in both seasons which had a superior influence on fruit weight as compared with all treatments in a consistent manner in both seasons and compared to the control. Such positive influence on fruit weight was followed in order by potassium silicate at 400 mg l^{-1} plus glycine betaine at 200 mg l^{-1}. Both combinations had a significant effect on fruit weight when compared with either proline alone or potassium silicate alone at the same concentration in both seasons. Additionally, the application of potassium silicate at either 400 or 200 mg l^{-1} significantly increased fruit weight consistently across both seasons. Similarly, the individual application of either Proline or glycine betaine resulted in a significant increase in fruit weight relative to the control in the two seasons. Thus, it was better to combine potassium silicate with either proline or with glycine betaine to have the most favorable influence on fruit weight at harvest. Thus, the combined influence of the enhancer of photosynthesis addition to the presence of the osmo-regulator such as proline or glycine betaine had the greatest potential to increase fruit weight of “Florida” peach fruits.

3.1.2. Stone weight

Changes in stone weight of “Florida” peach fruits in response to used applications were reported in Table 1. The data confirmed the previous trend that the combination of potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1} resulted in the highest stone weight as compared with the control and with many other treatments such as potassium silicate at 400 mg l^{-1} plus glycine betaine at 400 mg l^{-1} in addition to proline alone or potassium silicate alone at both rates at 200-400 mg l^{-1}. Moreover, the individual application of glycine betaine at 400 mg l^{-1} had a similar influence on stone weight compared to the control (which had the lowest stone weight), especially during the first season. However, the application of proline alone at 400 mg L-1 resulted in higher stone weight compared to that observed with glycine betaine at the same concentration in both seasons. Furthermore, the combined

Table 1. The effect of pre-harvest applications on some physical characteristics of "Florida" peach during the 2022 and 2023 seasons.

Treatments	Fruit weight (g)		Stone weight (g)		Fruit diameter (cm)		Fruit firmness (kg cm^{-2})	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	105.65 g*	87.07 g	4.70 f	4.13 g	4.90 e	4.40 f	6.70 h	5.80 e
Glycine betaine (400 mg l^{-1})	112.01 f	93.42 f	4.94 f	4.61 f	5.57 d	4.70 e	7.00 g	5.80 e
Potassium silicate (200 mg l^{-1})	115.69 e	98.58 e	5.50 e	5.24 e	5.97 c	5.50 c	7.70 e	6.90 c
Potassium silicate (400 mg l^{-1})	121.02 d	102.98 d	6.20 d	5.73 d	5.73 cd	5.17 d	7.40 f	6.50 d
Potassium silicate (200 mg l^{-1}+ glycine betaine (400 mg l^{-1})	125.71 c	109.50 c	6.78 c	6.24 c	6.33 b	5.73 bc	8.17 d	7.30 b
Proline (400 mg l^{-1})	126.41 bc	111.81 bc	7.02 c	6.70 b	6.37 b	5.93 b	8.27 c	7.43 b
Potassium silicate (400 mg l^{-1})+ glycine betaine (400 mg l^{-1}l)	128.80 b	114.17 b	7.41 b	6.89 b	6.57 ab	5.97 b	8.50 b	7.50 ab
Potassium silicate (200 mg l^{-1}) + Proline (400 mg l^{-1})	133.12 a	119.33 a	7.98 a	7.37 a	6.83 a	6.23 a	8.73 a	7.87 a
LSD $_{at\ 5\%}$	2.61	2.36	0.25	0.24	0.29	0.24	0.09	0.37

* Values in each column when accompanied with similar letters, were not significantly different by using the least significant difference at 5 % for comparing the means.

treatment had a greater influence on stone weight than the individual applications, consistently across both seasons.

3.1.3. Fruit diameter

The response of fruit diameter of "Florida" peach fruits to various treatments before harvest was shown in Table 1. The data revealed that again the greatest fruit diameter was obtained with the combination of potassium silicate at a rate of 200 mg l^{-1} plus proline at 400 mg l^{-1} in both seasons. Similarly, the combination of potassium silicate at 400 mg l^{-1} plus glycine betaine at 400 mg l^{-1} had a similar influence to the first combination, especially in the first season followed by the sole treatment of proline at 400 mg l^{-1}. Even the individual treatment of potassium silicate whether at 200 or 400 mg l^{-1} caused a significant increase in fruit diameter as compared with the control in both season. However, the highest magnitude was obtained with the combination of potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1}.

3.1.4. Fruit firmness

The influence of pre-harvest application on the firmness of "Florida" peach fruits at harvest was reported in Table 1. The data revealed that many combination treatments were able to delay the less of flesh firmness especially the combination of potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1} in both seasons which resulted in a great magnitude of increase in the flesh firmness in a sensitive climacteric fruit such as peach fruit. The individual application of potassium silicate or proline at the same similar concentration was also able to delay the loss of firmness and even the osmo-regulators whether proline or potassium silicate alone when compared with the control in both seasons. When we compare the influence of proline with potassium silicate at 400 mg l^{-1} (similar concentration), proline had superiorly in delaying the loss of flesh firmness in a consistent manner in the two seasons.

3.2. Chemical characteristics

3.2.1. Total soluble solids (TSS)

The data regarding the changes in TSS in response to various applications before harvest to "Florida" peaches is shown in Table 2. The data revealed that the highest increase in TSS was found with the combinations of potassium silicate at 400 mg l^{-1} plus glycine betaine at 400 mg l^{-1} in both seasons as compared with the control and with other combinations followed by potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1}. However, individual treatment of proline alone or potassium silicate alone at 400 mg l^{-1} had potential to cause a significant increase in TSS as compared with the control while potassium silicate at 200 mg l^{-1} did not result in a significant change in TSS. Furthermore, glycine betaine at 400 mg l^{-1} resulted in a slight increase in TSS as compared with the control. Thus, there was in general, an additive influence from combining either proline or glycine betaine to potassium silicate either at 200 or at 400 mg l^{-1}. This trend of results is favored since proline or glycine betaine are natural osmo-regulators while potassium silicate is an enhancer of the photosynthates in mature leaves.

3.2.2. Juice acidity

Change in juice acidity of "Florida" peaches in response to various pre-harvest treatments were reported in Table 2. The data provided evidences about the magnitudes of reductions in juice acidity by many treatments since the highest acidity values were found with the control fruits in both seasons. It was clear that the used combination treatments resulted in the highest acidity reduction such as proline plus potassium silicate at 200 mg l^{-1} and the combination of potassium silicate at 400 mg l^{-1} plus glycine betaine at 400 mg l^{-1}. However, lower but significant drop of juice acidity occurred with the application of potassium silicate at 200 mg l^{-1} plus glycine betaine at 400 mg l^{-1} in a consistant manner in both seasons. Meanwhile, all individual treatments were able to reduce the juice acidity relative to the control especially proline that was much more effective on lowering juice acidity as compared with potassium silicate even at the higher rate at 400 mg l^{-1}.

3.2.3. TSS/acidity ratio

The influence of field applications of some osmo-regulators and potassium silicate at two concentrations on the TSS to acidity ratio of "Florida" peach fruits were reported in Table 2. The data indicated that the combination treatments had the greatest TSS to acidity values starting with potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1} followed by potassium silicate at 400 mg l^{-1} plus glycine betaine at 400 mg l^{-1}. Even with the third used treatment potassium silicate at 200 mg l^{-1} plus glycine betaine at 400 mg l^{-1}. All these combinations achieved higher ratios of TSS to acidity than the control and every more than use of the sole treatments at different rates such as the application of potassium silicate at 200 mg l^{-1} as compared with the control in a consistent manner in both seasons. Even proline alone at 400 mg l^{-1} was effective on increasing TSS to acidity in the juice of "Florida" peaches by the harvest time much more than the control in both seasons. The increase observed was even greater than that resulting from the individual application of the other osmoregulator, specifically glycine betaine alone at 400 mg l^{-1}.

Table 2. The effect of pre-harvest applications on some chemical characteristics of "Florida" peach during the 2022 and 2023 seasons.

Treatments	TSS (ºBrix)		Acidity (%)		TSS/Acidity		Vitamin C (mg 100 g^{-1})	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	8.11 g*	7.58 g	0.94 a	0.86 a	8.60 g	8.86 g	11.28 g	10.48 g
Glycine betaine (400 mg l^{-1})	8.54 f	7.77 f	0.88 b	0.80 b	9.75 f	9.76 f	11.74 f	10.97 f
Potassium silicate (200 mg l^{-1})	8.28 g	7.64 fg	0.83 c	0.76 b	10.94e	10.57 e	11.51 fg	10.68 fg
Potassium silicate (400 mg l^{-1})	9.37 d	8.06 e	0.75 d	0.69 c	12.45d	12.31 d	12.77 d	12.04 d
Potassium silicate (200 mg l^{-1}+ glycine betaine (400 mg l^{-1})	9.04 e	8.61 c	0.73 d	0.65 d	13.52c	13.33 c	12.39 e	11.54 e
Proline (400 mg l^{-1})	9.81 c	8.44 d	0.67 e	0.61 e	15.41b	14.81 b	13.14 c	12.41 c
Potassium silicate (400 mg l^{-1})+ glycine betaine (400 mg l^{-1}l)	10.82 a	9.21 a	0.62 f	0.54 f	17.37a	17.20 a	14.09 a	13.44 a
Potassium silicate (200 mg l^{-1}) + Proline (400 mg l^{-1})	10.36 b	8.96 b	0.58 g	0.52 f	17.98a	17.15 a	13.70 b	12.99 b
LSD $_{\text{at 5\%}}$	0.22	0.14	0.04	0.04	0.91	0.68	0.36	0.31

* Values in each column when accompanied with similar letters, were not significantly different by using the least significant difference at 5% for comparing the means.

3.2.4. Vitamin C content

The results obtained for vitamin C are given in Table 2. The data indicated that the highest content was obtained with the combination treatments especially with the combination of potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1} followed by potassium silicate at 400 mg l^{-1} plus glycine betaine at 400 mg l^{-1}. Moreover, proline alone was able to cause a significant increase in vitamin C content of fruit juice in the two seasons. Thus, there was an additive effect when proline was added to potassium silicate at 200 mg l^{-1} in terms of the significant increase in vitamin C, even though the sole application of potassium silicate at 200 mg l^{-1} alone did not cause a significant increase in vitamin C content of fruit juice consistently. However, when potassium silicate was applied at 400 mg l^{-1}, there was a consistent increase in vitamin C content compared to the control. Even the osmo-regulator, namely glycine betaine alone was still able to increase vitamin C but in a lower magnitude than that obtained with proline alone in both seasons.

3.2.5. Total carotenoid

The influence of various used treatments on total carotenoid content of “Florida” peaches was shown in Table 3. The data revealed that the highest on total carotenoid at harvest was obtained with the combination of potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1} followed by the combination of potassium silicate at 400 mg l^{-1} plus glycine betaine at 400 mg l^{-1} as compared with control in both seasons. Meanwhile, all individual treatments proved to have an effective, significant influence on enhancing the on total carotenoid of treated peaches when compared with the control in both seasons.

Higher the concentration of applied potassium silicate greater the influence on carotene content. However, the application of glycine betaine at 400 mg l^{-1} in a combination resulted in greater influence on on total carotenoid than its individual treatments in both seasons.

3.2.6. Anthocyanin content of the skins

With regard to the changes in anthocyanin content in the “Florida” skin in response to various applications. The data reported in Table 3 revealed these changes. It was evident again that the greatest content of anthocyanin was found with the combination of potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1} in a consistent manner in both seasons. Moreover, when each compound in such combination was applied individually. It resulted in an increase of anthocyanin content but in a smaller magnitude than the combination. This conclusion is true for second combination of potassium silicate at 400 mg l^{-1} plus glycine betaine at 400 mg l^{-1} and even for the third combination of potassium silicate at 200 mg l^{-1} plus glycine betaine at 400 mg l^{-1}. Thus, it was desired to have the treatments combined as shown in Table 3. Moreover, the sole application of proline at 400 mg l^{-1} was able to cause a significant increase in anthocyanin content of the peach skins consistently in both seasons.

3.2.7. Electrolyte leakage of fruit tissues

The leakage of electrolytes as an indicator to the membrane integrity of fruit tissue at harvest time was also reported in Table 3. Lower the leakage indicates to more tissue integrity. The data revealed that the control fruits had the greatest leakage in both seasons. The least magnitude of such leakage was found with the combination of potassium silicate at 200 mg l^{-1} plus proline at 400 mg l^{-1}. Moreover, all the other applied combinations had less leakage of electrolytes than its individual components. Even in the case of applied proline individually, it was able to reduce electrolyte leakage in both seasons as compared with the control. When proline was included in a combination, it resulted in a better influence on the tissue integrity than that obtained when glycine

Table 3. The effect of pre-harvest applications on some chemical characteristics of "Florida" peach tissue during the 2022 and 2023 seasons.

Treatments	Total carotenoid (mg 100 g^{-1})		Anthocyanin (mg 100 g^{-1})		Electrolyte leakage (%)	
	2022	2023	2022	2023	2022	2023
Control	0.773 h*	0.640 h	4.09 h	3.70 g	18.67 a	19.72 a
Glycine betaine (400 mg l^{-1})	0.881 e	0.654 g	4.87 e	3.82 fg	17.93 b	19.10 b
Potassium silicate (200 mg l^{-1})	0.819 f	0.670 f	4.51 f	3.97 f	16.47 d	18.00 d
Potassium silicate (400 mg l^{-1})	1.010 c	0.745 d	5.49 c	4.73 d	17.28 c	18.63 c
Potassium silicate (200 mg l^{-1}+ glycine betaine (400 mg l^{-1})	0.792 g	0.710 e	4.32 g	4.35 e	15.38 f	16.83 f
Proline (400 mg l^{-1})	0.952 d	0.780 c	5.17 d	5.02 c	16.76 d	18.23 cd
Potassium silicate (400 mg l^{-1})+ glycine betaine (400 mg l^{-1}l)	1.072 b	0.808 b	5.91 b	5.27 b	15.87 e	17.51 e
Potassium silicate (200 mg l^{-1}) + Proline (400 mg l^{-1})	1.143 a	0.840 a	6.28 a	5.61 a	14.87 g	16.30 g
LSD $_{\text{at 5\%}}$	0.004	0.013	0.19	0.20	0.43	0.42

* Values in each column when accompanied with similar letters, were not significantly different by using the least significant difference at 5% for comparing the means.

betaine was individually applied. Plant defense against salt, heat, and water scarcity is largely dependent on proline (Ashraf and Harris, 2004). Proline foliar spraying alleviated the growth inhibition that heat-stressed crops caused (Makela et al., 1998). According to (Farag and Shehata, 2023), applying proline spray three times may improve the colour of pomegranates, particularly when fruit bagging is present. This finding was farther supported by the results on peach fruits since Proline applications resulted in higher anthocyanin in the fruit as compared with the control. Proline accumulation appears to be related to temperature stress. Either at a low temperature (Tarnizi and Marziah, 1995; Wang and Cui, 1996) or a high temperature (Ashraf et al., 1994). Proline functions as a molecular chaperone and an osmotic adjustment mediator of stress tolerance (Lehmann et al., 2010; Kavi Kishor and Sreenivasulu, 2014). Such improvement in plant tolerance was supported by our findings since Proline plus potassium silicate were able to reduce electrolyte leakage of treated peaches even with the sole application of Proline which reduced electrolyte leakage as compared with the control. Rising temperatures brought on by climate change have become a significant challenge for modern crop production in the last few decades, particularly in southern Mediterranean regions (Wang et al., 2020). As a result, efforts to maximize crop yields in order to guarantee food security for a growing global population continue to be difficult. Heat stress impairs the oxygen evolving complex, from photosystem II, RuBisCo, and energy-producing (ATP) processes, which all have a detrimental physiological impact on photosynthesis (Tan et al., 2020; Parrotta et al., 2020). Meanwhile, according to Sorwong and Sakhonwasee (2015), the reduction in leaf gas exchange traits caused by heat stress was mitigated by the application of exogenous glycine betaine (GB). Plants grow larger amounts of GB when subjected to abiotic stress (Storey et al., 1977). Numerous lines of transgenic plants that accumulate GB show significantly increased resistance to different forms of abiotic stress. As a result, it improves CO_2 assimilation's tolerance to high-temperature stress. Several reviews of the relationship between GB and tolerance to abiotic stress have recently been published Sakamoto and Murata (2002), Chen and Murata (2008) and Takabe et al. (2006). Yang et al. (2007) indicated that the accumulation of GB in vivo seemed to reduce the accumulation of ROS during heat stress by maintaining or increasing the activities of ROS scavenging enzymes (namely, catalase, ascorbate peroxidase, glutathione reductase, dehydroascorbate, and monodehydroascorbate reductase). According to Epstein (1999), silicon is the second most abundant element on Earth. It plays a significant role in the formation of clay minerals in soils. Potassium silicate is a highly available source of silicon and potassium that is primarily used as a silica amendment in agricultural systems, with the added benefit of providing potassium. In a number of horticultural crops, potassium nutrition can improve shelf life, ascorbic acid concentrations, fruit colour, soluble solids, fruit size, tree yields, and shipping quality (Kanai et al., 2007). According to Romero- Aranda et al. (2006), the application of potassium silicate does not release any environmentally persistent or hazardous byproducts because it does not enclose any volatile organic compounds. Numerous studies have demonstrated how potassium silicate helps reduce a variety of stress factors, such as drought, oxidative damage, salinity, and nutrient shortages (Chen et al., 2016; Gomaa et al., 2021). Additionally, silicate may promote plant pigments, cell division, photosynthesis, and the uptake of nutrients and water (Ma, 2004). Such mitigation or alleviation of tissue injury was in agreement with our findings since electrolyte leakage of fruit tissues was significantly reduced by proline alone or proline plus potassium silicate at 200 mg l^{-1} as shown in Table 3. Meanwhile, total carotenoid as a defense mechanism against abiotic stresses was significantly increased in fruit tissue especially with the above treatments. Thus, the increase in the protective pigments, namely carotenes and anthocyanins, were in agreement with the trend of our results that indicated to a further reduction of electrolyte leakage since less the leakage means more tissue integrity.

4. Conclusions

Summing up the results, it can be concluded that the use of potassium silicate at 200 mg l^{-1} + proline at 400 mg l^{-1} treatment or potassium silicate at 400 mg l^{-1} + glycine betaine at 400 mg l^{-1} two times caused an improved quality of peach fruits in reclaimed land.

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