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

Adel M. Al-Saif [Corresp., 1] , **Haitham El-khamissi** [2] , **Ibrahim A. Elnaggar** [3] , **Mohammed H. Farouk** [4] , **Magdy A. E Omar** [5] , **Abd El-wahed N. Abd El-wahed** [6] , **Ashraf E. Hamdy** [Corresp., 6] , **Hosny F. Abdel-Aziz** [6]

[1] Department of Plant Production, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia

[2] Department of Agriculture Biochemistry, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt., Cairo, Egypt

[3] Department of Horticulture, Faculty of Agriculture, Al-Azhar University in Cairo, Cairo, Egypt

[4] Key Laboratory of Product Quality and Security, Ministry of Education, Jilin Agricultural University, Jilin, China, China

[5] Department of Agricultural Botany, Faculty of Agriculture, Al-Azhar University, Cairo, Cairo, Egypt

[6] Department of Horticulture, Faculty of Agriculture, Al Azhar University, Cairo, Egypt

Corresponding Authors: Adel M. Al-Saif, Ashraf E. Hamdy
Email address: adelsaif@ksu.edu.sa, ashrafezat@azhar.edu.eg

Heat stress, low mango yields and inconsistent fruit quality are main challenges for growers. Recently, licorice-root extract (LRE) has been utilized to enhance vegetative growth, yield, and tolerance abiotic stresses fruit trees. Potassium sorbate (PS) also plays a significant role in various physiological and biochemical processes that are essential for mango growth, quality and abiotic stress tolerance. This work aimed to elucidate the effects of foliar sprays containing (LRE) and (PS) on the growth, yield, fruit quality, total chlorophyll content, and antioxidant enzymes of 'Osteen' mango trees. The mango trees were sprayed with (LRE) at 0, 2, 4 and 6g/l and PS 0, 1, 2, and 3mM. In mid-May, the mango trees were sprayed with a foliar solution, followed by monthly applications until one month before harvest. The results showed that trees with the highest concentration (6 g/L) of LRE exhibited the maximum leaf area, followed by those treated with the highest concentration (3 mM) of PS. Application of LRE and PS to Osteen mango trees significantly enhanced fruit weight, Number of fruits.tree^{-1}, yield (kg/tree), yield increasing%, and reduced No. of sun-burned fruits compared to the control. LRE and PS foliar sprays to Osteen mango trees significantly enhanced fruit total soluble solids °Brix, TSS/acid ratio, and Vitamin C content compared to the control. Meanwhile, Total acidity percentage in 'Osteen' mango fruits significantly decreased after both LRE and PS foliar sprays. 'Osteen' mango trees showed a significant increase in leaf area, total chlorophyll content, total pigments, and carotenoids of leaf. Our results suggest that foliar sprays containing LRE and PS 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 LRE. LRE and PS 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.

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Adel M. Al-Saif[1]*, Haitham El-khamissi[4], Ibrahim A. Elnaggar[2], Mohammed H. Farouk[3], Magdy A. Omar[5], Abd El-wahed N. Abd El-wahed[2], Ashraf E. Hamdy[2]*, Hosny F. Abdel-Aziz[2]

[1]Department of Plant Production, College of Food and Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia.
[2]Department of Horticulture, Faculty of Agriculture, Al-Azhar University, Cairo, 11884, Egypt.
[3]Key Laboratory of Product Quality and Security, Ministry of Education, Jilin Agricultural University, Changchun, PR China.
[4]Department of Agriculture Biochemistry, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.
[5]Department of Agricultural Botany, Faculty of Agriculture, Al-Azhar University, Cairo, 11884, Egypt.

Corresponding Author:
Adel M. Al-Saif[1] ; Ashraf E. Hamdy[2]
Riyadh 11451, Saudi Arabia., Cairo, 11884, Egypt
Email address: adelsaif@ksu.edu.sa; ashrafezat@azhar.edu.eg

Abstract

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40 mango trees showed a significant increase in leaf area, total chlorophyll content, total pigments,
41 and carotenoids of leaf. Our results suggest that foliar sprays containing LRE and PS
42 significantly improved growth parameters, yield, fruit quality, antioxidant content, and total
43 pigment concentration in 'Osteen' mango trees. Moreover, the most effective treatments were
44 3mM KS and 6g/L LRE. LRE and PS foliar spray caused a significant increase in yield
45 percentage by 305.77%, and 232.44%, in the first season, and 242.55%, 232.44% in the second
46 season, respectively.
47 Keywords: *Mangifera indica* L.; bio-stimulates; leaf area; yield increasing%; carotenoids;
48 sunburned

Introduction

50 Ensuring global food security for a growing population is a major challenge for modern
51 agriculture (Fróna at al., 2019). This challenge is compounded by several factors. Climate
52 change has reduced the productivity of fruit trees. Additionally, the decline of usable land and
53 the intensification of agricultural practices further complicate the situation. (Pandey, 2020). To
54 achieve sustainable farming, there is a growing interest in finding environmentally safe organic
55 materials (Durán-Lara, Valderrama & Marican, 2020).
56 Among tropical fruits, the mango stands out as one of the most essential globally, prized for its
57 flavor and nutritional value (Hussain et al., 2021). This fruit may be enjoyed sparkling, juiced, or
58 maybe integrated into diverse meals products. Mangoes boast an outstanding nutritional profile,
59 filled with both macro and micronutrients (Yahia et al., 2023). Low mango yields and
60 inconsistent fruit are main challenges for growers. These issues with flowering and fruiting,
61 along with abnormal flowering, terrible fruit set, and inconsistent fruit development (Shivran et
62 al., 2020). This changes to lower yields, culmination of subpar exceptional and restrained
63 availability at some stage in the year. Fortunately, research suggests a promising solution:
64 strategic application of nutrients and growth regulators (Ram et al., 2020). By influencing
65 flowering and fruiting patterns, these tools can assist us release the whole potential of various
66 mango cultivars ('Keitt', 'Tommy Atkins') (Ramírez & Davenport, 2010). This method has the
67 energy to seriously boom and stabilize mango production (Tirado-Kulieva et al., 2022).
68 Biostimulants have been recognized as a promising approach that utilizes natural products
69 (Santini et al., 2021). Biostimulants are a flexible, cost-effective, and widely applicable solution
70 that can improve agricultural productivity in a sustainable manner and mitigate the effects of
71 climate change (Fallovo et al., 2008; Rouphael & Colla, 2018). Generally, biostimulants have the
72 potential to enhance crop productivity through three key mechanisms: (i) optimizing root system
73 architecture to improve water and nutrient uptake, (ii) maximizing photosynthetic capacity to
74 promote growth, and (iii) reducing oxidative stress in plants by enhancing the antioxidant
75 defense system (De Pascale & Rouphael, 2018; Rouphael & Colla, 2018).
76 Recent research has explored the potential of plant extracts, like licorice root, to enhance fruit
77 tree growth and yield (Nasir et al., 2016). Licorice (*Glycyrrhiza glabra*), belonging to the
78 Leguminoseae family, thrives in Egypt and many other regions globally (Vlaisavljević et al.,
79 2018). The licorice root boasts some nutritional value and unique chemical compounds,

80 including gleserezin, glycyrrhejel. Additionally, rich in various elements and nutrients (Husain et
81 al., 2021). Licorice extract is believed to stimulate cellulose enzyme activity, crucial for cell
82 expansion, ultimately accelerating plant growth. It might also help reduce transpiration rates,
83 minimizing water loss and maintaining cell turgor (Peng et al., 2023).
84 Potassium is a vital mineral nutrient for plants (Wang et al., 2013). This element is crucial for
85 numerous functions within plants, influencing growth, yield, fruit development, quality, and even
86 their ability to withstand stress (Shahid et al., 2020). Studies have shown that potassium
87 improves fruit quality parameters like sugar content, color, and overall taste (Hernández-Pérez et
88 al., 2020). Beyond its role in fruit development, potassium is essential for plant life itself
89 (Sardans & Peñuelas, 2021). It activates numerous enzymes involved in photosynthesis, sugar
90 production, and overall plant metabolism, ultimately leading to increased crop yields (Nieves-
91 Cordones et al. 2016). Potassium also regulates various physiological processes like water
92 movement, respiration, and nutrient translocation within the plant. Additionally, it activates
93 enzymes like nitrate reductase and starch synthetase, which contribute to a healthy balance of
94 protein and carbohydrate production (Iqbal et al., 2022). Potassium even influences how plants
95 open and close their stomata (tiny pores on leaves). This, in turn, affects photosynthesis, nutrient
96 uptake, and overall plant function, ultimately impacting crop yield and fruit quality(Devin et al.,
97 2023). Studies have shown that KNO_3 increases the proportion of flowering shoots, flower
98 clusters, and vegetative growth, key to better yields and decreased alternate bearing (Alshallash
99 et al., 2023; Alebidi et al., 2023).
100 Studies show potassium is vital for healthy mango trees and delicious fruit. It improves fruit size,
101 sweetness, and color by strengthening the tree and boosting sugar production (Andreotti et al.,
102 2022; Ahmad et al., 2023). Field trials confirm that applying potassium, especially through
103 leaves, significantly increases mango yield and fruit quality of 'Hindi' mango trees (Baiea et al.,
104 2015).
105 Many studies have investigated mango cultivation, but none have looked at how licorice root
106 extract and potassium sorbate affect the growth, yield, fruit quality, and antioxidant enzymes of
107 'Osteen' mangoes. Moreover, this study aimed to elucidate the effects of licorice root extract and
108 potassium sorbate on the growth, yield, fruit quality, total chlorophyll content, and antioxidant
109 enzymes of 'Osteen' mango trees.
110

Materials & Methods

112 Licorice root extract Preparation
113 To prepare the Licorice root extract for commercial use (obtained from the Sekem Group in
114 Cairo, Egypt), it was mixed with water at a concentration of 250 g L⁻¹. The mixture was left at
115 room temperature for 24 hours, and then thoroughly blended before being filtered through
116 Whatman No. 42 filter papers. This filtration process resulted in obtaining a condensed brown
117 liquid extract. To enhance the properties of the filtered solution, gelatin from Sigma-Aldrich (at a
118 concentration of 2 g L⁻¹) was added. This step followed the methodology described by Younes,
119 et al. (2019) ; Younes et al. (2020). The resulting mixture was heated at a temperature of 30 ± 2

120 °C while stirring was done to ensure proper mixing following by storage for application on
121 mango trees. The chemical composition of the Licorice root extract was also analyzed, in Table
122 1, as reported by (Desoky et al., 2019; Rady et al., 2019; Younes et al., 2021)
123
124 2.1. Experimental site
125 This study was conducted on 7-year-old Osteen mango trees in a private farm located in the El
126 Salheya El Gedida district, El-Sharqia Governorate, Egypt (30.6547° N, 31.8733° E) weather
127 data Table 2. The trees are planted in sandy soil at a distance of 2m ×4m (1250 tree/ha) and
128 irrigated using a drip system. Management practices included regular irrigation, fertilization, and
129 pest and disease control. From mid-May to one month before harvest, the trees were sprayed
130 monthly interval with licorice root extract and potassium sorbate solutions as follows in Table 3.
131 Moreover, at 7:00 AM, we used backpack sprayers on each tree, applying 5 liters (6250 L/ha) of
132 both solutions to the point of runoff.

133 2.2. Measurements:
134 2.2.1. Leaf area:-Twenty leaves below panicles of the spring growth cycle according to
135 Walworth and Sumner (Walworth & Sumner, 1987) were taken (2nd week of June) for
136 measuring leaf area according of (Ahmed & Morsy, 1999) as the following:
137
138 Leaf area = 0.70 (L×W) -1.06 = ……… cm²
139
140 Where: L and W = leaf length and width, respectively.
141
142 2.2.3. Total pigments
143 Leaf total chlorophyll content and total carotenoids were extracted from fresh leaves of 'Osteen'
144 mango cultivar, following the method of Brito et al., (Brito et al., 2011), and the results were
145 calculated according to (Wellburn, 1994).
146
147 2.2.4. Determination proline content
148 To estimate proline content a rapid colorimetric method was used (Bates et al., 1973). Plant
149 tissue (0.5 g) was homogenized in a solution and filtered. The filtrate was then mixed with a
150 freshly prepared acid solution and heated. The reaction was stopped by cooling, and a specific
151 organic solvent was used to extract a colored compound. The amount of color formed was
152 measured using a spectrophotometer, and the proline content was determined using a standard
153 curve.
154
155 2.2.5. Determination relative water content.
156 Leaf relative water content (RWC) was determined following the method of (Yamasaki &
157 Dillenburg, 1999). Two leaves were randomly selected from the middle portion of each plant
158 replicate. The fresh weight (FM) of each leaf was measured after separation from the stem. To
159 determine the turgid weight (TM), leaves were rehydrated in closed containers with distilled

160 water for 24 hours at 22°C. After rehydration, the leaves were weighed again. Finally, dry weight
161 (DM) was obtained by oven drying at 80°C for 48 hours. All weights were measured with a
162 balance accurate to 0.001 g. The relative water content was calculated as follows:
163 RWC (%) = [(FM-DM) (TM –DM)] ×100.
164
165 2.3.7. Antioxidant enzyme activity
166 To extract polyphenol oxidase (POX), peroxidase (PPO), and catalase CAT, fresh leaves (0.5 g)
167 of Osteen mango cultivar were mashed in a mortar with 5 mL of 0.1 M cold phosphate buffer (pH
168 7.1), and the mixture was centrifuged at 15,000xg for 20 minutes at 4 ∘C. The supernatant was
169 used in an enzyme activity experiment (Esfandiari et al., 2007).
170 Peroxidase activity (POX) was measured using an approach that was based on (Amako et al.,
171 1994). Polyphenol oxidase (PPO) activity was measured in compliance with (Kavrayan &
172 Aydemir, 2001). The activity of the catalase (CAT) enzyme was measured in compliance with
173 (Aebi, 1984).
174

175 Total phenolic and total flavonoid
176 According to (Singleton et al., 1999), the total phenolic content of Osteen mango tree leaves was
177 measured using the Folin–Ciocalteu colorimetric method and represented as (mg/g) using gallic
178 acid as a standard. According to (Escriche & Juan-Borrás, 2018), the total flavonoid
179 concentration in fresh leaves of the Osteen mango cultivar was measured using the aluminum
180 chloride (AlCl$_3$) colorimetric method, with Rutin serving as a standard and being expressed as
181 mg/g.
182 2.8. Tree Yield
183 We harvested the fruit from each experimental tree when the flesh turned yellow and the
184 shoulders rounded or flattened according to (Ahmed et al., 2023) Moreover, on the 15th of
185 August in both seasons of the 'Osteen' mango cultivar according to (Khattab et al., 2021).
186 According to Elshahawy et al., (2022), the Osteen mango cultivar exhibits regular fruiting
187 behavior.
188 Then, the average yield was calculating in terms of number of fruits/tree and weight (kg). The
189 yield increasing percentage was computed using the equation of (Abd El-Naby, Mohamed & El-
190 Naggar, 2019).
191

192 $$Fruit\ Yield\ increment\ (\%) = \frac{[Yield\ (treatment) - Yield\ (control] \times 100}{Yield\ (control)}$$

193
194 To assess the percentage of sunburned fruit, we counted the number of sunburned fruits on each
195 tree at harvest. Then calculated the sunburn rate as a percentage using a formula developed by
196 (Mohsen & Ibrahim, 2021) equation as follows:
197 $$Sunburned\ fruits = \frac{No.of\ sunburned\ fruit/tree}{Total\ No.\ of\ fruits/tree} \times 100$$

198
199 2.9. Fruits Physical properties.

200 Fruit weight (g) was calculated at harvest time using a sample of five Osteen cv. mangoes. The
201 samples were then chosen and transferred to the horticulture lab.
202 2.10. Chemical characteristics of fruits.
203 Mango juice Extraction
204 10 g of mango pulp was weighed and added to a 100 mL beaker. The pulp was then
205 homogenized with distilled water using a blender to achieve a uniform mixture. The
206 homogenized mixture was subsequently filtered to remove any particulates. The filtrate was then
207 quantitatively transferred to a 100 mL volumetric flask. Distilled water was further added to the
208 flask to bring the final volume to the mark.
209
210 Fruit total soluble solids (TSS) of Osteen mango pulp was determined in two to three drops of
211 each sample juice by using a digital refractometer (force-Gouge ModelIGV-O.SA to FGV-100A.
212 Shimpo instruments) and expressed as °Brix according to(McKie & McCleary, 2016)
213
214 Total acidity percentage
215 A 10 mL aliquot of the pulp solution was measured into a conical flask. Two to three drops of
216 phenolphthalein indicator were added, and the flask was then swirled vigorously to ensure
217 thorough mixing. The solution was immediately titrated with 0.1 N NaOH solution from a
218 burette until a permanent pink endpoint was reached. The volume of NaOH solution consumed
219 was recorded, and the percent titratable acidity was expressed as citric acid (%) according to the
220 method of (McKie & McCleary, 2016).
221
222 Total soluble solids/acid ratio was calculated from the values of total soluble solids divided by
223 values of total acids. (McKie & McCleary, 2016).
224
225 The ascorbic acid content (vitamin C) of fruit juice was determined in triplicate (n=3) for each
226 treatment, with a sample volume of 2.0 ml per replicate. The analysis followed the method
227 described by McKie & McCleary (2016), which is based on the oxidation of ascorbic acid with
228 2,6-dichlorophenolindophenol dye. The results are expressed as (mg/100 ml) of juice and
229 represent the average value for each treatment.
230
231 Statistical Analysis
232 The design of the present study was a randomized complete block design (RCBD). The
233 information used to create the charts comes from three separate times when each treatment (9
234 trees/treatments was applied. The analysis of variance as one-way ANOVA was used through
235 Costat software (Ridgman, 1990), and means of different treatments were compared using the
236 Duncan test ($p \leq 0.05$).
237

Results
239 2.1. Effect of (LRE) and (PS) on leaf area of 'Osteen' mango under heat stress:

240   The results in Fig. 1 showed that spraying with licorice root extract and potassium sorbate in
241   mid- May significantly increased the leaf area of 'Osteen' mango trees in both studied seasons in
242   comparison to control. Additionally, a trend emerged where leaf area increased as the
243   concentration of licorice root extract and potassium sorbate increased. Leaf area promotion was
244   most dependent on the application of licorice root extract at 6 g/L, followed by 3 mM potassium
245   sorbate. Untreated trees consistently had the lowest leaf area values. This trend was observed in
246   both growing seasons.

247

248   2.2. Effect of (LRE) and (PS) on fruit physical properties:
249   The results in Figures (2a, and b) clearly showed that adding licorice root and potassium sorbate
250   extract at various phenological stages significantly increased fruit weight (g), and No. of
251   fruits/tree of Osteen mango trees in comparison to those of control in the two studied seasons.
252   These results are in line with findings of (Baiea et al., 2015) who found that spraying Hindi
253   mango trees four times with different types of potassium were very effective in improving
254   number of fruits or weight (kg/tree) comparing with the control. Fruit weight (g), and No. of
255   fruits/tree promotion were most dependent on the application of licorice root extract at 6 g/L,
256   followed by 3 mM potassium sorbate. Trees treated with 6 g/L licorice root extract exhibited the
257   maximum fruit weight (g), and No. of fruits/tree, followed by those treated with 3 mM potassium
258   sorbate. Additionally, a trend emerged where fruit weight (g), and No. of fruits/tree increased as
259   the concentration of potassium sorbate and licorice root extract increased.

260

261   2.3. Effect of (LRE) and (PS) on fruit yield.tree^{-1}:

262

263   The results illustrated in Figure (3A and B) revealed notable enhancements in fruit yield (kg/tree)
264   and yield increasing (%) when 'Osteen' mango trees were subjected to the addition of licorice
265   root extract and potassium sorbate as foliar spray at different phenological stages. These
266   improvements were observed across various growth stages and were found to be significantly
267   higher compared to the control group in both seasons under investigation. Specifically, the
268   application of 3mM potassium sorbate or 6.g^{-1} licorice root extract resulted in a more pronounced
269   increase in fruit yield (kg/tree) compared to other treatments or the control group. Licorice root
270   extract and potassium sorbate foliar spray caused a significant increase in yield percentage by
271   305.77%, and 232.44%, in the first season, and 242.55%, 232.44% in the second season,
272   respectively.

273

274   2.4. Effect of (LRE) and (PS) on No. of sun-burned fruits:
275   Figure 4 represents the response of the number of sun-burned fruits of 'Osteen' mango trees to
276   licorice root extract and potassium sorbate foliar spray. Both potassium sorbate and licorice root
277   extract foliar spray significantly reduced the number of sun-burned fruits of 'Osteen' mango
278   trees in comparison to the control group in the two studied seasons. The lowest number of sun-
279   burned fruits of Osteen mango trees were possessed from LER6 (6g/l licorice root extract) and or

280 PS3 (3mM PS). Meanwhile, the control group had the highest number of sun-burned fruits of
281 Osteen mango trees in both seasons. Additionally, a trend was observed: as the level of
282 potassium sorbate and licorice root extract increased, the number of sun-burned fruits of Osteen
283 mango trees decreased.

284

285

286 2.5. Effect of (LRE) and (PS) on some fruit chemical characteristics:

287

288 Foliar application of both (LRE) and (PS) significantly increased TSS (Brix˚), TSS/acid ratio,
289 and Vitamin C in comparison to the control group, as shown in figures 5a, 5c, and 5d.
290 Conversely, total acidity% in 'Osteen' mango fruits significantly decreased in response to the
291 foliar application during both study seasons (Fig. 5b). Concerning fruit chemical characteristics,
292 the data revealed that higher levels of (LRE) and (PS) applied as foliar sprays were superior to
293 the control group and to treatments with lower spraying concentrations. Among all treatments,
294 3mM potassium sorbate (PS3) and 6g/l licorice root extract (LER6) resulted in fruits with the
295 highest TSS%, TSS/acid ratio, and Vitamin C content, compared to the control group and other
296 treatments. On the other hand, 'Osteen' mango fruits from treatments T3 and T6 showed the
297 lowest values of total acidity compared with fruits from other foliar spray treatments or the
298 untreated group.

299

300

301 2.6 The photosynthetic Pigments Leaf of 'Osteen' mango cv. Under heat stress
302 It is clear from Figure 6 that the photosynthetic pigments of leaf Osteen mango CV were
303 significantly influenced by foliar spray with licorice root extract (LRE) and (PS) during the 2022
304 and 2023 seasons under heat stress (sunburn). The application of different LRE and PTS
305 concentrations on mango tree leaves resulted in an increase in photosynthetic pigments under
306 heat stress. As shown in Figure 6, increasing the LRE concentrations from 2-6 g/L and (PS)
307 from 1-3 mM led to an increase in the values of chlorophylls (a and b) and total chlorophyll,
308 carotenoids, and total pigments. With a LRE concentration of 6 g/L (LER6), the highest values
309 for chlorophyll a (1.389), chlorophyll b (0.899), total chlorophyll (2.267), carotenoids (0.433),
310 and total pigments (2.689 mg/g fresh weight) were obtained compared to the control, which had
311 the lowest values for these characteristics under heat stress during both seasons. Additionally,
312 spraying (PS) at 3 mM (PS3) had the greatest impact on the photosynthetic pigment contents
313 compared to other PTS concentrations and the control treatment. The value for total pigments
314 (2.219 mg/g fresh weight) was higher than that of the control (non-treated) (1.111 mg/g fresh
315 weight) under heat stress during the 2022-2023 seasons (Figure 6E).

316

317

318 2.7 Antioxidant activity leaf of Osteen mango cv. under heat stress

319 Polyphenol oxidase (PPO), peroxidase (POX), and catalase (CAT) activities were significantly
320 influenced by the foliar spray of (LRE) and (PS) on Osteen mango leaves under heat stress
321 (sunburn) during the 2022 and 2023 seasons (Figure 7). Based on the results, the highest
322 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
323 were found under control conditions (non-treated). According to Figure 7 A-C, the enzyme
324 activities decreased with increasing concentrations of LRE and PTS sprayed on mango leaves.
325 The lowest activities of PPO (2.75 U/g F.Wt) and POX (5.39 U/g F.Wt) enzymes were observed
326 when spraying Osteen leaves with 6 g/l of LRE (T3), while the lowest activity of CAT (8.35 U/g
327 F.Wt) was recorded at 3mM of (PS) (PS3). Agricultural production is adversely affected by
328 global warming and the anticipated rise in temperatures(Challinor et al., 2014; Fahad et al.,
329 2017).
330
331 2.7 Total flavonoids, total phenolic and proline of Leaf Osteen mango cv. Under heat stress
332 The content of total flavonoid in leaves of Osteen mango is shown in (figure 8A). The highest
333 (66.90 mg/g F.W) and lowest (24.03 mg/g F.W) values were observed with control (heat stress
334 non-treated) and T3 6 g/l LRE, respectively in 2022 and 2023 seasons. Total flavonoid content
335 decreased by 26%, 32.66%, and 63% at 2, 4, and 6 g/L LRE, respectively, and by 2.46%, 32.2%,
336 and 48.28% at 1, 2, and 3 mM PS, respectively. Figure 8B illustrates data about the total
337 phenolic content. The highest amounts of total phenolic (50.67 mg/g F.W) were found in leaves
338 under control and the lowest amount (15.46 mg/g F.W) was treated with T3 6 g/l LRE. Total
339 phenolic decreased by 69.43% and 59.57% at T3 6 g/l LRE and PS3 3 mM PS, respectively.
340 Within the kingdom of plants, flavonoids and phenolics are the most extensively dispersed
341 secondary metabolites. These compounds play a vital role in plant growth and defense
342 mechanisms. The results for proline variation in leaves of treated and non-treated Osteen mango
343 trees under heat stress are presented in Figures 8C. Osteen mango leaves exposed to high
344 temperatures showed higher proline content. The highest accumulation of proline (0.280 mg/100
345 g F.W) belonged to control leaves. According to (Bernardo et al., 2018), raising temperatures to
346 extremely high levels led to excessive proline production in grapevine. The trees sprayed with
347 (T3) 6 g/l LRE showed lower proline content (0.026 mg/100g F.W) compared to control and
348 other treatments.
349

Discussion

351 Heat stress causes many disorders in mango growth, which led to a reduction in leaf area.
352 Spraying with (LER) and (PS) in our study showed a mitigating effect on heat stress. These
353 results are consistent with the findings in numerous studies support the use of foliar potassium to
354 enhance plant growth. (Abd El-Rahman, 2021) observed this when added potassium silicate to
355 'Sedika' mango trees,(Ayed et al., 2022) with 'Keitt' mango trees, and (EL-Gioushy, 2021) with
356 orange trees. All these studies found that foliar application of potassium significantly improved
357 vegetative growth compared to the control group. The leaf area increasing might be due to

358 potassium spray (Rouphael & Colla, 2018). Potassium plays a vital role by activating enzymes
359 for organic substance synthesis, promoting photosynthesis, and transporting carbohydrate
360 assimilates to storage organs (Fallovo et al., 2008). It's also involved in several basic
361 physiological functions. Similarly licorice root extracts improving the vegetative growth of
362 plants (Nasir et al., 2016). The increase in fruit weight of 'Osteen' mango trees could be
363 attributed to the increase in leaf area caused by potassium sorbate and licorice root extract
364 application and subsequently stimulation of photosynthesis intensity shared in increasing the
365 fruit weight. Similarly, the study focused on licorice root extract as a potential vegetarian
366 alternative to synthetic growth regulators. This extract is gaining interest due to its reported
367 ability to improve plant growth and production in practical applications. Licorice root contains
368 glycyrrhizin, a compound composed of calcium and potassium salts of glycyrrhizic acid, a
369 trihydroxy acid (Rady et al., 2019). Moreover, it contained a wide range of elements and
370 nutrients (Hamam et al., 2021). As a matter of fact, adding a lot of potassium sorbate as foliar
371 spray at different fruit growth stage may be attributed to the physiological role of potassium
372 which is needed for many biochemical processes. Potassium also regulates various physiological
373 processes like water movement, respiration, and nutrient translocation within the plant.
374 Additionally, it activates enzymes like nitrate reductase and starch synthetase, which contribute
375 to a healthy balance of protein and carbohydrate production(Iqbal et al., 2022).

376 Despite being one of the important activities in tropical regions, mango production has been
377 largely ignored in systematic impact analyses of climate change (Nath et al., 2019). Heat stress
378 can reduce fruit yield in mango tree cultivars, leading to a decline in overall tree productivity.
379 This study aligns with previous findings by (El-Merghany, et al., 2019) who reported that
380 licorice root extract application to 'Ferehy' date Palm trees significantly increased fruit weight
381 and yield per tree. Similarly, (Ahmed et al., 2023) found that adding 4-8 g/L of the extract to red
382 globe grapevines in April to June increased yield per tree compared to the control group.
383 Similarly, in a study by Yassin, et al. (2023), applying potassium silicate at concentrations of
384 100, and 200 ppm increased the number of fruits and fruit yield per tree of Wonderful and H116
385 pomegranate compared to the control group. Additionally, (Silem, Ismail & Mohamed, 2023)
386 reported that applying potassium silicate at a concentration of 500 ppm to mango trees at the
387 beginning of growth, after fruit setting, and one month later increased fruit yield per tree
388 compared to the control group. The increasing in yield /tree of 'Osteen' mango trees might be
389 due to licorice root extract has been found to be an amazing biostimulant that increases not only
390 growth but also the yields of various crops (Alshallash et al., 2022). According to (Diab & Abd
391 El-hmied, 2022) they found that foliar spraying the 'Kitte' cv. mango with licorice root extract at
392 5 or 10 g/l concentration on three occasions, at the beginning of growth, after fruit set, and three
393 weeks after fruit set, significantly increased tree yield in comparison to the control group.
394 It could be concluded that Application of (LRE) and (PS) to Osteen mango trees at different
395 growth stages significantly enhanced fruit weight, number of fruits per tree, yield (kg/tree), and
396 yield increase percentage, compared to the control. The most effective treatments were 6g/L
397 (LRE) and 3mM (PS).
398 Our results align with the findings of (Ahmed et al., 2023), who reported that foliar spraying the
399 'Red Glob' cv. grapevine with licorice root extract at a concentration of 4 or 8 g/L, applied three

400 times in mid-April, May, and June, significantly reduced the number of sun-burned fruits. The
401 presence of various beneficial compounds in licorice root extract, including phenolics,
402 triterpenes, saponins, amino acids, polysaccharides, vitamins, and growth-promoting
403 phytohormones, likely contributes to enhanced vegetative growth. These compounds may
404 stimulate activity in the apical meristem, the plant's growth center, by promoting cell division
405 and elongation(Pandey, 2017). The reduction in No. of sun-burned fruits might be attributed to
406 the enhanced vegetative growth in mango trees caused by potassium application (Baiea, et al.,
407 2015). Additionally, potassium may influence a tree's canopy size, which could in turn help the
408 tree withstand environmental challenges like drought and high radiation. (Hamdy et al., 2022;
409 Alharbi et al., 2022). It could be concluded that Application of potassium sorbate and licorice
410 root extract to Osteen mango trees significantly reduced No. of sun-burned fruits, compared to
411 the control. The most effective treatments were 6g/L licorice root extract and 3mM potassium
412 sorbate.
413 The mango fruit quality results in this study were consistent with those reported by (Baiea, El-
414 Sharony & El-Moneim, 2015) found that spraying Hindi mango trees four times with Potassium
415 were very effective in improving enhanced fruit quality. In addition, fruit total acidity was
416 reduced compared with the control. Likewise, (El-Morsy, et al. 2017) on Red Globe where the
417 highest values of fruit chemical characteristics were obtained with addition of licorice extract
418 foliar spraying treatments 20 and 15 g/l. Similarly, (Obenland et al., 2015) found that potassium
419 sorbate foliar spray at concentration 1.3g/l significantly increased fruit Flame seedless SSC in
420 comparison to control. Potassium treatments may be responsible for the enhanced chemical
421 characteristics of 'Osteen' mango fruits. This is likely because potassium acts as a catalyst for
422 numerous biological processes within the trees, leading to improved overall tree health and
423 nutrient status (Amtmann et al., 2005).
424 Licorice extract application may be responsible for the observed improvements in physical and
425 chemical fruit quality, as well as increased yield. This effect could be attributed to the presence
426 of mevalonic acid in the extract. Mevalonic acid acts as a precursor to gibberellin, a plant
427 hormone that stimulates leaf cell expansion. These results in increased leaf area and chlorophyll
428 content, ultimately leading to improved fruit set and yield (Petoumenou & Patris, 2021). We can
429 conclude that application of (LRE) and (PS) to Osteen mango trees significantly enhanced fruit
430 TSS%, TSS/acid ratio, and Vitamin C content compared to the control. Meanwhile, total acidity
431 percentage in 'Osteen' mango fruits significantly decreased in response to the foliar spray. The
432 most effective treatments were 3mM (PS) and 6g/L (LRE).
433 High temperatures or severe heat waves are among the abiotic stresses that inhibit mango
434 growth, development, and crop quality(Muthuramalingam et al., 2023). A water shortage, often
435 caused by heat and intense light, harms plants' ability to photosynthesize by inducing stomatal
436 closure, mesophyll compactness, and photoinhibition. Mango leaf photosynthesis, transpiration,
437 and water potential can all be impaired when exposed to high temperatures and low air relative
438 humidity (Faria et al., 2016; Khanum et al., 2020).

439 Spraying LRE led to a reduction in sunburn and improved the photosynthesis system because it
440 behaves similarly to gibberellin, which promotes vegetative growth. This extract contains
441 nutritive components including N, Mg, Zn, Cu, and Fe. Since nitrogen aids in the creation of
442 chlorophyll, these minerals play a significant role in the process of chlorophyll synthesis.
443 Furthermore, iron contributes to the crucial steps that lead to chlorophyll production by
444 increasing the number and size of chloroplasts and grana(Venzhik, Shchyogolev & Dykman,
445 2019). Spraying mango leaves with (PS) at different concentrations enhances chlorophyll content
446 and plant pigments because potassium is a major nutrient that directly participates in the vital
447 functions of plants, most notably regulating the photosynthesis process and osmotic regulation of
448 stomatal activity and transpiration. It also plays a crucial role in plant survival under various
449 stresses (Araujo et al., 2015; Tränkner, Tavakol & Jákli, 2018). (Alsalhy & Aljabary, 2020)
450 discovered that grape cv. Halawany leaf chlorophyll content increased when LRE was applied as
451 a spray at a level of 2.5 g/l. (Silem et al., 2023) reported that the application of potassium silicate
452 as a spray to Keitte mango tree leaves at 500 ppm elevated total chlorophyll contents in leaves
453 during the 2021 and 2022 seasons under salinity stress compared to the control group. These
454 findings align with those of .(Younes et al., 2021) and (Abdel-Mola et al., 2022).
455 We can conclude that application of (LRE) and (PS) to Osteen mango trees significantly
456 increased leaf Chl A, Chl B, total chlorophyll content, carotenoids and total pigments under heat
457 stress compared to the control. The most effective treatments were 3mM (PS) and 6g/L (LRE).
458 Elevated temperatures can cause harm to plant cells in various ways, including interfering with
459 protein synthesis and function, enzyme deactivation, and membrane rupture. These processes
460 affect physiological functions such as respiration and photosynthesis. One common issue is an
461 excess of harmful substances, like reactive oxygen species (ROS), leading to oxidative stress
462 (Hasanuzzaman et al., 2013). In response to stressful conditions, plants exhibit an internal
463 defensive mechanism through ROS scavenging, which is demonstrated by the activities of
464 enzymatic antioxidants such as superoxide dismutase (SOD), peroxidase (POX), and catalase
465 (CAT) (You & Chan, 2015; Rossi et al., 2017).
466 Under heat stress (sunburn), PPO, POX, and CAT enzyme activities increased with increasing
467 ROS levels(You & Chan, 2015). Our study's results showed that all treatments decreased the
468 activities of antioxidant enzymes PPO, POX, and CAT (Figure 7A-C). This suggests that Osteen
469 mango trees treated with LRE and PTS are more stable, producing fewer ROS and, therefore,
470 requiring less of these enzymes. In contrast, leaves of untreated mango trees are exposed to heat
471 stress, which increases ROS emission and necessitates the upregulation of antioxidant enzyme
472 activities to maintain cellular balance. Azab et al. (2013) discovered that foliar application of
473 potassium reduced SOD, CAT, and PPO activities in well-watered Squash plants(Azab et al.,
474 2022). However, under drought stress, tomato plants responded more favorably to potassium
475 application in terms of antioxidant enzyme activity than to a well-watered treatment. Rady et
476 al.(Rady et al., 2019) found that licorice root extract (LRE) application increased the activity of
477 antioxidant enzymes (POX, CAT) and decreased hydrogen peroxide (H_2O_2) and superoxide
478 radical ($O_2^{\bullet-}$) levels in common bean plants under salt stress when compared to the control

479   without LRE. (Hamdy et al., 2022) found that leaf Keitt mango content of antioxidants, such as
480   CAT, POX, and PPO enzyme activities, decreased under solar radiation (sunburn) following
481   kaolin application. These findings are consistent with (Cabo et al., 2020). It could be concluded
482   that Enzyme activities of PPO, POX, and CAT all declined with increasing concentrations of
483   LRE and PTS sprayed on mango leaves. The lowest activities of PPO (2.75 U/g F.Wt) and POX
484   (5.39 U/g F.Wt) were observed at the highest concentration of LRE (6 g/L, T3). Meanwhile, the
485   lowest CAT activity (8.35 U/g F.Wt) was recorded at the highest concentration of (PS) (3 mM,
486   T6).
487   According to (Tohidi, et al., 2017), these substances have a wide range of biochemical and
488   molecular functions in plants, including those of signaling molecules, plant defense, regulating
489   auxin transport, antioxidant activity, and free radical scavenging. Phenols and flavonoids, which
490   are non-enzymatic antioxidants, accumulate in different tissues and scavenge free radicals,
491   helping plants tolerate salt stress (Şirin & Aslım, 2019). According to our findings, control (heat
492   stress non-treated) significantly increased the amount of total flavonoids and total phenolic
493   (figure 8A-B). One of the defense strategies employed by plants against oxidative stress is the
494   rise of antioxidants, such as total phenolics and flavonoids, under high temperatures(Wen et al.,
495   2008). From these results, we suggest that the increase in phenolic compounds may be due to the
496   activity of phenylalanine ammonia-lyase under high temperatures(Gebauer, Strain & Reynolds,
497   1997). However, spraying the leaves with LRE and PTS at all concentrations caused all the
498   values of flavonoids and phenolics to decrease, likely due to a reduction in the harmful effects of
499   high temperature on the leaves, which lessened the need for phenylalanine to be directed towards
500   synthesizing these compounds. According to Rady et al.(Rady et al., 2019), common bean plants
501   grown under salt stress can benefit from the application of LRE as a natural biostimulant that can
502   effectively boost their salt tolerance. Our outcomes were in agreement with those attained by
503   (Dinis et al., 2018; Younes et al., 2021). Plant cells exposed to any stress exhibit proline
504   accumulation, which is an indicator of the damage (Per et al., 2017; Dinis et al., 2018). Plant
505   antioxidant systems contain a variety of low-molecular-weight substances, including proline and
506   ascorbic acid (Rady et al., 2019). All treatments with LRE and PTS resulted in reduced proline
507   levels compared to control. This decrease is likely due to LRE and PTS mitigating the negative
508   effects of heat stress on Osteen mango leaves through improved physiological performance.
509   Potassium is essential for physiological processes in plants, which helps them endure stressful
510   environments (Wang et al., 2013). The findings suggested that spraying LRE and PTS reduced
511   the oxidative damage to cell membranes, as seen by the decrease in proline. These results are in
512   agreement with (Cabo et al., 2020), (Dbara, et al., 2022), and (Shehzad et al., 2020), who found
513   that adequate external supply of potassium led to a significant reduction in the activities of
514   antioxidant enzymes and proline in drought-stressed plants. (Younes et al., 2021) found that
515   applying LRE as a biostimulant may be useful to improve bulb quality and, eventually, the
516   productivity of onion cultivars in field conditions.
517   It could be concluded that Flavonoid content significantly decreased following treatments.
518   Levels dropped by 26%, 32.66%, and 63% at increasingly higher concentrations (2, 4, and 6 g/L)

519 of (LRE), respectively. Similarly, (PS) treatments resulted in a decrease of 2.46%, 32.2%, and
520 48.28% at concentrations of 1, 2, and 3 mM, respectively. Total phenolic content also showed a
521 substantial reduction. The greatest decline (69.43%) was observed in leaves treated with 6 g/L
522 LRE (T3), while the highest concentration of PTS (3 mM, T6) caused a 59.57% decrease.
523 Proline accumulation was highest in untreated leaves (control). Conversely, proline levels were
524 significantly lower in leaves treated with 6 g/L LRE (T3), reaching only 0.026 mg/100g fresh
525 weight (FW) compared to the control value of 0.280 mg/100g FW. This suggests that this
526 concentration of LRE may inhibit proline production.
527 These results are consistent with the findings in numerous studies support the use of foliar
528 potassium to enhance plant growth. (Abd El-Rahman, 2021) observed this when added
529 potassium silicate to 'Sedika' mango trees,(Ayed et al., 2022) with 'Keitt' mango trees, and (EL-
530 Gioushy, 2021) with orange trees. All these studies found that foliar application of potassium
531 significantly improved vegetative growth compared to the control group. The leaf area increasing
532 might be due to potassium spray (Rouphael & Colla, 2018). Potassium plays a vital role by
533 activating enzymes for organic substance synthesis, promoting photosynthesis, and transporting
534 carbohydrate assimilates to storage organs (Fallovo et al., 2008). It's also involved in several
535 basic physiological functions. Similarly licorice root extracts improving the vegetative growth of
536 plants (Nasir et al., 2016).
537

Conclusions

539 This study demonstrated that foliar application of (LRE) and (PS) at specific concentrations (3
540 mM potassium sorbate and 6 g/L licorice root extract) significantly improved fruit yield, quality,
541 and antioxidant enzyme activity in Osteen mango trees compared to the control. These
542 treatments increased fruit weight, number of fruits, yield per tree, soluble solids content (TSS),
543 TSS/acid ratio, and vitamin C content, while reducing total acidity and fruit enzyme activities
544 (PPO, POX, and CAT). However, both licorice root extract and potassium sorbate caused a
545 decrease in flavonoid and phenolic content, with the highest concentration (6 g/L LRE and 3 mM
546 PTS) showing the most significant reductions. Additionally, proline accumulation was inhibited
547 by the highest concentration of licorice root extract (6 g/L LRE). These findings suggest that
548 licorice root extract and potassium sorbate can be effective growth promoters for Osteen mango
549 trees, but their influence on certain fruit quality parameters like fruit weight and yield should be
550 considered.
551

553

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562 **Conflicts of Interest**

563 The authors declare no conflicts of interest

564

565 **Author Contributions**

566 Conceptualization, H.F.A. and A.E.H.; methodology, EAE; software, M.O.; validation, H.F.A.
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572

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574 The following information was supplied regarding data availability: The raw measurements are
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576

577 **Supplemental Information**

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Table 1

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

1 Table 1. Chemical analysis of licorice root extract (LRE) according to Rady et al., desoky, et. al.,

2 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.

Weather data of El Salheya El Gedida district, El-Sharqia Governorate, Egypt (means 2022 and 2023)

2 Table 2: Weather data of El Salheya El Gedida district, El-Sharqia Governorate, Egypt

3 (means 2022 and 2023)

Months	T2M	TMIN	TMAX	RH2M	RAIN	SRAD
January	12.11	6.68	19.42	51.78	2.20	13.08
February	13.64	7.56	21.63	57.93	5.60	15.29
March	15.81	9.19	23.99	57.68	11.00	19.55
April	19.69	12.34	28.40	51.01	2.40	23.47
May	26.35	17.31	36.70	39.58	0.10	27.32
June	29.57	21.53	38.58	44.71	0.00	27.62
July	30.65	22.43	39.82	44.28	0.00	28.26
August	30.71	22.88	39.60	45.50	0.00	26.21
September	27.69	20.80	36.26	53.63	0.00	22.95
October	24.72	18.75	32.49	61.41	19.40	17.80
November	20.72	15.16	28.72	58.28	0.00	14.73
December	14.91	10.08	21.60	63.37	12.80	12.05
Average and Sum	22.21	15.39	30.60	52.43	53.50	20.70

Interpretation

T2M	Temperature Average at 2 Meters (°C)
TMIN	Temperature at 2 Meters Minimum (°C)
TMAX	Temperature at 2 Meters Maximum (°C)
RH2M	Relative Humidity Average at 2 Meters (%)
RAIN	Precipitation (mm)
SRAD	Solar Radiation (MJ/m^2/day)

Foliar sprays on mango trees

1   Table 3. Foliar sprays on mango trees:

Treatments	Foliar spray material	Concentrations
Control	Water spray	0.0
LRE2	Licorice root extract	2g/l
LRE4	Licorice root extract	4g/l
LRE6	Licorice root extract	6g/l
PS1	potassium sorbate	1mM
PS2	potassium sorbate	2mM
PS3	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, LRE2, LRE4, LRE6,: 2, 4 and 6g/l Licorice root extract, PS1, PS2 and PS3.: 1, 2 and 3mM potas
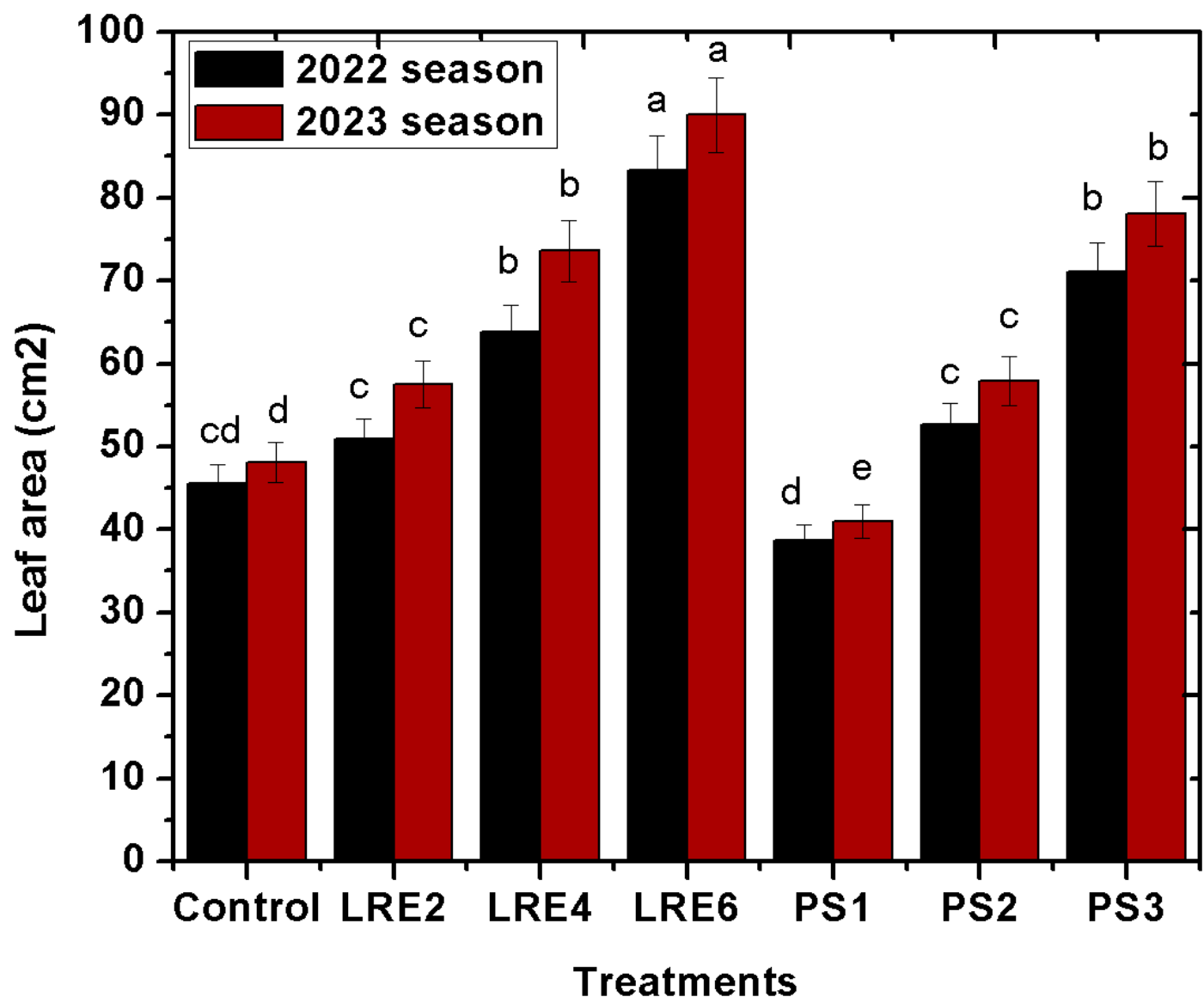
Figure 2

Figure 2. Effect of licorice-root extract and Potassium sorbate spray on fruit weight and No. of fruit/tree of the 'Osteen' mango cultivar in 2022 and 2023 seasons. Control: water spray, LRE2, LRE4, LRE6,: 2, 4 and 6g/l Licorice root extract, PS1, PS2 and
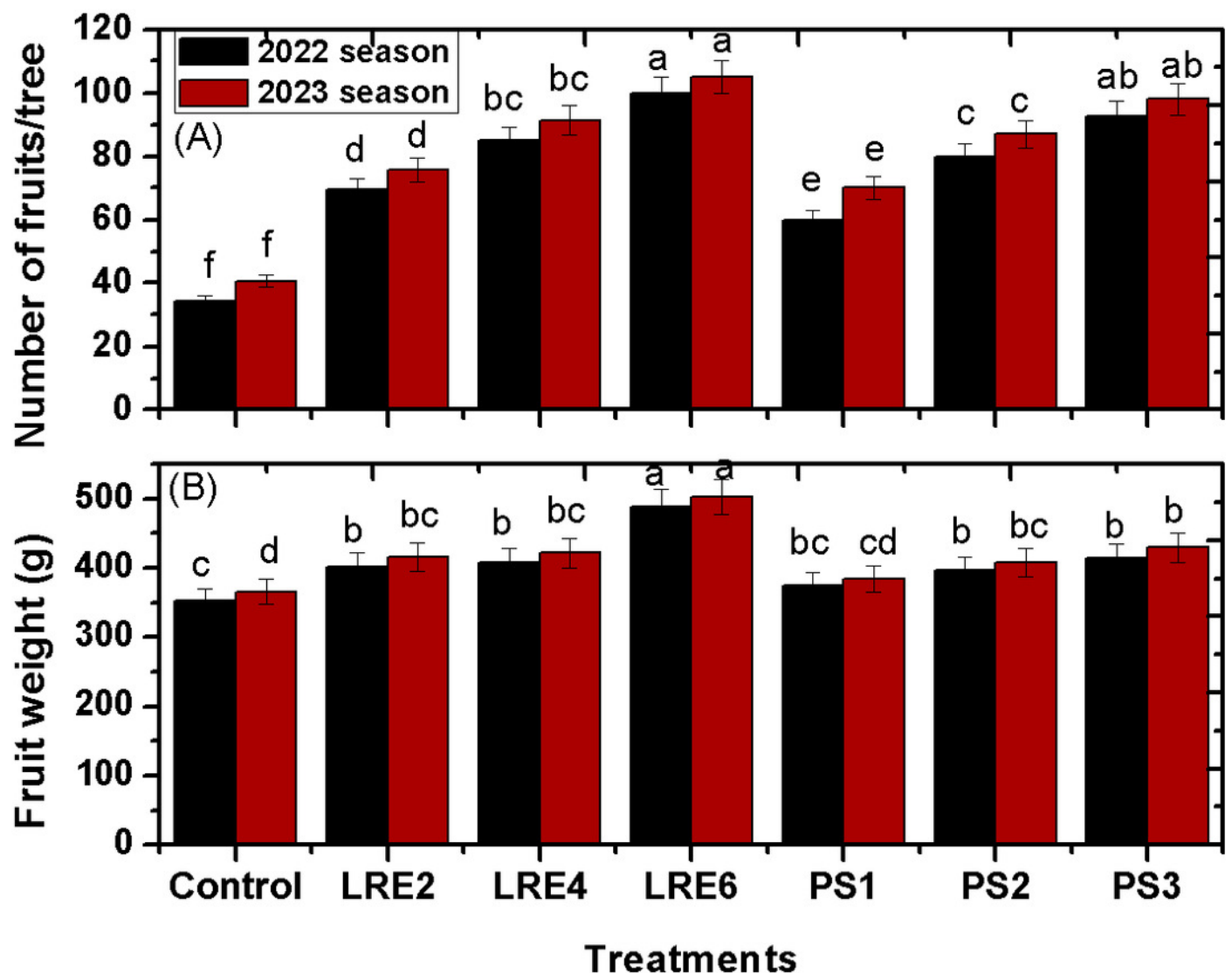
Figure 3

Figure 3. Effect of licorice-root extract and Potassium sorbate 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, LRE2, LR
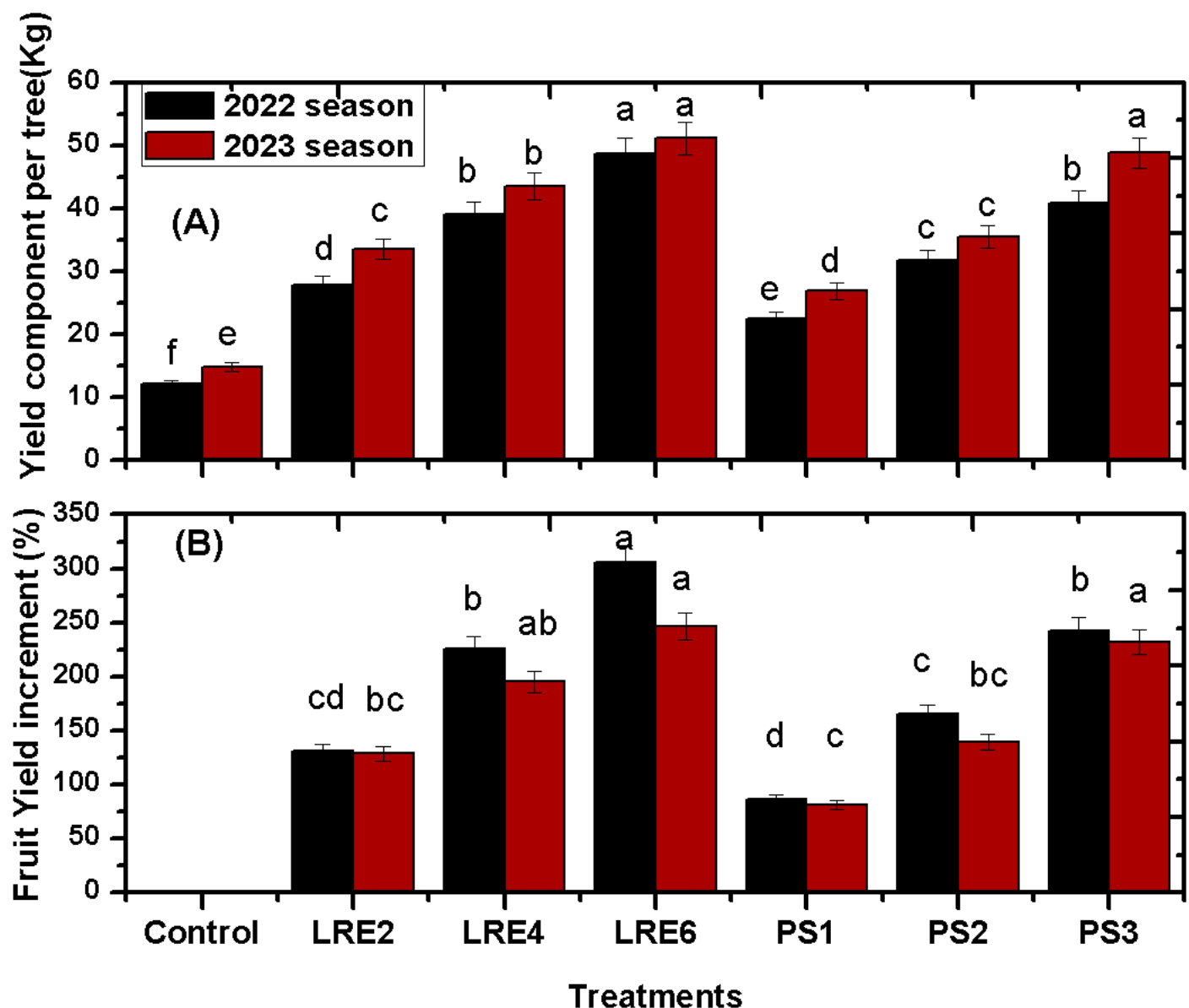
Figure 4

Figure 4. Effect of licorice-root extract and Potassium sorbate spray on No. of sun-burned fruits of the 'Osteen' mango cultivar in 2022 and 2023 seasons. Control: water spray, LRE2, LRE4, LRE6,: 2, 4 and 6g/l Licorice root extract, PS1, PS2 and PS3.: 1,
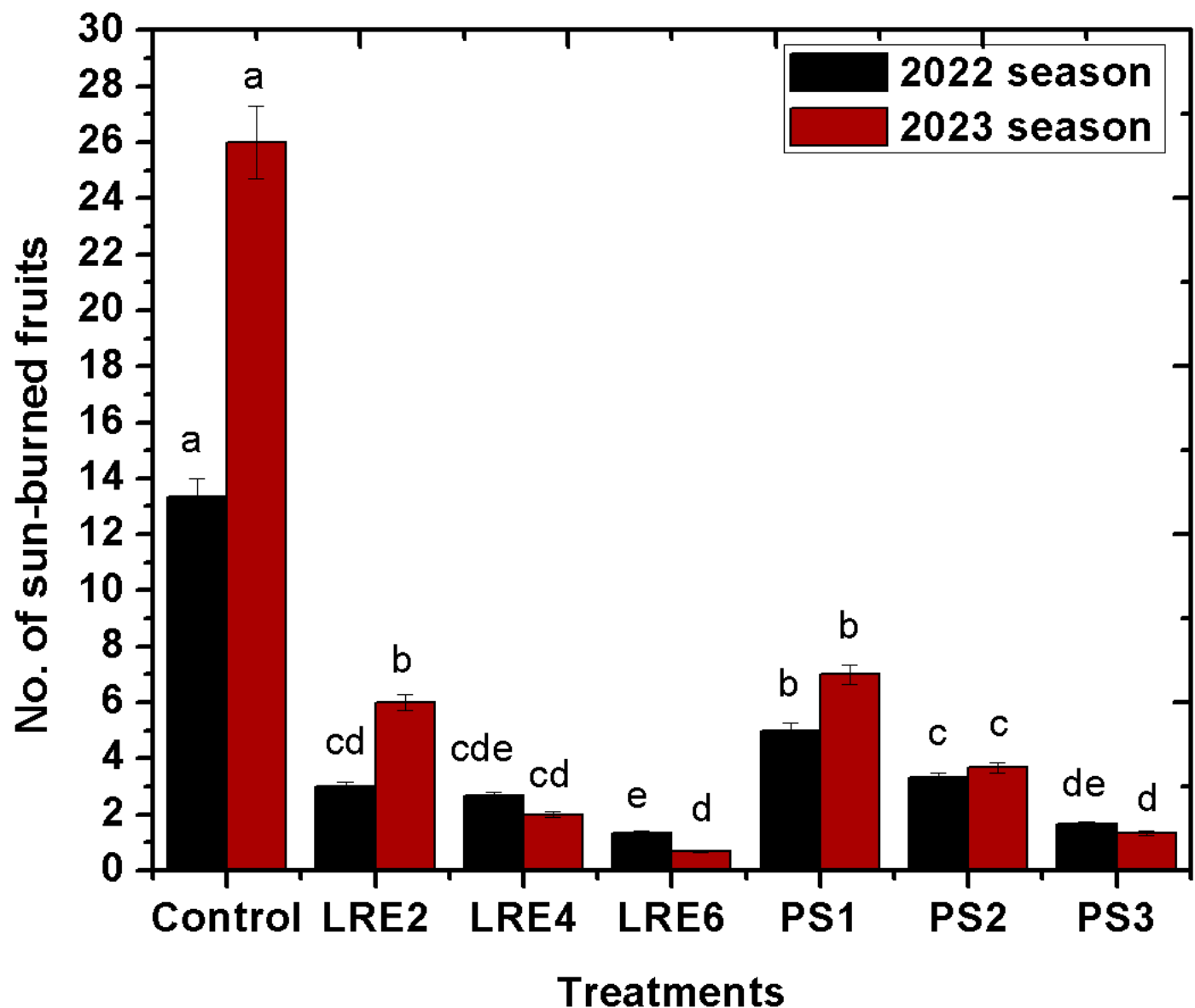
Figure 5

Figure 5. Effect of licorice-root extract and Potassium sorbate spray on some of fruit chemical characteristics of the 'Osteen' mango cultivar in 2022 and 2023 seasons. A): TSS Brix°, B): Total acidity%, C):TSS/acid ratio and Vitamine C. Control: water sp
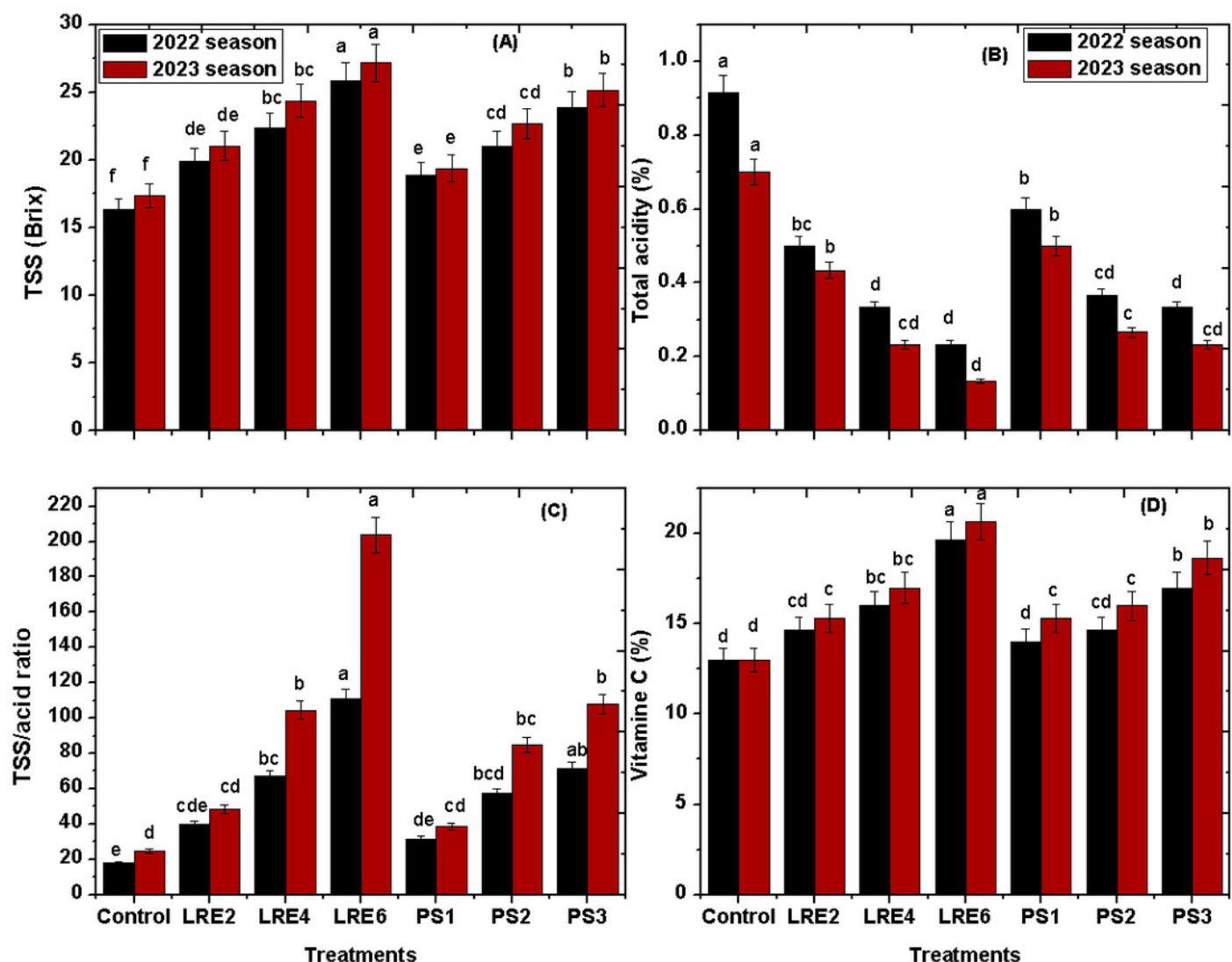
Figure 6

Figure 6. Effect of licorice-root extract and Potassium sorbate on the photosynthetic Pigments Leaf of the 'Osteen' mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, LRE2, LRE4, LRE6,: 2, 4 and 6g/l Licorice root extract, PS1, PS
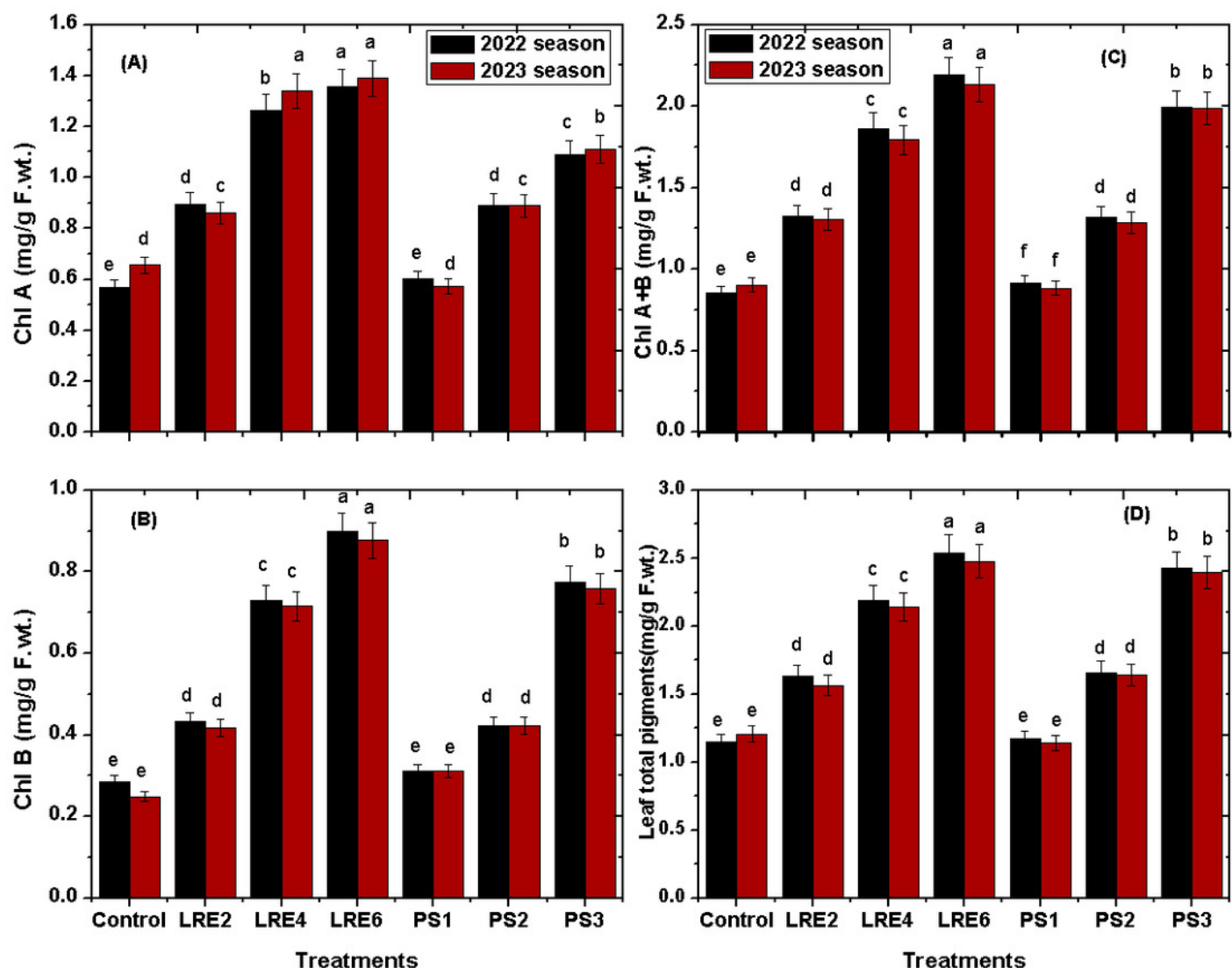
Figure 7

Figure 7. Effect of licorice-root extract and Potassium sorbate on carotenoids, catalase activity, peroxidase activity and polyphenol oxidase activity of leaves osteen mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, LRE2, LRE4,
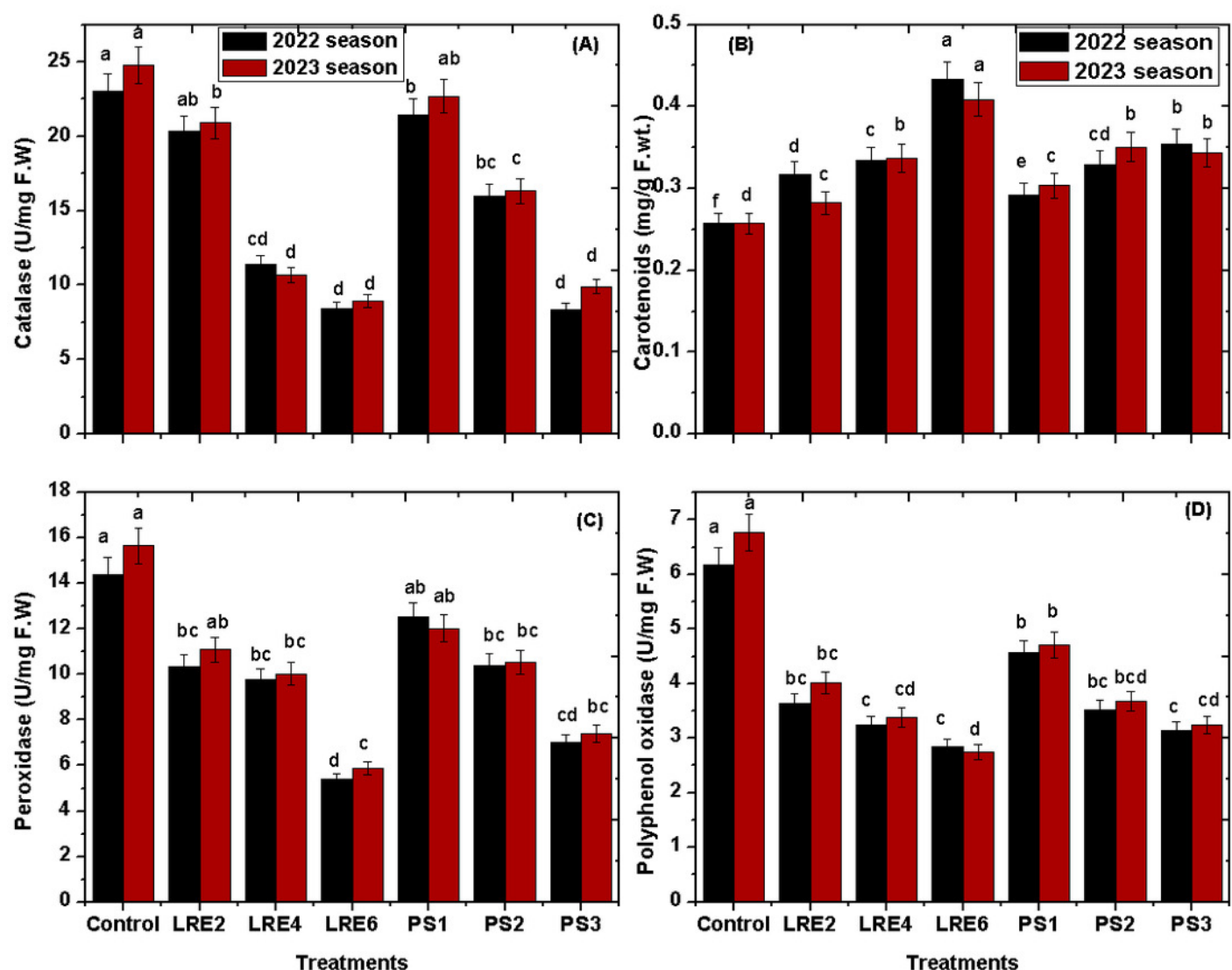
Figure 8

Figure 8. Effect of licorice-root extract and Potassium sorbate on Total flavonoids, total phenolic and proline of leaves osteen mango cv. under heat stress in 2022 and 2023 seasons. Control: water spray, LRE2, LRE4, LRE6,: 2, 4 and 6g/l Licorice root ext