Licorice-root extract and potassium sorbate spray improved the yield and fruit quality and decreased heat stress of the 'osteen' mango cultivar (#100914)

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Licorice-root extract and potassium sorbate spray improved the yield and fruit quality and decreased heat stress of the 'osteen' mango cultivar

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Heat stress, low mango yields and inconsistent fruit quality are main challenges for growers. Recently, licorice-root extract (LiRE) have been utilized to enhance the vegetative growth, yield, and toleranceabioticstresses of fruit trees. Potassium sorbate (KSb) also plays a significant role in various physiological and biochemical processes that are essential for mango growth, productivity, and fruit development, quality and abiotic stress tolerance. This work aimed to elucidate the effects of foliar sprays containing (LiRE) and (KSb) on the growth, yield, fruit quality, total chlorophyll content, and antioxidant enzymes of 'Osteen' mango trees. The mango trees were sprayed with (LiRE) at concentrations (0, 2, 4 and 6g/l) and (KSb) (0, 1, 2, and 3mM). The foliar spray was done starting in mid-May (after fruit set stage) to one month pre-harvest. The results showed that trees treated with the highest concentration (6 g/L) of (LiRE) exhibited the maximum leaf area, followed by those treated with the highest concentration (3 mM) of (KSb). Application of (LiRE) and (KSb) to Osteen mango trees significantly enhanced fruit weight, No. of fruits.tree-1, yield (kg/tree), yield increasing%, and reduced No. of sun-burned fruits compared to the control. (LiRE) and (KSb) foliar sprays to Osteen mango trees significantly enhanced fruit T.S.S%, T.S.S/acid ratio, and Vitamin C content compared to the control. Meanwhile, total acidity percentage in 'Osteen' mango fruits significantly decreased in response to the foliar spray. 'Osteen' mango trees showed a significant increase in total chlorophyll content of leaf, total pigments, and carotenoids. Our results suggest that foliar sprays containing (LiRE) and (KSb) significantly improved growth parameters, yield, fruit quality, antioxidant content, and total pigment concentration in 'Osteen' mango trees. Moreover, the most effective treatments were 3mM KS and 6g/L LiRE. LiRE and KSb foliar spray caused a significant increase in yield percentage by 305.77%, and 232.44%, in the first season, and 242.55%, 232.44% in the second season, respectively.

Licorice-Root Extract and Potassium Sorbate Spray Improved the Yield and Fruit Quality and decreased heat stress of the 'Osteen' Mango Cultivar

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Abstract

Heat stress, low mango yields and inconsistent fruit quality are main challenges for growers. Recently, licorice-root extract (LiRE) have been utilized to enhance the vegetative growth, yield, and tolerance abiotic stresses of fruit trees. Potassium sorbate (KSb) also plays a significant role in various physiological and biochemical processes that are essential for mango growth, productivity, and fruit development, quality and abiotic stress tolerance. This work aimed to elucidate the effects of foliar sprays containing (LiRE) and (KSb) on the growth, yield, fruit quality, total chlorophyll content, and antioxidant enzymes of 'Osteen' mango trees. The mango trees were sprayed with (LiRE) at concentrations (0, 2, 4 and 6g/l) and (KSb) (0, 1, 2, and 3mM). The foliar spray was done starting in mid-May (after fruit set stage) to one month pre-harvest. The results showed that trees treated with the highest concentration (6 g/L) of (LiRE) exhibited the maximum leaf area, followed by those treated with the highest concentration (3 mM) of (KSb). Application of (LiRE) and (KSb) to Osteen mango trees significantly enhanced fruit weight, No. of fruits.tree-1, yield (kg/tree), yield increasing%, and reduced No. of sun-burned fruits compared to the control. (LiRE) and (KSb) foliar sprays to Osteen mango trees significantly enhanced fruit T.S.S%, T.S.S/acid ratio, and Vitamin C content compared to the control. Meanwhile, total acidity percentage in 'Osteen' mango fruits significantly decreased in response to the foliar spray. 'Osteen' mango trees showed a significant increase in total chlorophyll content of leaf, total pigments, and carotenoids. Our results suggest that foliar sprays containing (LiRE) and (KSb) significantly improved growth parameters, yield, fruit quality, antioxidant content, and total pigment concentration in 'Osteen' mango trees. Moreover, the most effective treatments were 3mM KS and 6g/L LiRE. LiRE and KSb foliar spray caused a significant increase in yield percentage by 305.77%, and 232.44%, in the first season, and 242.55%, 232.44% in the second season, respectively.

Keywords: *Mangifera indica* L.; bio-stimulates; leaf area; yield increasing%; total pigments; sunburned

Introduction

Ensuring global food security for a growing population is a major challenge for modern agriculture(Fróna, Szenderák & Harangi-Rákos, 2019). This challenge is compounded by climate change, which harms fruit trees productivity, the decline of land, and the intensification of agronomic performs(Pandey, 2020). To achieve sustainable farming, there is a growing interest in finding environmentally safe organic materials(Durán-Lara, Valderrama & Marican, 2020). Biostimulants have been recognized as a promising approach that utilizes natural products(Santini et al., 2021). Biostimulants are a flexible, cost-effective, and widely applicable solution that can improve agricultural productivity in a sustainable manner and mitigate the effects of climate change(Fallovo et al., 2008; Rouphael & Colla, 2018). Generally, biostimulants have the potential to enhance crop productivity through three key mechanisms: (i) optimizing root system architecture to improve water and nutrient uptake, (ii) maximizing photosynthetic capacity to promote growth, and (iii) reducing oxidative stress in plants by enhancing the antioxidant defense system (De Pascale & Rouphael, 2018; Rouphael & Colla, 2018).

The mango is the maximum essential tropical fruits globally, prized for its flavor and nutritional value(Hussain et al., 2021). This flexible fruit may be enjoyed sparkling, juiced, or maybe integrated into diverse meals products. Mangoes boast an outstanding nutritional profile, filled with both macro and micronutrients(Yahia et al., 2023). Low mango yields and inconsistent fruit best are main challenges for growers. These issues often stem from troubles with flowering and fruiting, along with abnormal flowering, terrible fruit set, and inconsistent fruit development(Shivran et al., 2020). This translates to lower yields, culmination of subpar exceptional and restrained availability at some stage in the year. Fortunately, research suggests a promising solution: strategic application of nutrients and growth regulators. By influencing flowering and fruiting patterns, these tools can assist us release the whole potential of various mango types(Ramírez & Davenport, 2010). This method has the energy to seriously boom and stabilize mango production(Tirado-Kulieva et al., 2022).

Potassium is a vital mineral nutrient for plants(Wang et al., 2013). This element is crucial for numerous functions within plants, influencing growth, yield, fruit development, quality, and even their ability to withstand stress. (Shahid et al., 2020). Studies have shown that potassium improves fruit quality parameters like sugar content, color, and overall taste(Hernández-Pérez et al., 2020). Beyond its role in fruit development, potassium is essential for plant life itself(Sardans & Peñuelas, 2021). It activates numerous enzymes involved in photosynthesis, sugar production, and overall plant metabolism, ultimately leading to increased crop yields(Nieves-Cordones, Al Shiblawi & Sentenac, 2016). Potassium also regulates various physiological processes like water movement, respiration, and nutrient translocation within the plant. Additionally, it activates enzymes like nitrate reductase and starch synthetase, which contribute to a healthy balance of protein and carbohydrate production(Iqbal et al., 2022). Potassium even influences how plants open and close their stomata (tiny pores on leaves). This, in turn, affects photosynthesis, nutrient uptake, and overall plant function, ultimately impacting crop yield and fruit quality(Devin et al., 2023). Studies have shown that KNO3 increases the proportion of flowering shoots, flower clusters, and vegetative growth, main to better yields and decreased exchange bearing(Alshallash et al., 2023; Alebidi et al., 2023).

Extensive research has established potassium as an essential element for optimal growth, yield, fruit quality, and stress tolerance in mango trees (Andreotti et al., 2022; Ahmad et al., 2023). Its influence extends to various biochemical and physiological processes fundamental to plant health. Studies have demonstrated that potassium application positively impacts mango fruit quality, enhancing parameters such as total soluble solids, total sugars, and coloration(Abidi et al., 2023). These benefits can be attributed to potassium's role in strengthening stress tolerance and promoting sugar formation and accumulation within the fruit (Okba et al., 2021). Field trials have consistently shown significant improvements in mango productivity following potassium application (Afiqah et al., 2014). For example, a promising approach involves foliar application of potassium citrate at a concentration of 0.3%. This treatment demonstrably improved yield, fruit quality, and leaf mineral content compared to the control group (Cakmak, 2005). Further investigations have explored the effectiveness of potassium citrate and carbonate in enhancing various aspects of mango production. Applying potassium citrate at 1895 g and potassium carbonate at 850 g demonstrated positive effects on yield, fruit quality, and a range of physical and chemical properties of the fruit (Baiea, El-Sharony & El-Moneim, 2015). These findings were corroborated by studies employing foliar application of diverse potassium sources on 'Hindi' mango trees Furthermore, fruit quality parameters such as TSS percentage and vitamin C content also improved. However, as with the 'Hindi' mango study, a decrease in fruit acidity was observed. Multiple applications at key developmental stages (full bloom, fruit set, fruit growth, and pre-harvest) significantly improved fruit retention, yield (measured by both fruit number and weight per tree), and fruit weight itself. Similar positive outcomes were observed in Keitt mango trees treated with potassium nitrate. Here, five foliar applications of a 2% potassium nitrate solution led to significant increases in several growth and yield parameters. These included the number of branches per tree, branch diameter, leaf number per branch, number of panicles per tree, retained fruits per tree, fruit weight, and overall fruit yield per tree (Baiea, El-Badawy & El-Gioushy, 2015). Collectively, these studies reinforce the critical role of potassium in mango trees. By contributing to various aspects of tree growth, fruit quality, and stress tolerance, potassium application has been shown to significantly improve both productivity and the development of desirable fruit characteristics.

Recent research has explored the potential of plant extracts, like licorice root, to enhance fruit tree growth and yield (Nasir et al., 2016). Licorice (*Glycyrrhiza glabra*), belonging to the Leguminoseae family, thrives in Egypt and many other regions globally (Vlaisavljević et al., 2018). The licorice root boasts some nutritional value and unique chemical compounds, including gleserezin, glycyrrhejel. Additionally, it's rich in various elements and nutrients (Husain et al., 2021). Licorice extract is believed to stimulate cellulose enzyme activity, crucial for cell expansion, ultimately accelerating plant growth. It might also help reduce transpiration rates, minimizing water loss and maintaining cell turgor (Peng et al., 2023). While there is a wealth of studies on mango cultivation, the impact of potassium sorbate, and licorice root extract, impact on 'Osteen' mango boom, yield, fruit best, and antioxidant enzymes stays unexplored. Moreover, this study aimed to elucidate the effects of potassium sorbate and licorice root extract on the growth, yield, fruit quality, total chlorophyll content, and antioxidant enzymes of 'Osteen' mango trees.

Materials & Methods

Licorice root extract Preparation

To prepare the Licorice root extract for commercial use (obtained from the Sekem Group in Cairo, Egypt), it was mixed with water at a concentration of 250 g L-1. The mixture was left at room temperature for 24 hours, and then thoroughly blended before being filtered through Whatman No. 42 filter papers. This filtration process resulted in obtaining a condensed brown liquid extract. To enhance the properties of the filtered solution, gelatin from Sigma-Aldrich (at a concentration of 2 g L-1) was added. This step followed the methodology described by Younes et al. (Younes et al., 2020).. The resulting mixture was heated at a temperature of 30 ± 2 °C while stirring to ensure proper mixing. Subsequently, it was stored for later use in treating 'Osteen' Mango trees. It is worth noting that the chemical composition of the Licorice root extract was also analyzed, and the findings regarding various chemical constituents can be found in Table 1, as reported by Younes et al.(Younes et al., 2021)

2.1. Experimental site

This study was conducted on 7-year-old Osteen mango trees in a private farm located in the El-Salehia Elgadedah district, El-Sharqia Governorate, Egypt. The trees were planted in sandy soil and irrigated using a drip system with artesian water. Management practices included regular irrigation, fertilization, and pest and disease control. From mid-May to one month before harvest, the trees were sprayed monthly with licorice root extract and potassium sorbate solutions as follows in Table 2.

2.2. Measurements:

2.2.1. Leaf area:-Twenty leaves below panicles of the spring growth cycle according to Walworth and Sumner (Walworth & Sumner, 1987) were taken (2nd week of June) for measuring leaf area according of (Ahmed & Morsy) as the following:

$$\text{Leaf area} = 0.70\,(L\times W) - 1.06 = \ldots\ldots\ldots\ \text{cm}^2 \quad (1)$$

Where: L and W = leaf length and width, respectively.

2.2.3. Photosynthetic pigments
Leaf total chlorophyll content and total carotenoids were extracted from fresh leaves of 'Osteen' mango cultivar, following the method of Brito et al., (Brito et al., 2011), and the results were calculated according to (Wellburn, 1994).
2.2.4. Determination proline content
To estimate proline content a rapid colorimetric method was used (Qi et al., 2018). Plant tissue (0.5 g) was homogenized in a solution and filtered. The filtrate was then mixed with a freshly prepared acid solution and heated. The reaction was stopped by cooling, and a specific organic solvent was used to extract a colored compound. The amount of color formed was measured using a spectrophotometer, and the proline content was determined using a standard curve.

2.2.5. Determination relative water content.
Leaf relative water content (RWC) was determined following the method of Yamasaki and Dillenburg (Yamasaki & Dillenburg). Two leaves were randomly selected from the middle portion of each plant replicate. Fresh weight (FM) of each leaf was measured after separation from the stem. To determine the turgid weight (TM), leaves were rehydrated in closed containers with distilled water for 24 hours at 22°C. After rehydration, leaves were weighed again. Finally, dry weight (DM) was obtained by oven drying at 80°C for 48 hours. All weights were measured with a balance accurate to 0.001 g. The relative water content was calculated as follows:
RWC (%) = [(FM-DM) (TM –DM)] ×100.

2.2.6. Photosynthetic pigments
Fresh Osteen mango leaves were used to extract chlorophyll A, B, total chlorophyll, and total carotenoids. Leaf tissue (0.2 g) was homogenized with 80% acetone (10 mL) and centrifuged at 12,000 x g for 10 minutes. The resulting extract (3 mL) was then used for spectrophotometric measurements following the method of (Brito et al., 2011), and (Wellburn, 1994) provided the calculations for the results.

2.3.7. Antioxidant enzyme activity
Fresh leaves (0.5 g) of the osteen mango cultivar were mashed in a mortar with 5 mL of 0.1 M cold phosphate buffer (pH 7.1) and centrifuged at 15,000 x g for 20 min at 4 ◦C in order to extract PPO, POX, CAT . An enzyme activity experiment was conducted using the supernatant

(Esfandiari et al.). The activity of polyphenol oxidase (PPO) was determined in accordance with (Kavrayan & Aydemir, 2001). The experiment used to measure peroxidase activity (POX) followed (Amako, Chen & Asada, 1994). Catalase (CAT) enzyme activity was determined in accordance with Aebi(Aebi, 1984).

Total phenolic and total flavonoid

According to (Singleton, Orthofer & Lamuela-Raventós, 1999), the total phenolic content of osteen mango tree leaves was measured using the Folin–Ciocalteu colorimetric method and represented as (mg/g) using gallic acid as a standard. According to (Escriche & Juan-Borrás, 2018), the total flavonoid concentration in fresh leaves of the osteen mango cultivar was measured using the aluminum chloride (AlCl3) colorimetric method, with Rutin serving as a standard and being expressed as mg/g.

2.8.Tree Yield

We harvested the fruit from each experimental tree when the flesh turned yellow and the shoulders rounded or flattened according to Ahmed et al. (Ahmed et al., 2023) Moreover, on the 15th of August in both seasons of the 'Osteen' mango cultivar according to Khattab (M. Khattab et al., 2021).

Then, the average yield was calculating terms of number of fruits/tree and weight (kg). The yield increasing percentage was computed using the equation of (Abd El-Naby et al., 2019).

$$Yield\ increasing\ (\%) = -\frac{(Yield\ (treatment) - Yield\ (control) \times 100)}{Yield\ (control)}$$

2.9. Fruits Physical properties.

Fruit weight (g) was calculated at harvest time using a sample of five Osteen cv. mangoes. The samples were then chosen and transferred to the horticulture lab.

2.10. Chemical characteristics of fruits.

Fruit total soluble solids TSS% was measured using a digital refractometer (force-Gouge ModelIGV-O.SA to FGV-100A. Shimpo instruments). Total acidity was determined by titration and expressed as citric acid according to (McKie & McCleary, 2016).

Total soluble solids/acid ratio was calculated from the values of total soluble solids divided by values of total acids. (McKie & McCleary, 2016).

Statistical Analysis

The design of the present study was a complete randomized block design. The analysis of variance as one-way ANOVA was used through Costat software (Ridgman, 1990), and means of different treatments were compared using the Duncan test ($p \leq 0.05$).

Results

2.1. Effect of (LiRE) and (KSb) on leaf area of 'Osteen' mango under heat stress:

The results in Fig. 1 showed that spraying with licorice root extract and potassium sorbate in April significantly increased the leaf area of ‘Osteen’ mango trees in both studied seasons in comparison to control. Additionally, a trend emerged where leaf area increased as the concentration of licorice root extract and potassium sorbate increased. Leaf area promotion was most dependent on the application of licorice root extract at 6 g/L, followed by 3 mM potassium sorbate. Trees treated with 6 g/L licorice root extract exhibited the maximum leaf area, followed by those treated with 3 mM potassium sorbate. Untreated trees consistently had the lowest leaf area values. This trend was observed in both growing seasons. These results are consistent with the findings in numerous studies support the use of foliar potassium to enhance plant growth. (Abd El-Rahman, 2021) observed this when added potassium silicate to ‘Sedika’ mango trees,(Ayed et al., 2022) with ‘Keitt’ mango trees, and (EL-Gioushy, 2021) with orange trees. All these studies found that foliar application of potassium significantly improved vegetative growth compared to the control group. The leaf area increasing might be due to potassium spray [5]. Potassium plays a vital role by activating enzymes for organic substance synthesis, promoting photosynthesis, and transporting carbohydrate assimilates to storage organs [6]. It's also involved in several basic physiological functions. Similarly licorice root extracts improving the vegetative growth of plants(Nasir et al., 2016).

2.2. Effect of (LiRE) and (KSb) on fruit physical properties:

The results in Figures (2a, and b) clearly showed that adding licorice root and potassium sorbate extract at various phenological stages significantly increased fruit weight (g), and No. of fruits/tree of Osteen mango trees in comparison to those of control in the two studied seasons. These results are in line with findings of Baiea et al. (Baiea, El-Sharony & El-Moneim, 2015) who found that spraying Hindi mango trees four times with different types of potassium were very effective in improving number of fruits or weight (kg/tree)comparing with the control. Fruit weight (g), and No. of fruits/tree promotion were most dependent on the application of licorice root extract at 6 g/L, followed by 3 mM potassium sorbate. Trees treated with 6 g/L licorice root extract exhibited the maximum fruit weight (g), and No. of fruits/tree, followed by those treated with 3 mM potassium sorbate. Additionally, a trend emerged where fruit weight (g), and No. of fruits/tree increased as the concentration of potassium sorbate and licorice root extract increased. The increase in fruit weight of ‘Osteen’ mango trees could be attributed to the increase in leaf area caused by potassium sorbate and licorice root extract application and subsequently stimulation of photosynthesis intensity shared in increasing the fruit weight. Similarly, the study focused on licorice root extract as a potential vegetarian alternative to synthetic growth regulators. This extract is gaining interest due to its reported ability to improve plant growth and production in practical applications. Licorice root contains glycyrrhizin, a compound composed of calcium and potassium salts of glycyrrhizic acid, a trihydroxy acid.Rady et al. (Rady et al., 2019). Moreover, it contained a wide range of elements and nutrients (Hamam et al., 2021). As a matter of fact, adding a lot of potassium sorbate as foliar spray at different fruit growth stage may be attributed to the physiological role of potassium which is needed for many biochemical processes. Potassium also regulates various physiological processes like water movement, respiration, and nutrient translocation within the plant. Additionally, it activates enzymes like nitrate reductase and starch synthetase, which contribute to a healthy balance of protein and carbohydrate production(Iqbal et al., 2022).

2.3. Effect of (LiRE) and (KSb) on fruit yield.tree-1:

The results illustrated in Figure (2A and B) revealed notable enhancements in fruit yield (kg/tree) and yield increasing (%) when 'Osteen' mango trees were subjected to the addition of licorice root extract and potassium sorbate as foliar spray at different phenological stages. These improvements were observed across various growth stages and were found to be significantly higher compared to the control group in both seasons under investigation. Specifically, the application of 3mM potassium sorbate or 6g/l licorice root extract resulted in a more pronounced increase in fruit yield (kg/tree) compared to other treatments or the control group. Licorice root extract and potassium sorbate foliar spray caused a significant increase in yield percentage by 305.77%, and 232.44%, in the first season, and 242.55%, 232.44% in the second season, respectively. This study aligns with previous findings by (El-Merghany, et al., 2019) who reported that licorice root extract application to 'Ferehy' date Palm trees significantly increased fruit weight and yield per tree. Similarly, et al. 2023a) found that adding 4-8 g/L of the extract to red globe grapevines in April to June increased yield per tree compared to the control group. Similarly, in a study by (Yassin, et al., 2023), applying potassium silicate at concentrations of 100, and 200 ppm increased the number of fruits and fruit yield per tree of Wonderful and H116 pomegranate compared to the control group. Additionally, (Silem, et al., , 2023) reported that applying potassium silicate at a concentration of 500 ppm to mango trees at the beginning of growth, after fruit setting, and one month later increased fruit yield per tree compared to the control group. The increasing in yield /tree of 'Osteen' mango trees might be due to licorice root extract has been found to be an amazing biostimulant that increases not only growth but also the yields of various crops (Alshallash et al., 2022). According to (Diab & Abd El-hmied, 2022) they found that foliar spraying the 'Kitte' cv. mango with licorice root extract at 5 or 10 g/l concentration on three occasions, at the beginning of growth, after fruit set, and three weeks after fruit set, significantly increased tree yield in comparison to the control group.
It could be concluded that Application of (LiRE) and (KSb) to Osteen mango trees at different growth stages significantly enhanced fruit weight, number of fruits per tree, yield (kg/tree), and yield increase percentage, compared to the control. The most effective treatments were 6g/L (LiRE) and 3mM (KSb).

2.4. Effect of (LiRE) and (KSb) on No. of sun-burned fruits:

Figure 3 represents the response of the number of sun-burned fruits of 'Osteen' mango trees to licorice root extract and potassium sorbate foliar spray. Both potassium sorbate and licorice root extract foliar spray significantly reduced the number of sun-burned fruits of 'Osteen' mango trees in comparison to the control group in the two studied seasons. The lowest the number of sun-burned fruits of Osteen mango trees were possessed from T3 (6g/l licorice root extract) and or T6 (3mM potassium sorbate). Meanwhile, the control group had the highest number of sun-burned fruits of Osteen mango trees in both seasons. Additionally, a trend was observed: as the level of potassium sorbate and licorice root extract increased, the number of sun-burned fruits of Osteen mango trees decreased. Our results align with the findings of Ahmed et al.(Ahmed, Eliwa & Ismail, 2023b), who reported that foliar spraying the 'Red Glob' cv. grapevine with licorice root extract at a concentration of 4 or 8 g/L, applied three times in mid-April, May, and June, significantly reduced the number of sun-burned fruits. The presence of various beneficial compounds in licorice root extract, including phenolics, triterpenes, saponins, amino acids, polysaccharides, vitamins, and growth-promoting phytohormones, likely contributes to enhanced vegetative growth. These compounds may stimulate activity in the apical meristem, the plant's growth center, by promoting cell division and elongation(Pandey, 2017). The reduction in No. of sun-burned fruits might be attributed to the enhanced vegetative growth in mango trees caused by potassium application(Baiea, et al., 2015). Additionally, potassium may influence a tree's canopy size, which could in turn help the tree withstand environmental challenges like drought and high radiation. (Hamdy et al., 2022; Alharbi et al., 2022).

It could be concluded that Application of potassium sorbate and licorice root extract to Osteen mango trees significantly reduced No. of sun-burned fruits, compared to the control. The most effective treatments were 6g/L licorice root extract and 3mM potassium sorbate.

2.5. Effect of (LiRE) and (KSb) on some fruit chemical characteristics:

Foliar application of both (LiRE) and (KSb) significantly increased TSS%, TSS/acid ratio, and Vitamin C in comparison to the control group, as shown in figures 5a, 5c, and 5d. Conversely, total acidity% in 'Osteen' mango fruits significantly decreased in response to the foliar application during both study season's (Fig. 5b). Concerning fruit chemical characteristics, the data revealed that higher levels of (LiRE) and (KSb) applied as foliar sprays were superior to the control group and to treatments with lower spraying concentrations. Among all treatments, 3mM potassium sorbate (T6) and 6g/l licorice root extract (T3) resulted in fruits with the highest TSS%, TSS/acid ratio, and Vitamin C content, compared to the control group and other treatments. On the other hand, 'Osteen' mango fruits from treatments T3 and T6 showed the lowest values of total acidity compared with fruits from other foliar spray treatments or the untreated group. These results were consistent with those reported by Baiea et al. (Baiea, El-Sharony & El-Moneim, 2015) found that spraying Hindi mango trees four times with Potassium were very effective in improving enhanced fruit quality. In addition, fruit total acidity was reduced comparing with the control. Likewise, (El-Morsy, et al. 2017) on Red Globe where the highest values of fruit chemical characteristics were obtained with addition of licorice extract foliar spraying treatments 20 and 15 g/l. Similarly, (Obenland et al., 2015) found that potassium sorbate foliar spray at concentration 1.3g/l significantly increased fruit Flame seedless SSC in comparison to control. Potassium treatments may be responsible for the enhanced chemical characteristics of 'Osteen' mango fruits. This is likely because potassium acts as a catalyst for numerous biological processes within the trees, leading to improved overall tree health and nutrient status(Amtmann et al., 2005). Licorice extract application may be responsible for the observed improvements in physical and chemical fruit quality, as well as increased yield. This effect could be attributed to the presence of mevalonic acid in the extract. Mevalonic acid acts as a precursor to gibberellin, a plant hormone that stimulates leaf cell expansion. These results in increased leaf area and chlorophyll content, ultimately leading to improved fruit set and yield (Petoumenou & Patris, 2021).

We can conclude that application of (LiRE) and (KSb) to Osteen mango trees significantly enhanced fruit TSS%, TSS/acid ratio, and Vitamin C content compared to the control. Meanwhile, total acidity percentage in 'Osteen' mango fruits significantly decreased in response to the foliar spray. The most effective treatments were 3mM (KSb) and 6g/L (LiRE).

2.6 The photosynthetic Pigments Leaf of 'Osteen' mango cv. Under heat stress

It is clear from Figure 6 that the photosynthetic pigments of leaf osteen mango CV were significantly influenced by foliar spray with licorice root extract (LiRE) and (KSb) during the 2022 and 2023 seasons under heat stress (sunburn). The application of different LiRE and PTS concentrations on mango tree leaves resulted in an increase in photosynthetic pigments under heat stress. As shown in Figure 6, increasing the LiRE concentrations from 2-6 g/L and (KSb) from 1-3 mM led to an increase in the values of chlorophylls (a and b) and total chlorophyll, carotenoids, and total pigments. With a LiRE concentration of 6 g/L (T3), the highest values for chlorophyll a (1.389), chlorophyll b (0.899), total chlorophyll (2.267), carotenoids (0.433), and total pigments (2.689 mg/g fresh weight) were obtained compared to the control, which had the lowest values for these characteristics under heat stress during both seasons. Additionally, spraying (KSb) at 3 mM (T6) had the greatest impact on the photosynthetic pigment contents compared to other PTS concentrations and the control treatment. The value for total pigments (2.219 mg/g fresh weight) was higher than that of the control (non-treated) (1.111 mg/g fresh weight) under heat stress during the 2022-2023 seasons (Figure 6E). High temperatures or severe heat waves are among the abiotic stresses that inhibit mango growth, development, and crop quality(Muthuramalingam et al., 2023). A water shortage, often caused by heat and intense light, harms plants' ability to photosynthesize by inducing stomatal closure, mesophyll compactness, and photoinhibition. Mango leaf photosynthesis, transpiration, and water potential can all be impaired when exposed to high temperatures and low air relative humidity(Faria et al., 2016; Khanum et al., 2020). Spraying LiRE led to a reduction in sunburn and improved the photosynthesis system because it behaves similarly to gibberellin, which promotes vegetative growth. This extract contains nutritive components including N, Mg, Zn, Cu, and Fe. Since nitrogen aids in the creation of chlorophyll, these minerals play a significant role in the process of chlorophyll synthesis. Furthermore, iron contributes to the crucial steps that lead to chlorophyll production by increasing the number and size of chloroplasts and grana(Venzhik, Shchyogolev & Dykman, 2019). Spraying mango leaves with (KSb) at different concentrations enhances chlorophyll content and plant pigments because potassium is a major nutrient that directly participates in the vital functions of plants, most notably regulating the photosynthesis process and osmotic regulation of stomatal activity and transpiration. It also plays a crucial role in plant survival under various stresses(Araujo et al., 2015; Tränkner, Tavakol & Jákli, 2018). (Alsalhy & Aljabary, 2020) discovered that grape cv. Halawany leaf chlorophyll content increased when LiRE was applied as a spray at a level of 2.5 g/l. (Silem, et al., 2023) reported that the application of potassium silicate as a spray to keitte mango tree leaves at 500 ppm elevated total chlorophyll contents in leaves during the 2021 and 2022 seasons under salinity stress compared to the control group. These findings align with those of .(Younes et al., 2021) and (Abdel-Mola et al., 2022).

We can conclude that application of (LiRE) and (KSb) to Osteen mango trees significantly increased leaf Chl A, Chl B, total chlorophyll content, carotenoids and total pigments under heat stress compared to the control. The most effective treatments were 3mM (KSb) and 6g/L (LiRE).

2.7 Antioxidant activity Leaf of Osteen mango cv. under heat stress

Polyphenol oxidase (PPO), peroxidase (POX), and catalase (CAT) activities were significantly influenced by the foliar spray of (LiRE) and (KSb) on osteen mango leaves under heat stress (sunburn) during the 2022 and 2023 seasons (Figure 7). Based on the results, the highest activities of PPO (6.76 U/g F.Wt), POX (15.66 U/g F.Wt), and CAT (24.81 U/g F.Wt) enzymes were found under control conditions (non-treated). According to Figure 7 A-C, the enzyme activities decreased with increasing concentrations of LiRE and PTS sprayed on mango leaves. The lowest activities of PPO (2.75 U/g F.Wt) and POX (5.39 U/g F.Wt) enzymes were observed when spraying osteen leaves with 6 g/l of LiRE (T3), while the lowest activity of CAT (8.35 U/g F.Wt) was recorded at 3mM of (KSb) (T6). Agricultural production is adversely affected by global warming and the anticipated rise in temperatures(Challinor et al., 2014; Fahad et al., 2017).

Elevated temperatures can cause harm to plant cells in various ways, including interfering with protein synthesis and function, enzyme deactivation, and membrane rupture. These processes affect physiological functions such as respiration and photosynthesis. One common issue is an excess of harmful substances, like reactive oxygen species (ROS), leading to oxidative stress (Hasanuzzaman, Nahar & Fujit, 2013). In response to stressful conditions, plants exhibit an internal defensive mechanism through ROS scavenging, which is demonstrated by the activities of enzymatic antioxidants such as superoxide dismutase (SOD), peroxidase (POX), and catalase (CAT) (You & Chan, 2015; Rossi et al., 2017).

Under heat stress (sunburn), PPO, POX, and CAT enzyme activities increased with increasing ROS levels(You & Chan, 2015). Our study's results showed that all treatments decreased the activities of antioxidant enzymes PPO, POX, and CAT (Figure 7A-C). This suggests that osteen mango trees treated with LiRE and PTS are more stable, producing fewer ROS and, therefore, requiring less of these enzymes. In contrast, leaves of untreated mango trees are exposed to heat stress, which increases ROS emission and necessitates the upregulation of antioxidant enzyme activities to maintain cellular balance. Azab et al. (2013) discovered that foliar application of potassium reduced SOD, CAT, and PPO activities in well-watered Squash plants(Azab et al., 2022). However, under drought stress, tomato plants responded more favorably to potassium application in terms of antioxidant enzyme activity than to a well-watered treatment. Rady et al.(Rady et al., 2019) found that licorice root extract (LRE) application increased the activity of antioxidant enzymes (POX, CAT) and decreased hydrogen peroxide (H_2O_2) and superoxide radical ($O_2^{\bullet-}$) levels in common bean plants under salt stress when compared to the control without LRE. (Hamdy et al., 2022) found that leaf Keitt mango content of antioxidants, such as CAT, POX, and PPO enzyme activities, decreased under solar radiation (sunburn) following kaolin application. These findings are consistent with (Cabo et al., 2020).

It could be concluded that Enzyme activities of PPO, POX, and CAT all declined with increasing concentrations of LiRE and PTS sprayed on mango leaves. The lowest activities of PPO (2.75 U/g F.Wt) and POX (5.39 U/g F.Wt) were observed at the highest concentration of LiRE (6 g/L, T3). Meanwhile, the lowest CAT activity (8.35 U/g F.Wt) was recorded at the highest concentration of (KSb) (3 mM, T6).

2.7 Total flavonoids, total phenolic and proline of Leaf Osteen mango cv. Under heat stress
The content of total flavonoid in leaves of osteen mango is shown in (figure 8A). The highest (66.90 mg/g F.W) and lowest (24.03 mg/g F.W) values were observed with control (heat stress non-treated) and T3 6 g/l LiRE, respectively in 2022 and 2023 seasons. Total flavonoid content decreased by 26%, 32.66%, and 63% at 2, 4, and 6 g/L LiRE, respectively, and by 2.46%, 32.2%, and 48.28% at 1, 2, and 3 mM KSB, respectively. Figure 8B illustrates data about the total phenolic content. The highest amounts of total phenolic (50.67 mg/g F.W) were found in leaves under control and the lowest amount (15.46 mg/g F.W) was treated with T3 6 g/l LiRE. Total phenolic decreased by 69.43% and 59.57% at T3 6 g/l LiRE and T6 3 mM PTS, respectively. Within the kingdom of plants, flavonoids and phenolics are the most extensively dispersed secondary metabolites. These compounds play a vital role in plant growth and defense mechanisms.

According to (Tohidi, et al., 2017), these substances have a wide range of biochemical and molecular functions in plants, including those of signaling molecules, plant defense, regulating auxin transport, antioxidant activity, and free radical scavenging. Phenols and flavonoids, which are non-enzymatic antioxidants, accumulate in different tissues and scavenge free radicals, helping plants tolerate salt stress (Şirin & Aslım, 2019). According to our findings, control (heat stress non-treated) significantly increased the amount of total flavonoids and total phenolic (figure 8A-B). One of the defense strategies employed by plants against oxidative stress is the rise of antioxidants, such as total phenolics and flavonoids, under high temperatures(Wen et al., 2008). From these results, we suggest that the increase in phenolic compounds may be due to the activity of phenylalanine ammonia-lyase under high temperatures(Gebauer, Strain & Reynolds, 1997). However, spraying the leaves with LiRE and PTS at all concentrations caused all the values of flavonoids and phenolics to decrease, likely due to a reduction in the harmful effects of high temperature on the leaves, which lessened the need for phenylalanine to be directed towards synthesizing these compounds. According to Rady et al.(Rady et al., 2019), common bean plants grown under salt stress can benefit from the application of LRE as a natural biostimulant that can effectively boost their salt tolerance. Our outcomes were in agreement with those attained by (Dinis et al., 2018; Younes et al., 2021).

The results for proline variation in leaves of treated and non-treated osteen mango trees under heat stress are presented in Figures 8C. Osteen mango leaves exposed to high temperatures showed higher proline content. The highest accumulation of proline (0.280 mg/100 g F.W) belonged to control leaves. According to Bernardo et al. [26], raising temperatures to extremely high levels led to excessive proline production in grapevine. The trees sprayed with (T3) 6 g/L LiRE showed lower proline content (0.026 mg/100g F.W) compared to control and other treatments. Plant cells exposed to any stress exhibit proline accumulation, which is an indicator of the damage(Per et al., 2017; Dinis et al., 2018). Plant antioxidant systems contain a variety of low-molecular-weight substances, including proline and ascorbic acid(Rady et al., 2019). All treatments with LiRE and PTS resulted in reduced proline levels compared to control. This decrease is likely due to LiRE and PTS mitigating the negative effects of heat stress on osteen mango leaves through improved physiological performance. Potassium is essential for physiological processes in plants, which helps them endure stressful environments (Wang et al., 2013). The findings suggested that spraying LiRE and PTS reduced the oxidative damage to cell membranes, as seen by the decrease in proline. These results are in agreement with (Cabo et al., 2020), (Dbara, et al., 2022), and (Shehzad et al., 2020), who found that adequate external supply of potassium led to a significant reduction in the activities of antioxidant enzymes and proline in drought-stressed plants. (Younes et al., 2021) found that applying LRE as a biostimulant may be useful to improve bulb quality and, eventually, the productivity of onion cultivars in field conditions.

It could be concloded that Flavonoid content significantly decreased following treatments. Levels dropped by 26%, 32.66%, and 63% at increasingly higher concentrations (2, 4, and 6 g/L) of lithium-resveratrol (LiRE), respectively. Similarly, proanthocyanidin content (PTS) treatments resulted in a decrease of 2.46%, 32.2%, and 48.28% at concentrations of 1, 2, and 3 mM, respectively. Total phenolic content also showed a substantial reduction. The greatest decline (69.43%) was observed in leaves treated with 6 g/L LiRE (T3), while the highest concentration of PTS (3 mM, T6) caused a 59.57% decrease. Proline accumulation was highest in untreated leaves (control). Conversely, proline levels were significantly lower in leaves treated with 6 g/L

LiRE (T3), reaching only 0.026 mg/100g fresh weight (FW) compared to the control value of 0.280 mg/100g FW. This suggests that this concentration of LiRE may inhibit proline production.

Conclusions

This study demonstrated that foliar application of (LiRE) and (KSb) at specific concentrations (3 mM potassium sorbate and 6 g/L licorice root extract) significantly improved fruit yield, quality, and antioxidant enzyme activity in Osteen mango trees compared to the control. These treatments increased fruit weight, number of fruits, yield per tree, soluble solids content (TSS), TSS/acid ratio, and vitamin C content, while reducing total acidity and fruit enzyme activities (PPO, POX, and CAT). However, both licorice root extract and potassium sorbate caused a decrease in flavonoid and phenolic content, with the highest concentration (6 g/L LiRE and 3 mM PTS) showing the most significant reductions. Additionally, proline accumulation was inhibited by the highest concentration of licorice root extract (6 g/L LiRE). These findings suggest that licorice root extract and potassium sorbate can be effective growth promoters for Osteen mango trees, but their influence on certain fruit quality parameters like fruit weight and yield should be considered.

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The authors declare no conflicts of interest

Author Contributions

Conceptualization, H.F.A. and A.E.H.; methodology, EAE; software, M.O.; validation, H.F.A. and A.E.H.; and A.N.A; formal analysis, H.K; investigation, H.F.A.; resources, H.K.; data curation, M.O.; writing—original draft preparation, A.E.H. and H.K; writing—review and editing, M.H.F.; visualization, A.E.H.; supervision, A.E.H.; project administration, A.M.S.; funding acquisition, A.M.S. All authors have read and agreed to the published version of the manuscript.

Data Availability

The following information was supplied regarding data availability: The raw measurements are available in the Supplemental File.

Supplemental Information

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Table 1(on next page)

Table 1

Chemical analysis of licorice root extract (LRE) according to Rady et al., desoky, et. al., and Younes et al. [35–37]

Table 1. Chemical analysis of licorice root extract (LRE) according to Rady et al., desoky, et. al., and Younes et al. [35–37]

Constituents	Value
Na+ (mg 100mg-1 dr.wt.)	101.54
K+ (mg 100mg-1 dr.wt.)	376.96
Ca2+ (mg 100mg-1 dr.wt.)	754.90
Mg2+ (mg 100mg-1 dr.wt.)	524.78
Fe+ (mg 100mg-1 dr.wt.)	32.88
Zn2+ (mg 100mg-1 dr.wt.)	0.91
Total phenols (mg of GAE g-1 dr.wt.)	4.38
Total flavonoids (mg of QE g-1 dr.wt.)	2.14
Total antioxidant capacity(mg of AAE g-1 dr.wt.)	72.99
Tannins (mg 100 g-1 dr.wt.)	33.98
Saponins (mg 100 g-1 dr.wt.)	21.00
Ascorbic acids (mg 100 g-1 dr.wt.)	2.77
Ferric reducing antioxidant power (mg 100-1 Dr.wt.)	43.90

Aae, L-ascorbic acid equivalent; dr.wt, dry weight; GAE, gallic acid equivalent; QE, quercetin equivalent; mg, milligram.

Table 2(on next page)

Table 2

Foliar sprays on mango trees

Table 2. Foliar sprays on mango trees:

Treatments	Foliar spray material	Concentrations
Control	Water spray	0.0
T1	Licorice root extract	2g/l
T2	Licorice root extract	4g/l
T3	Licorice root extract	6g/l
T4	potassium sorbate	1mM
T5	potassium sorbate	2mM
T6	potassium sorbate	3mM

Figure 1

Figure 1

Effect of licorice-root extract and Potassium sorbate spray on leaf area of the 'Osteen' mango cultivar in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate

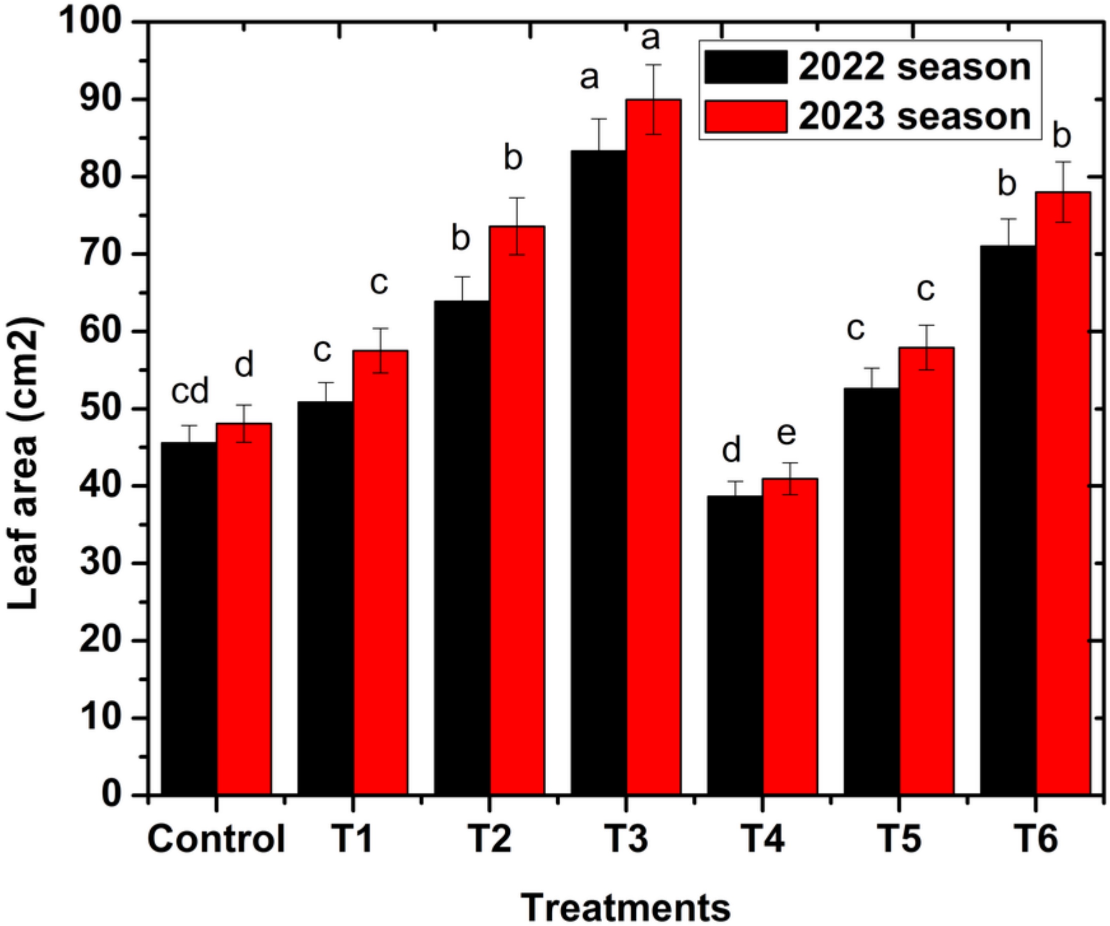

Figure 2

2a

Effect of licorice-root extract and Potassium sorbate spray on fruit weight of the ‘Osteen’ mango cultivar in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

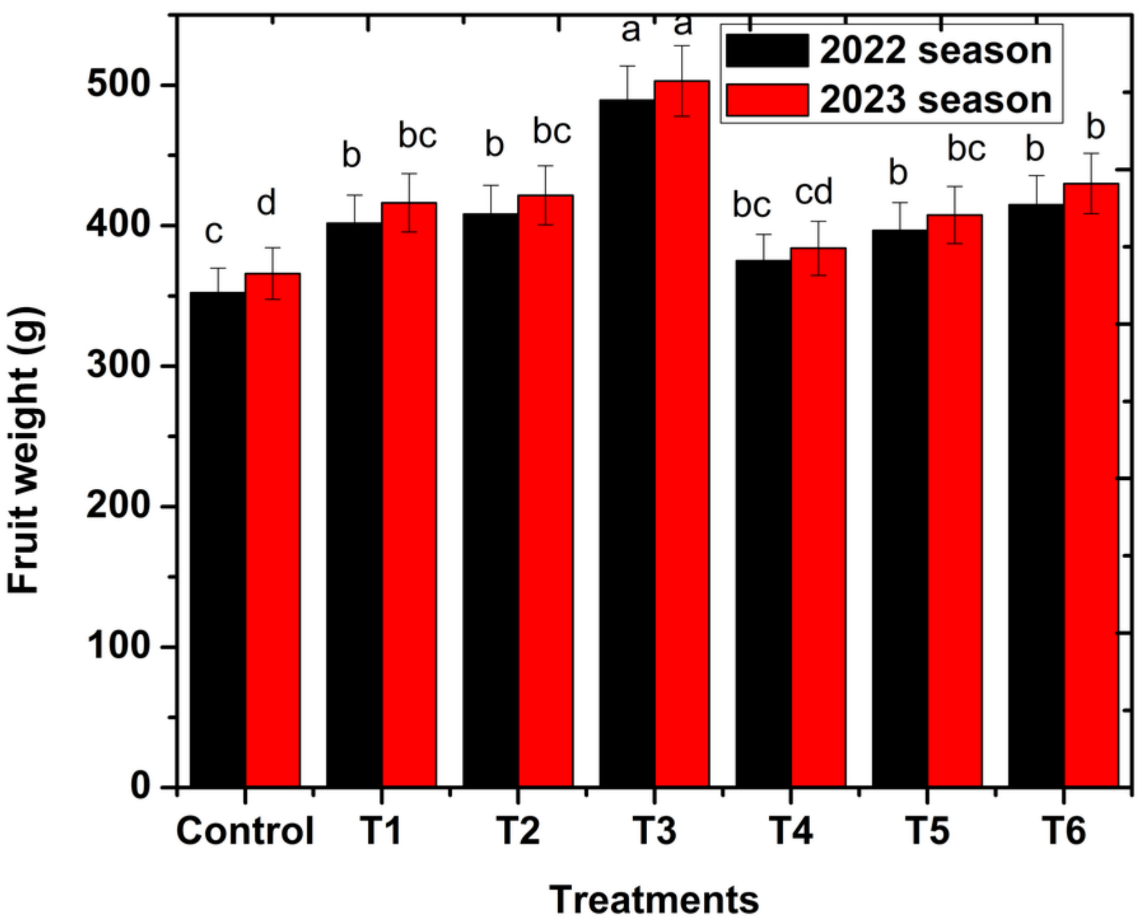

Figure 3

2b

Effect of licorice-root extract and Potassium sorbate spray on No. of fruit/tree of the ‘Osteen’ mango cultivar in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

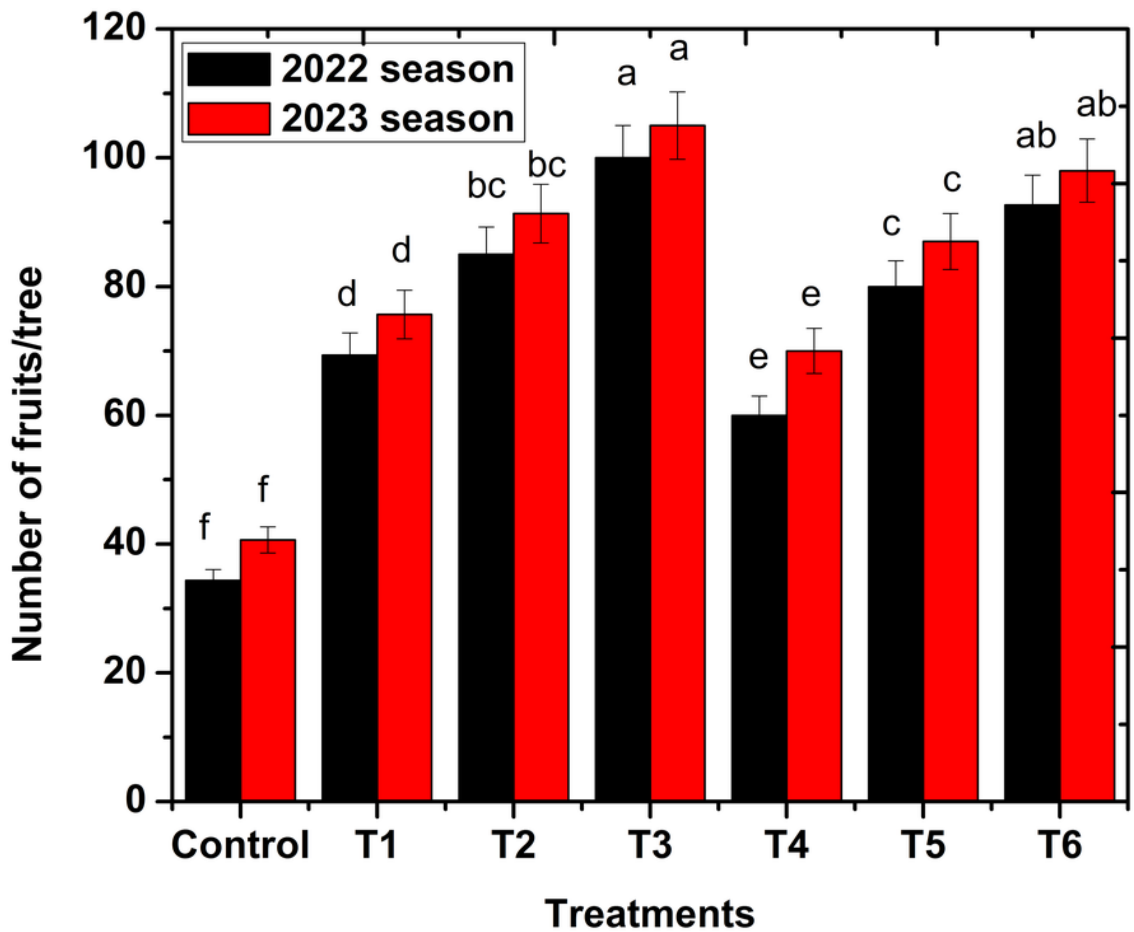

Figure 4

3A

Effect of (LiRE) and (KSb) spray on yield /tree and yield increasing (%) of the 'Osteen' mango cultivar in 2022 and 2023 seasons. A): yield component/tree (kg) and B): yield increasing %. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

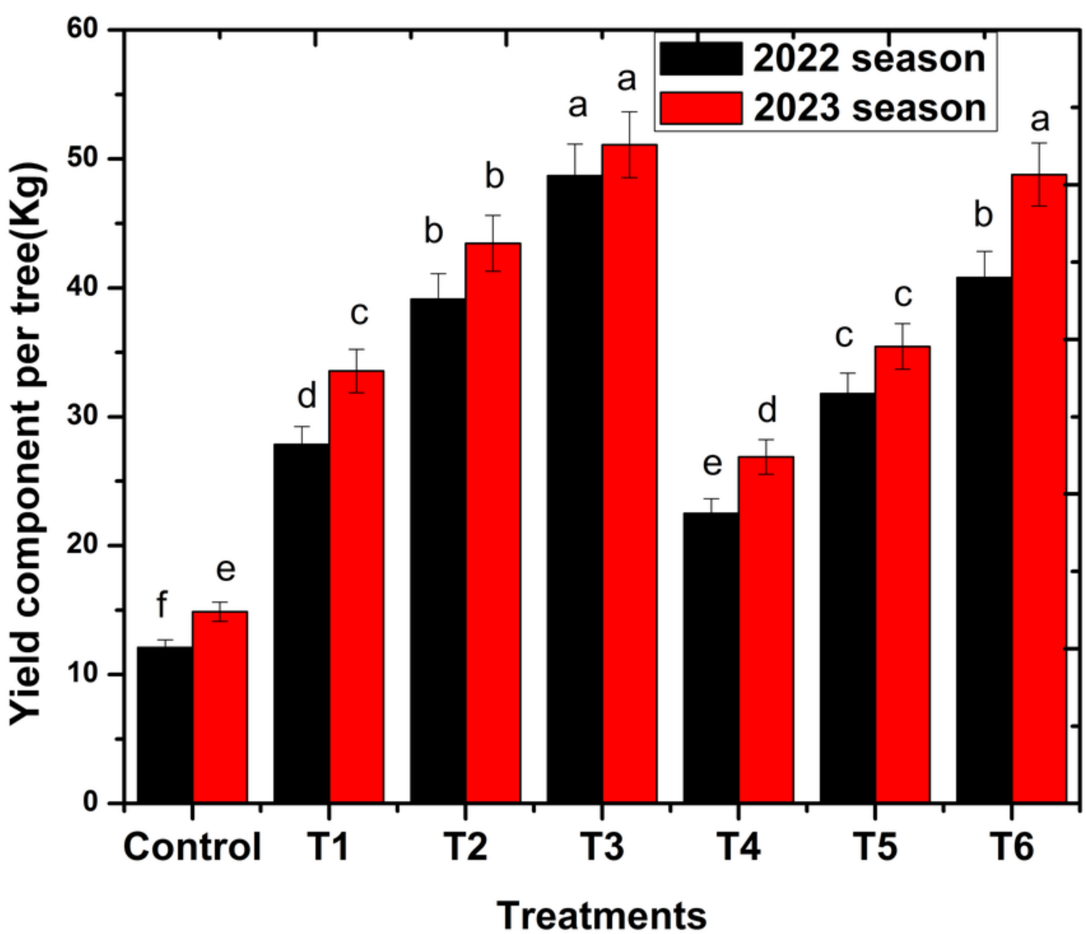

Figure 5

3B

Effect of (LiRE) and (KSb) spray on yield increasing (%) of the 'Osteen' mango cultivar in 2022 and 2023 seasons. A): yield component/tree (kg) and B): yield increasing %. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

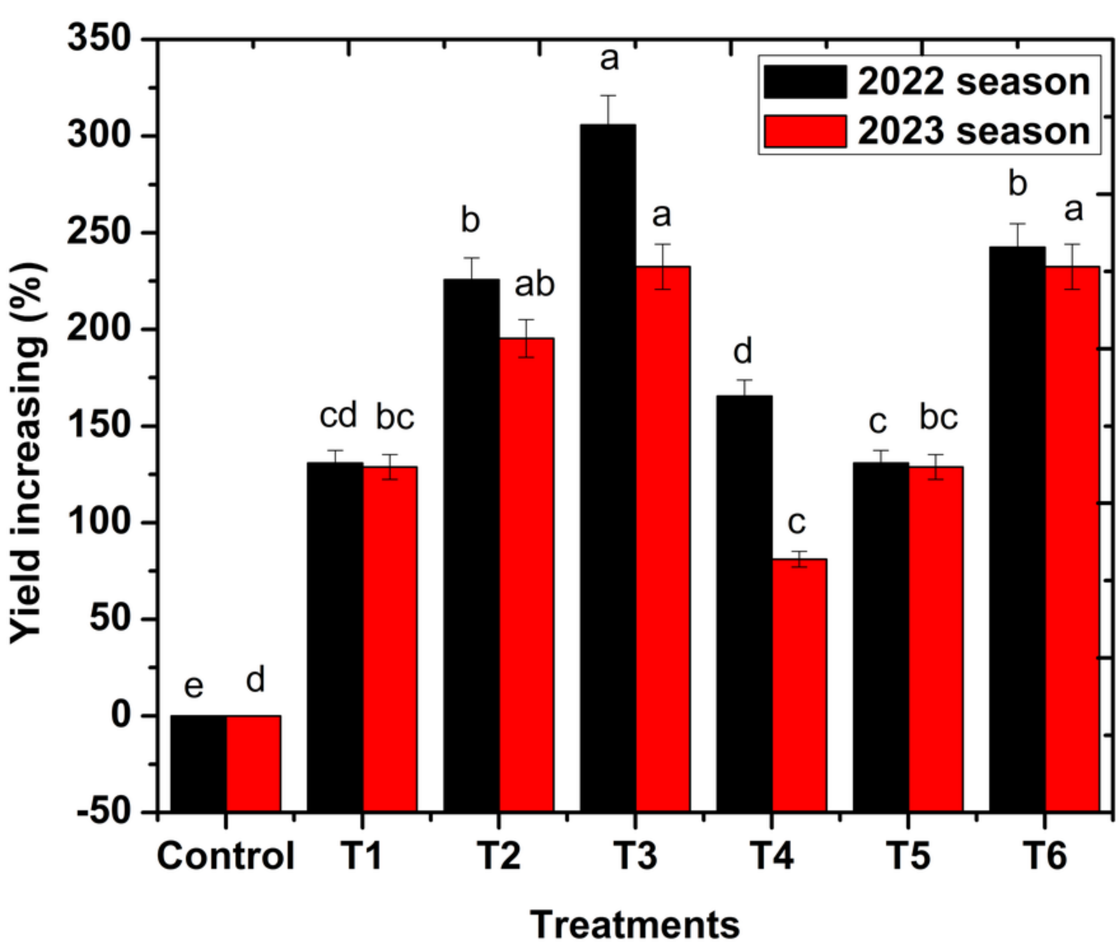

Figure 6

4

Effect of (LiRE) and (KSb) spray on No. of sun-burned fruits of the 'Osteen' mango cultivar in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

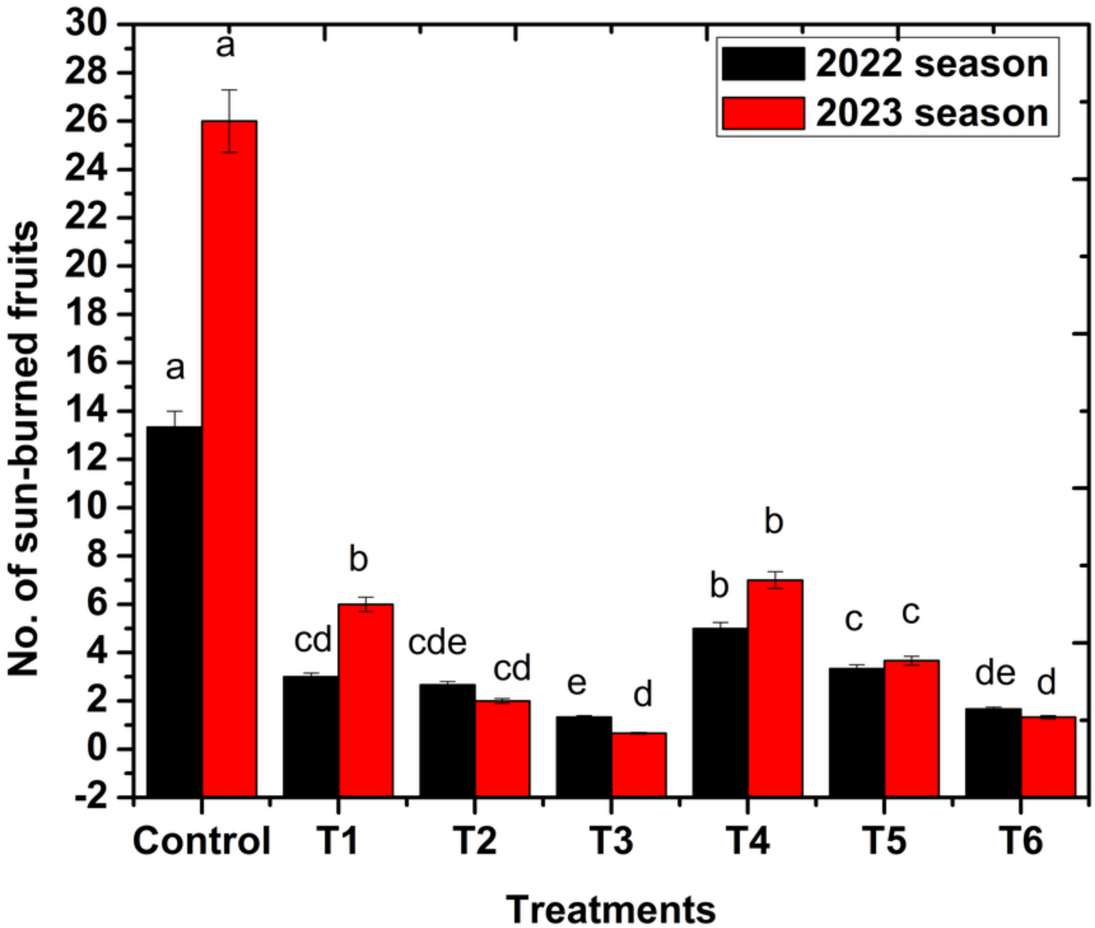

Figure 7

5

Effect of (LiRE) and (KSb) spray on some of fruit chemical characteristics of the 'Osteen' mango cultivar in 2022 and 2023 seasons. A): TSS%, B): Total acidity%, C):TSS/acid ratio and Vitamine C. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

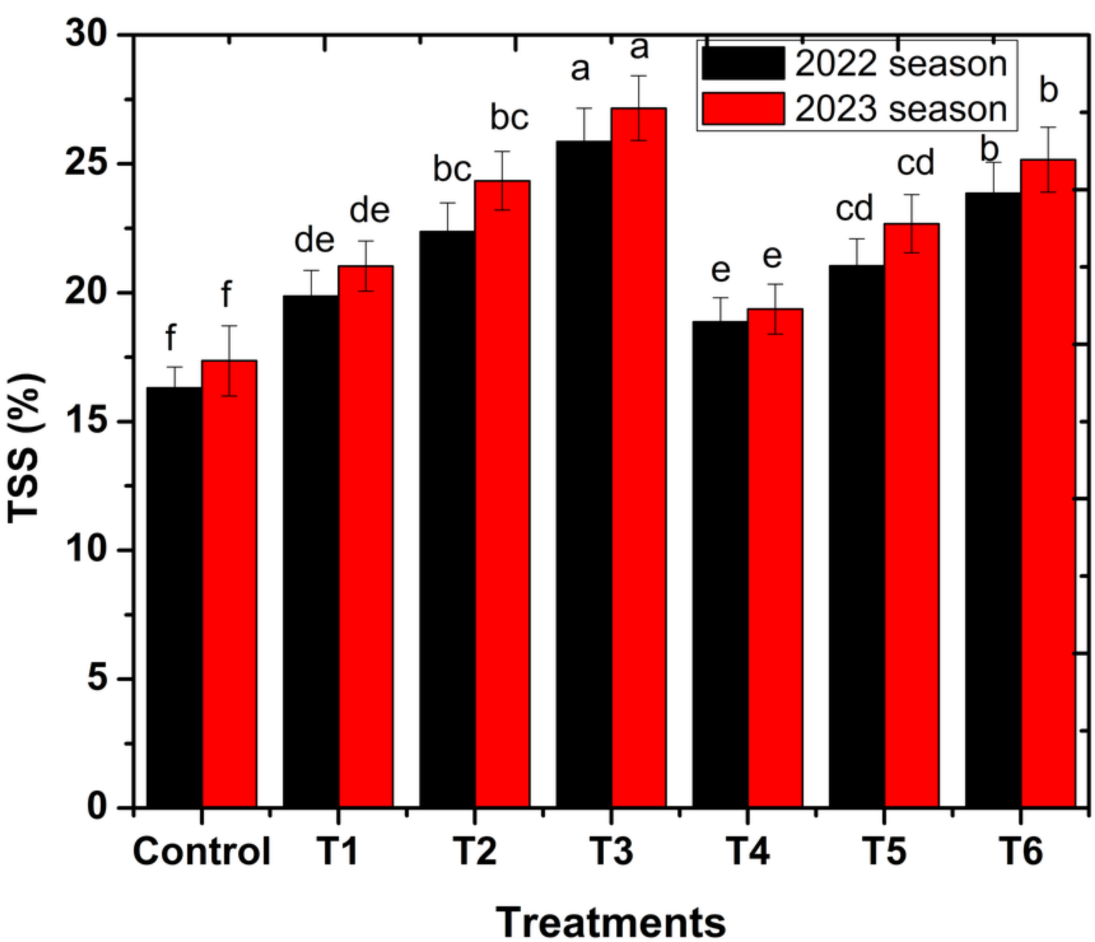

Figure 8

5B

Effect of (LiRE) and (KSb) spray on some of fruit chemical characteristics of the 'Osteen' mango cultivar in 2022 and 2023 seasons. A): TSS%, B): Total acidity%, C):TSS/acid ratio and Vitamine C. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

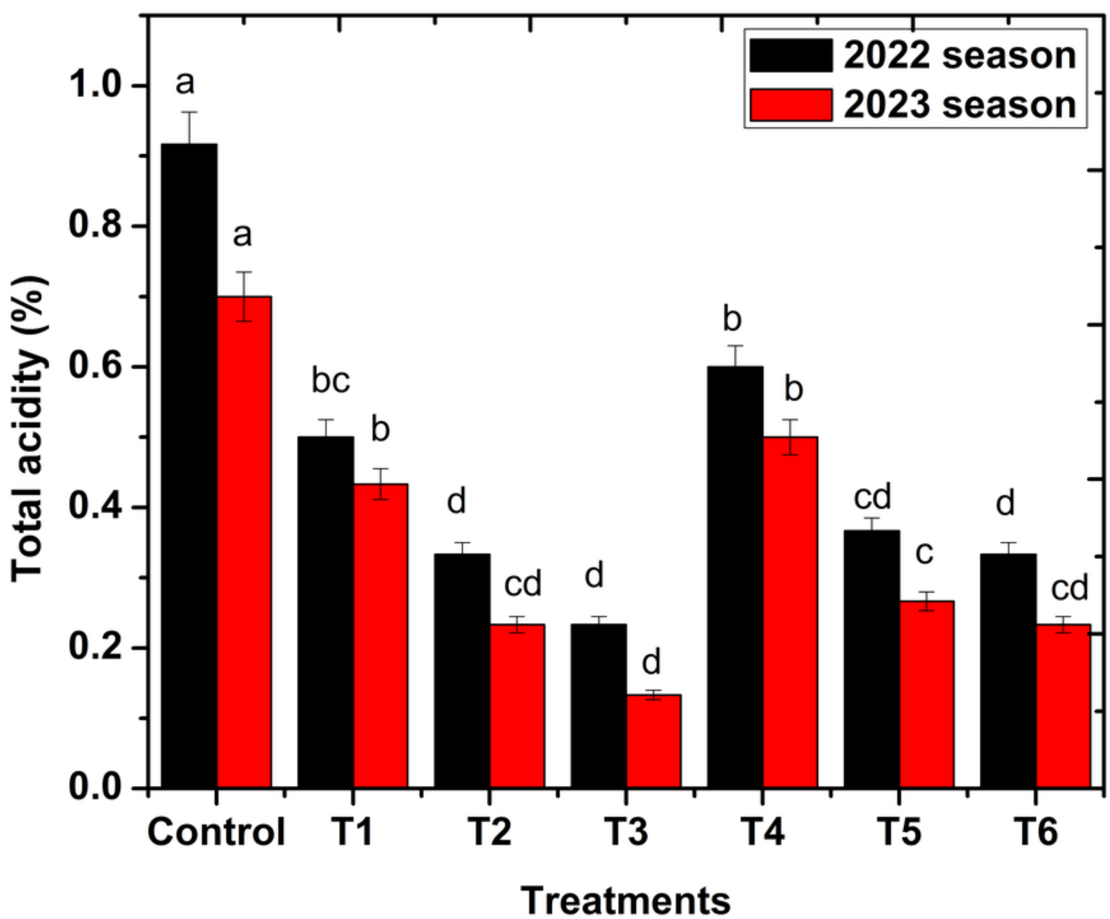

Figure 9

5C

Effect of (LiRE) and (KSb) spray on some of fruit chemical characteristics of the 'Osteen' mango cultivar in 2022 and 2023 seasons. A): TSS%, B): Total acidity%, C):TSS/acid ratio and Vitamine C. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

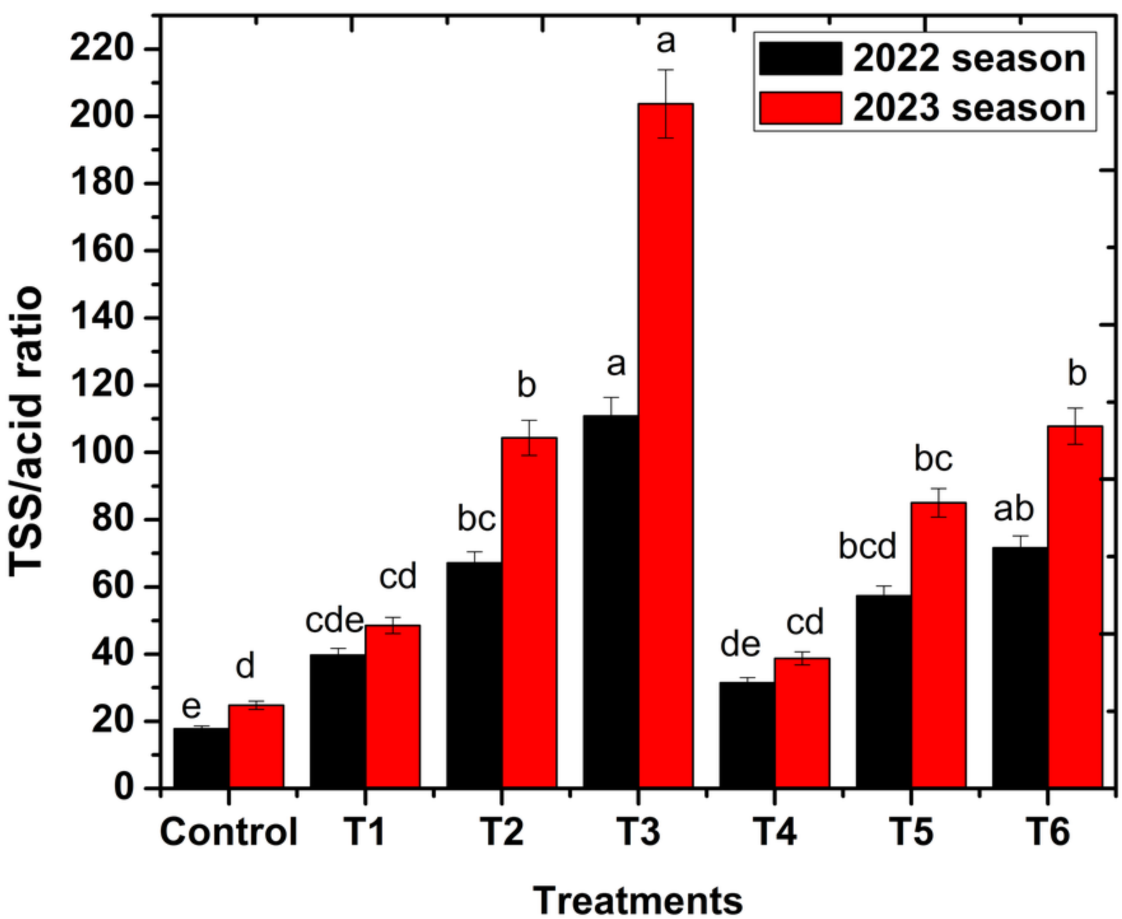

Figure 10

5D

Effect of (LiRE) and (KSb) spray on some of fruit chemical characteristics of the ‘Osteen’ mango cultivar in 2022 and 2023 seasons. A): TSS%, B): Total acidity%, C):TSS/acid ratio and Vitamine C. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

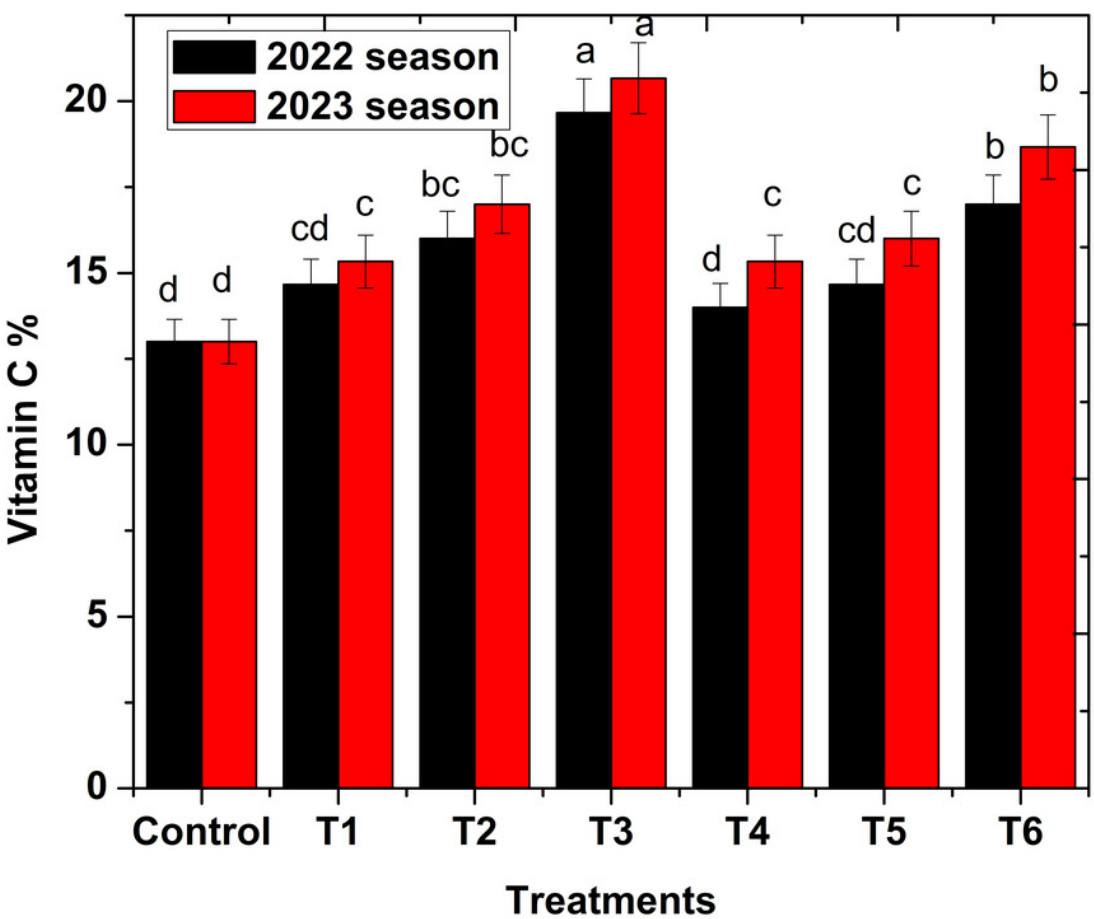

Figure 11

6A

Effect of (LiRE) and (KSb) on the photosynthetic Pigments Leaf of the 'Osteen' mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1, T2 and T3: 2, 4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

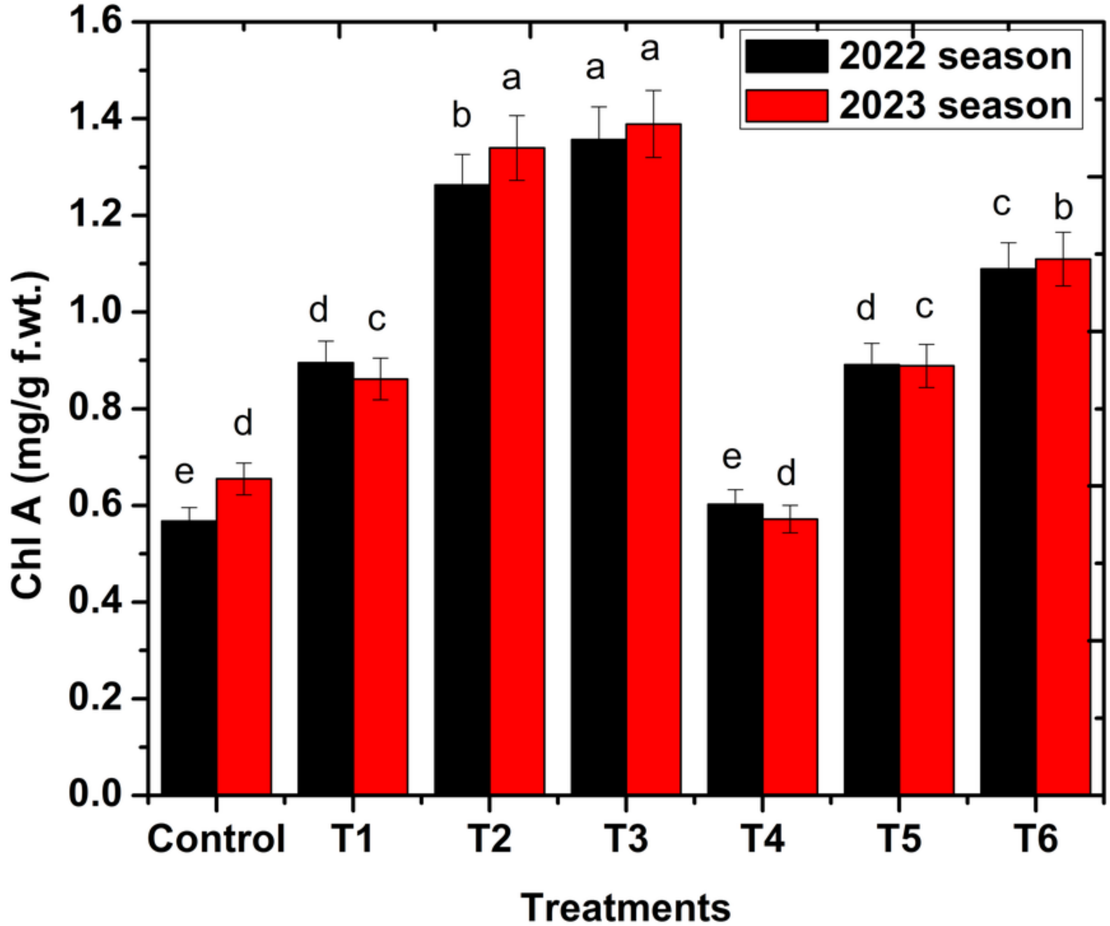

Figure 12

6B

Effect of (LiRE) and (KSb) on the photosynthetic Pigments Leaf of the ‘Osteen’ mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1, T2 and T3: 2, 4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

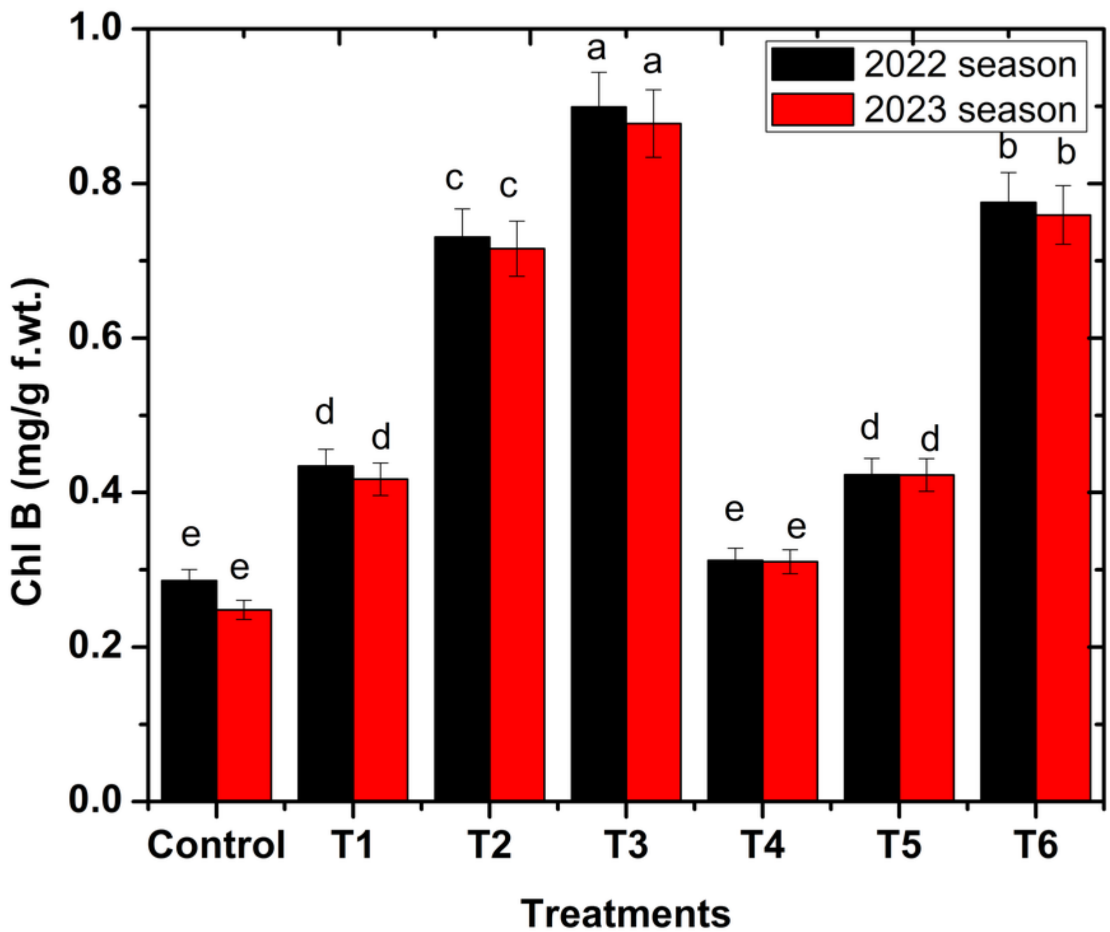

Figure 13

6C

Effect of (LiRE) and (KSb) on the photosynthetic Pigments Leaf of the ‘Osteen’ mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1, T2 and T3: 2, 4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

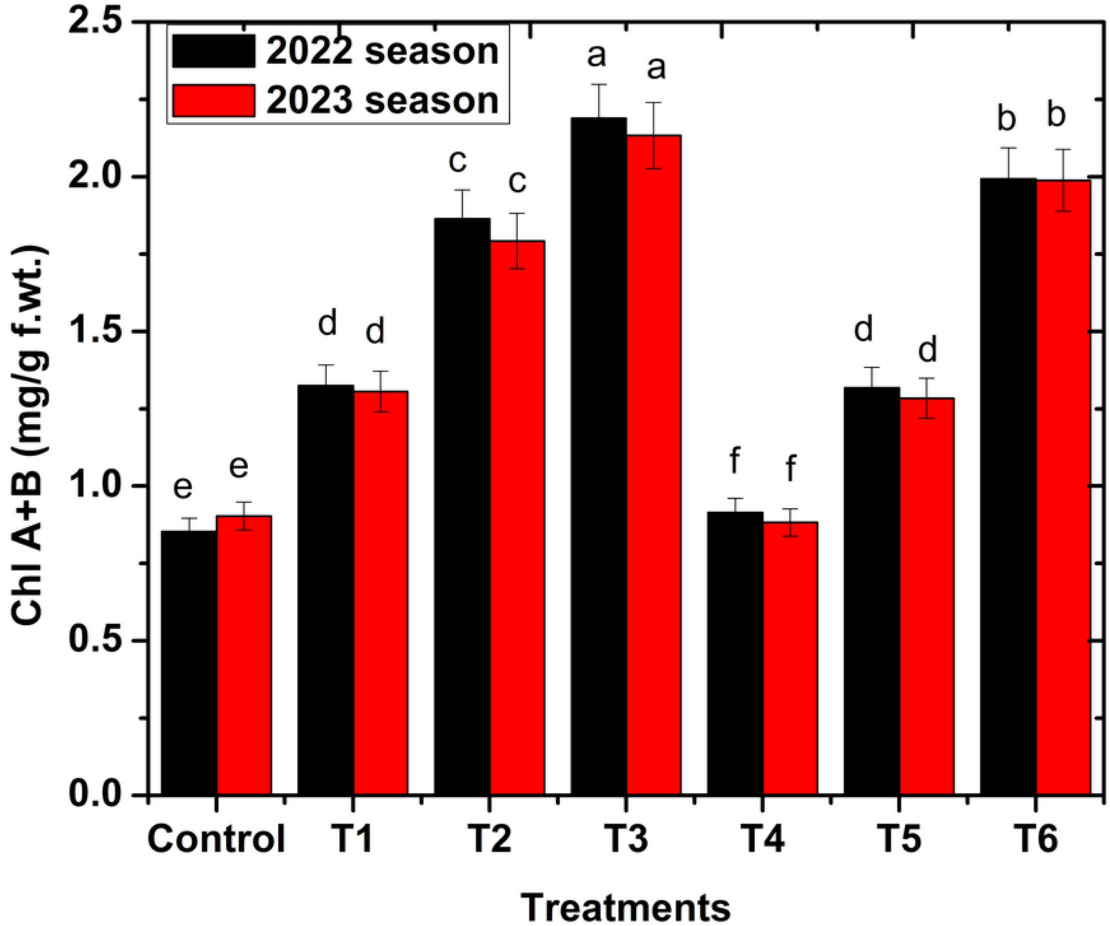

Figure 14

6D

Effect of (LiRE) and (KSb) on the photosynthetic Pigments Leaf of the 'Osteen' mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1, T2 and T3: 2, 4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

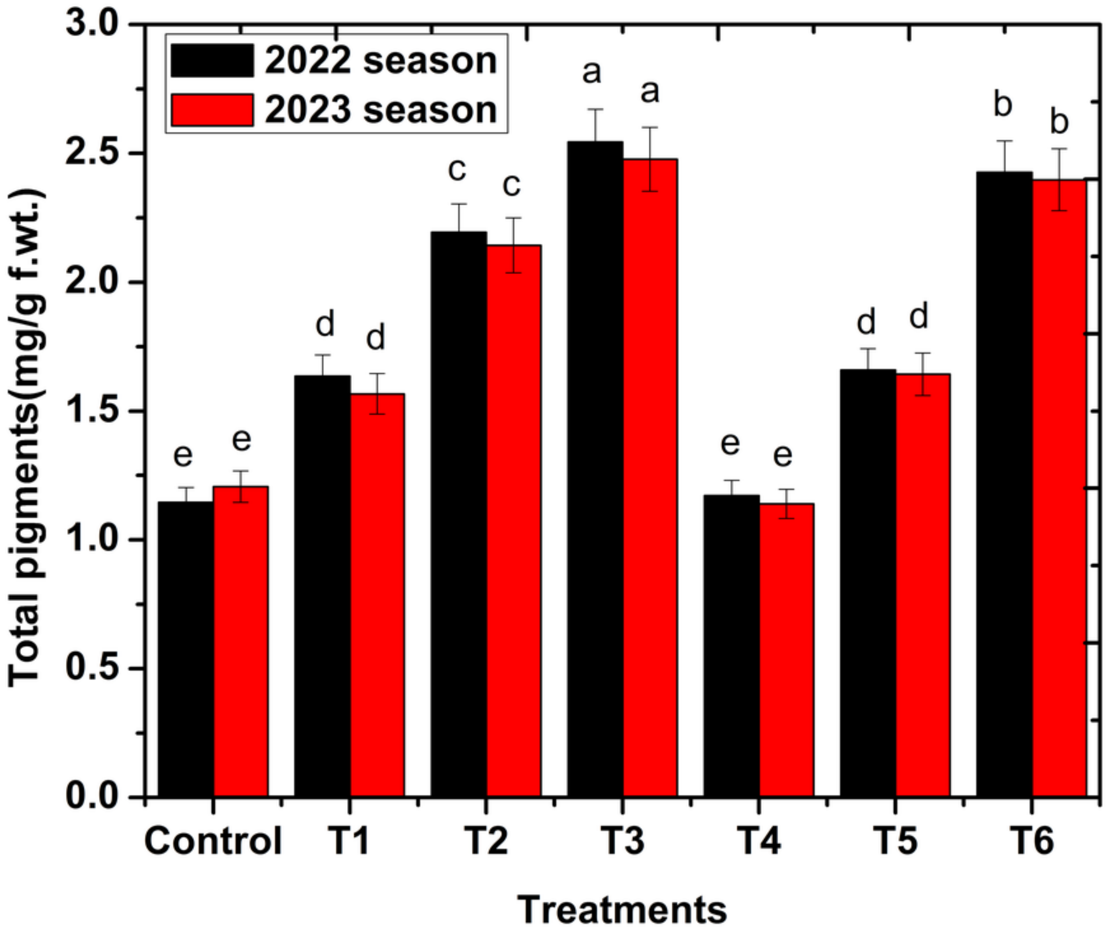

Figure 15

6E

Effect of (LiRE) and (KSb) on the photosynthetic Pigments Leaf of the ‘Osteen’ mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1, T2 and T3: 2, 4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassium sorbate.

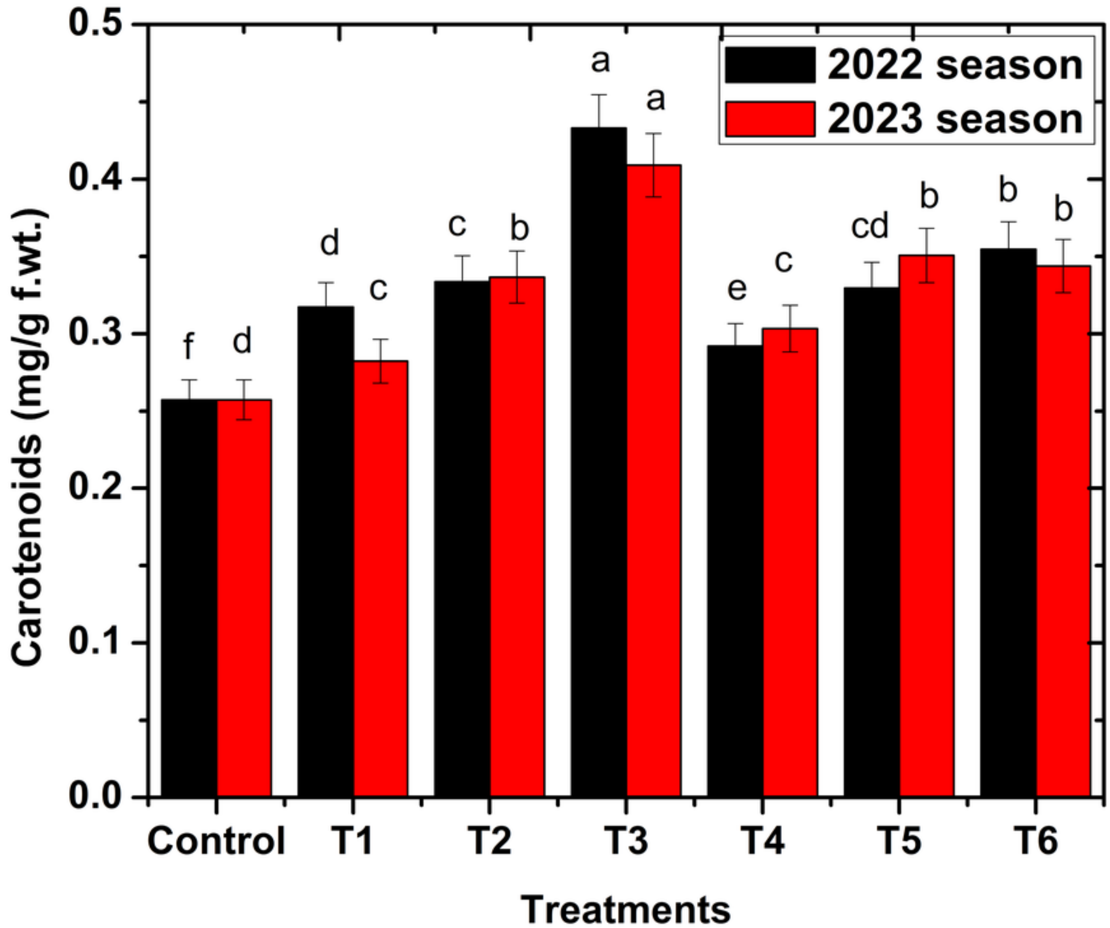

Figure 16

7A

Effect of (LiRE) and (KSb) on catalase activity, peroxidase activity and polyphenol oxidase activity of leaves osteen mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

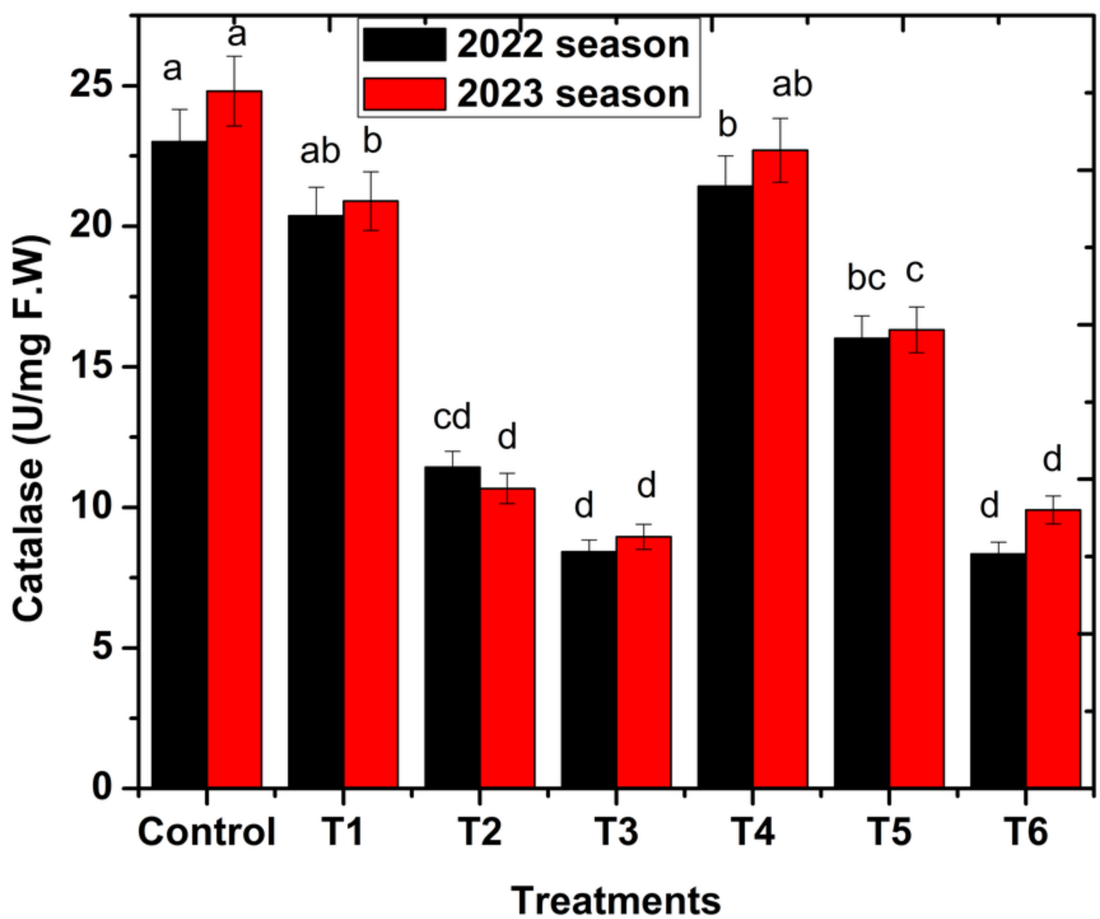

Figure 17

6B

Effect of (LiRE) and (KSb) on catalase activity, peroxidase activity and polyphenol oxidase activity of leaves osteen mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

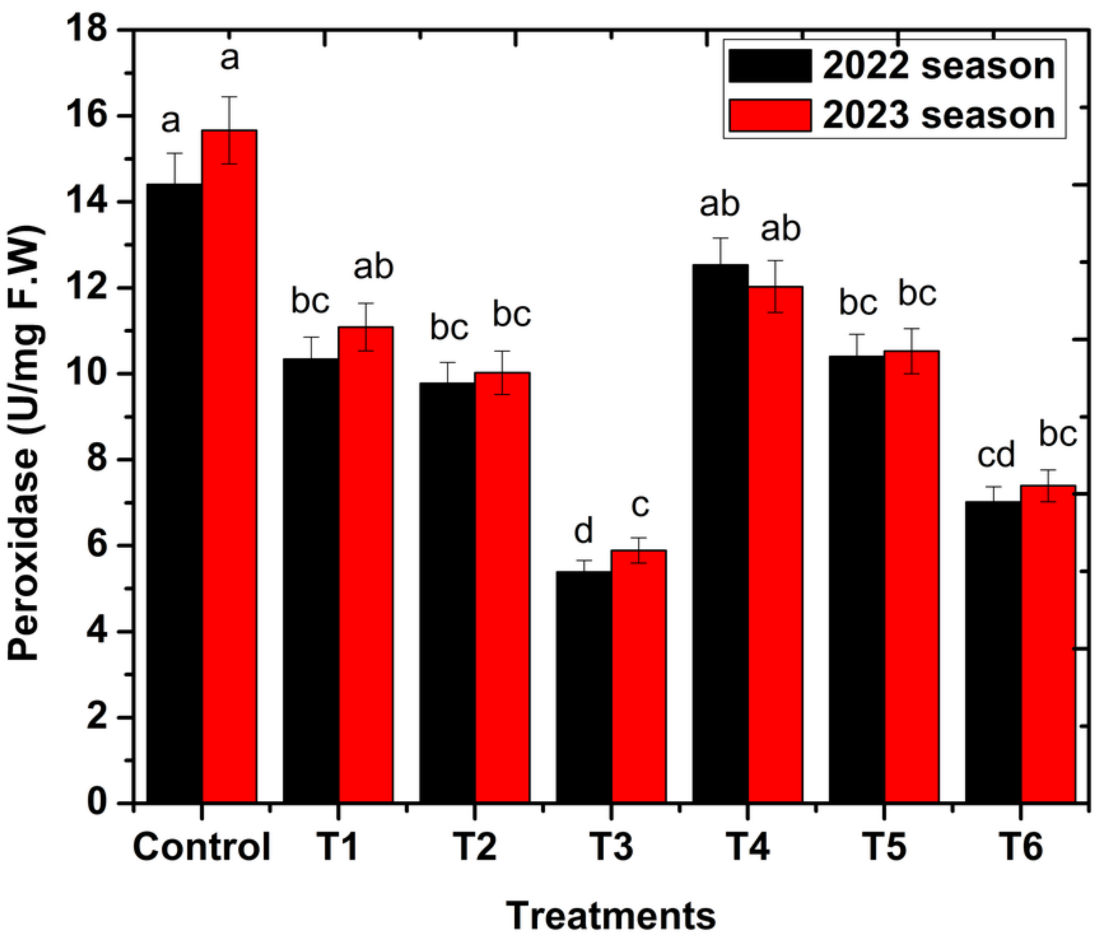

Figure 18

6C

Effect of (LiRE) and (KSb) on catalase activity, peroxidase activity and polyphenol oxidase activity of leaves osteen mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

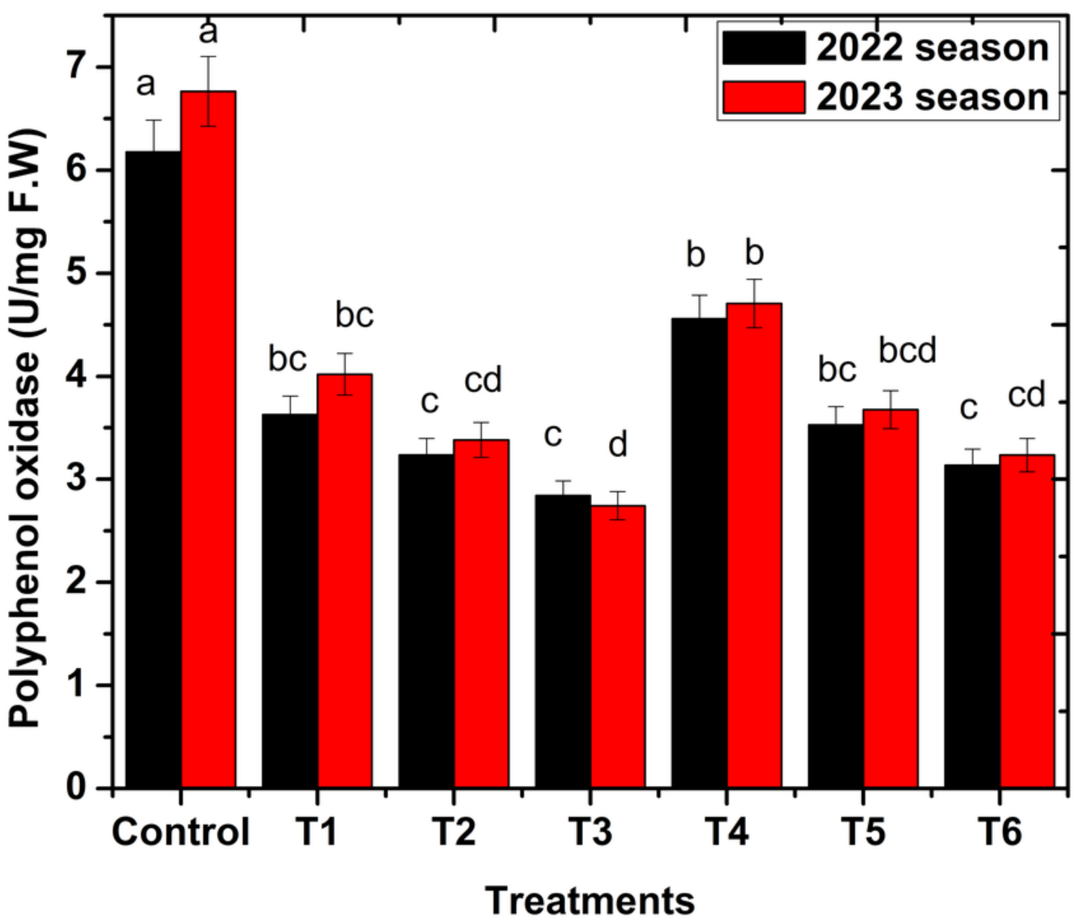

Figure 19

8A

Effect of (LiRE) and (KSb) on Total flavonoids, total phenolic and proline of leaves osteen mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

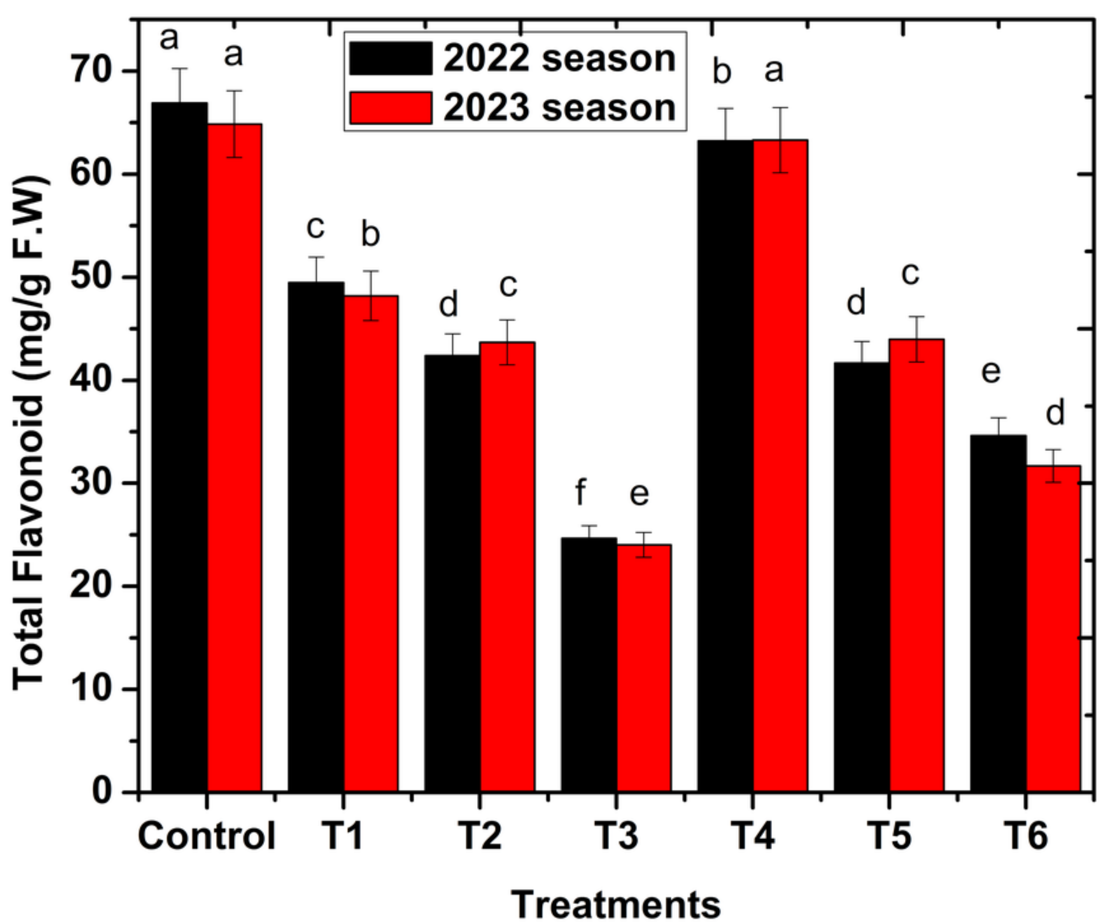

Figure 20

8B

Effect of (LiRE) and (KSb) on Total flavonoids, total phenolic and proline of leaves osteen mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.

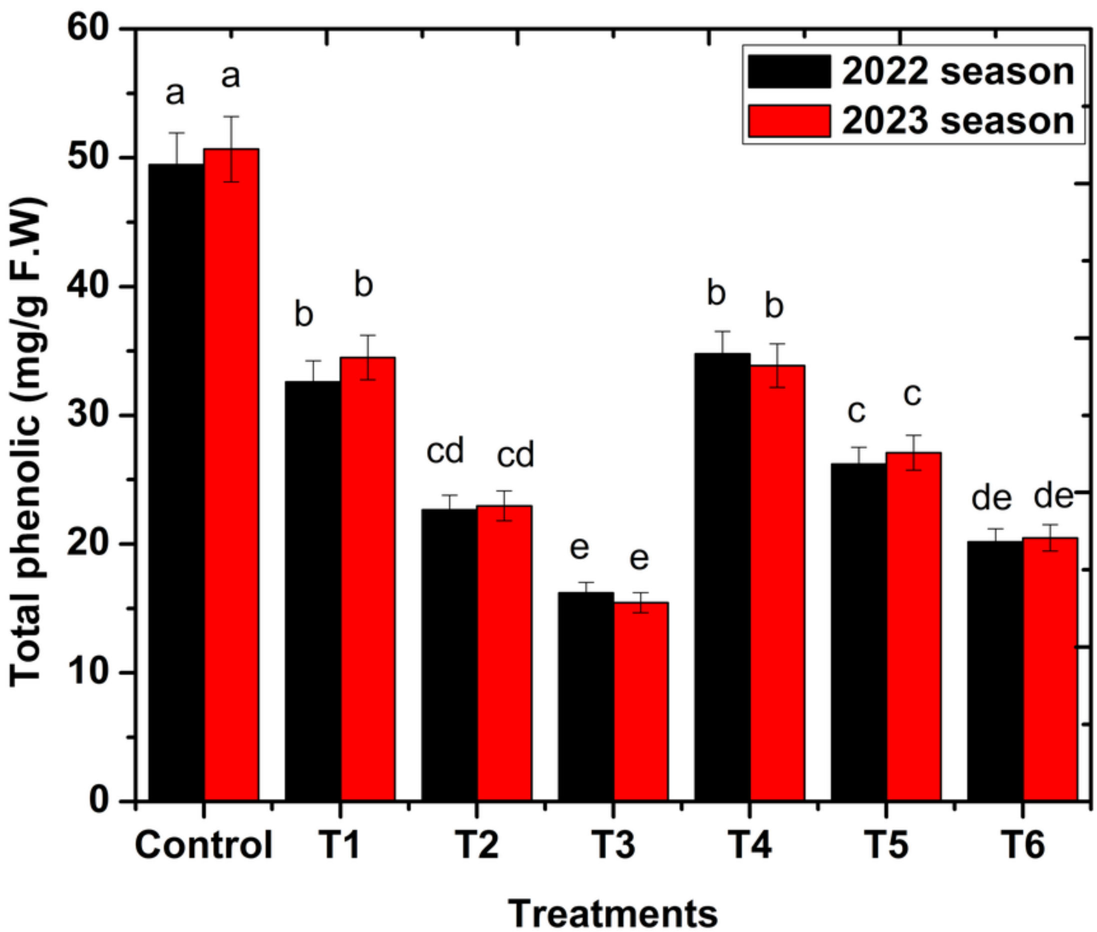

Figure 21

8C

Effect of (LiRE) and (KSb) on Total flavonoids, total phenolic and proline of leaves osteen mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, T1,T2 and T3 : 2,4 and 6g/l Licorice root extract, T4,T5 and T6: 1,2 and 3mM potassiumsorbate.