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Growing possibilities of pitaya (*Hylocereus spp*.) under protected cultivation in subtropical conditions

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ABSTRACT

Global climate change has recently increased interest in some tropical fruit species in the Mediterranean and Aegean regions of Türkiye. Among these tropical species, pitaya (dragon fruit) has gained popularity due to its tolerance to drought, ability to bear fruit one year after planting, suitability for soilless cultivation, and significant export potential. The objective of thise study is to investigate pitaya cultivation under protected cultivation in subtropical conditions. The research was conducted between 2020 and 2022 in the Manavgat district of Antalya on White Jaina and Red Jaina pitaya cultivars. The morphological parameters of the plants were evaluated as well as their physical properties and yield characteristics. The findings have revealed that the duration from flowering to harvest ranged between 44 and 45 days on average for both cultivars. The average fruit weight was measured as 264.60 g and 344.00 g for White Jaina and Red Jaina, respectively, and the difference was found to be statistically significant (P<0.05). Depending on the cultivar, the fruit circumference was measured as 20.58 cm and 21.99 cm, the fruit length as 13.07 cm and 12.22 cm, and the soluble solids content as 10.98% and 12.35%, respectively. By the end of the second year of the study, the yield per hectare was calculated as 1.74 tons ha^{-1} for White Jaina and 1.65 tons ha^{-1} for Red Jaina. The findings have indicated that both pitaya cultivars could be cultivated under protected cultivation conditions in Manavgat, which has a colder winter climate than the Alanya and Gazipaşa districts of Antalya.

1. Introduction

Pitaya, commonly covering several cactus genera (*Cereus spp*., *Opuntia spp*., and *Hylocereus spp*.), is primarily cultivated for the fruits of the Hylocereus spp. genus for commercial purposes. Among these, the most widely grown species are *H. polyrhizus*, *H. megalanthus*, and *H. undatus* (Luders and McMahon 2006). While the origin of pitaya is considered to be tropical forest regions, its commercial cultivation has been reported in Mexico, South America, Thailand, and Vietnam (Borchetia et al. 2022). Although data regarding pitaya production are not provided in FAQ statistics, producer countries provide this information through their official sources. Globally, the highest production is achieved in Vietnam, with 30000 hectares of cultivation area and 640000 tons of production. Vietnam also holds a prominent position as both the leading producer and exporter at the global level (Fernandes et al. 2017; Gezici 2019).

Pitaya is widely used in the food, cosmetics, and pharmaceutical industries for its nutritional content and health benefits. This fruit is a rich source of betalains, polyphenolic compounds, carotenoids, and antioxidants (Kiranmai 2022). It also contains high total phenols, flavonoids, and vitamin C (Fernandes et al. 2017). Among pitaya cultivars, those with red flesh are particularly rich in antioxidants such as beta-carotene, lycopene, vitamin E, phosphorus, and calcium, which contribute to healthy bone, teeth, and skin development. Additionally, its black seeds are an important source of essential fatty acids (Gonzaga 2017; Borchetia et al. 2022). Pitaya has been reported to help digestion, exhibit anti-diabetic properties, reduce blood pressure, neutralize toxins, especially heavy metals and the treatment of asthma and coughs. Furthermore, it is known to help prevent various types of cancer, particularly colon cancer (Prisa 2022).

Pitaya could adapt to subtropical regions. While pitaya plants are typically cultivated in open fields under tropical climates, it has also been grown under nets or greenhouses in certain microclimates in subtropical regions. For instance, in subtropical areas such as Israel and California, pitaya have been grown under nets to protect the plants from the harmful effects of sunlight (Mizrahi et al. 2002). Pitaya is sensitive to day temperature changes during the period from fruit set to harvest. In greenhouses, temperatures during November can range from a minimum of -2°C to a maximum of +15°C; however, higher temperatures with limited fluctuations are essential for the flowering and fruit set of the pitaya (Prisa 2022).

Studies on pitaya cultivation have been conducted across various geographical regions and environmental conditions. Some of these studies are summarized below:

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In *Hylocereus undatus*, it was reported that approximately 21 days are required from bud formation to flowering, and about 35 days from pollination to fruit harvest (Costa et al. 2014). Menezes et al. (2015) found that the duration from flowering to harvest for *H. undatus* took 41 days. It was also found that the average fruit weight was 442.47 g, fruit length was 93.73 mm, fruit diameter was 83.41 mm, pulp firmness was 6.16 N, and the total soluble solids content was 19.58%. Budhathoki et al. (2023) reported that, in *Hylocereus polyrhizu*, pitayas were randomly collected from various regions in Nepal, and fruit weight was found to have ranged from 20.12 to 300 g, fruit length ranged from 0.48 to 9.84 cm, fruit diameter ranged from 0.35 to 8.42 cm, and soluble solids content ranged from 11.7% to 14.70%. Gübbük et al. (2017) observed that flowering in the 'Bloody Mary' and 'Cosmic Charlie' cultivars began in May-June and continued until September, requiring 35-40 days from flowering to fruit harvest. For the 'Bloody Mary' cultivar, fruit yield per plant was 8-10 fruits in the first year and over 15 fruits in the second year. In contrast, the 'Cosmic Charlie' cultivar yielded 4-5 fruits per plant in the first year and 8-10 fruits in the second year. Fruit weight was recorded as 400-600 g for 'Bloody Mary' and 600-700 g for 'Cosmic Charlie.' Zimmerman et al. (2017) examined a total of 25 pitaya cultivars in the U.S. Virgin Islands. It was found that cultivars such as 'Dark Star,' 'Delight,' 'Makisupa,' 'Halley's Comet,' 'Physical Graffiti,' and 'Purple Haze' had a high production potential. In the Philippines, pitaya harvest begins in May, approximately 30-35 days after flowering, with peak yields occurring between July and October and continuing until November (Rodeo et al. 2018). In *Hylocereus undatus* (white) and *Hylocereus polyrhizus* (red) species, the maximum fruit length was reported as 9.51 cm, fruit diameter as 7.19 cm, and fruit weight as 265.86 g (Parmar and Karetha 2020). For the yellow pitaya species (*Selenicereus megalanthus*), flowering begins in spring and continues until autumn, while fruit harvest starts in summer and ends in winter. The period from flower formation to fruit harvest ranges from 147 to 166 days, while the period from pollination to fruit harvest is between 96 and 110 days (Rabelo et al. 2020). In red pitaya (*Hylocereus polyrhizus*), the harvest season extends from April to September, with an annual yield of 20.1 tons per hectare (Then et al. 2020). In *H. undatus* (white) and *Hylocereus* (red-fleshed) species, 8% of flower buds form in July, 77% by late August, and the remaining 15% in September. The fruits of *Hylocereus* species reach harvest maturity approximately 40-45 days after pollination, with the fruit ripening period extending from September to early December. The average fruit weight was recorded as 273 g for *H. undatus* and 315 g for *Hylocereus* (Trivellini et al. 2020).

In Türkiye, tropical fruit cultivation has not yet reached the desired level when considering the production area and volume. However, Gübbük et al. (2017) reported that some tropical fruit species gave positive results in open fields and greenhouse conditions in specific microclimate locations such as Gazipaşa and Alanya. However, the climate in the Manavgat location is colder compared to Alanya and Gazipaşa. The aim of the study was to determine whether pitaya can be grown in greenhouses in cool subtropical climates.

2. Materials and Methods

2.1. Plant material and cultivation conditions

The study was conducted at the Ilıca campus of Akdeniz University's Manavgat Vocational School (Manavgat, Antalya, Türkiye; 36°48'31.08" N and 31°23'16.47" E, at an altitude of 24 m above sea level) between November 2020 and December 2022. The greenhouse structure is made of iron, top height and height from the gutter were 4.20 m and 3.00 m, respectively. The greenhouse was covered with plastic and ventilated from the sides and top. The White Jaina and Red Jaina cultivars were used as the plant material. In the trellising system, galvanized steel poles measuring 150 cm in length were installed, and circular rings with a diameter of 70 cm were mounted on top of the poles. Fifty centimeters of each pole were embedded into the soil for stabilization. The plants were planted on November 6, 2020, with a spacing of 1.8 m between plants and 3.0 m between rows, with four plants arranged around each trellising system (Figure 1).

A double-line drip irrigation system was installed for each row. To protect the plants from high-temperature stress during the summer months, 40% shading net was used in the greenhouse (Figure 1). Cultural practices were performed following the methodology outlined by Gübbük et al. (2017).

Temperature and humidity were recorded hourly using a mini meteorological station during the growing period. During the vegetation period, the minimum temperature ranged between 10.57°C and 24.63°C, the average temperature ranged between 14.02°C and 28.71°C, and the maximum temperature ranged between 20.21°C and 34.06°C. Relative humidity values varied from a minimum of 40.72% to 51.79%, an average of 56.84% to 71.18%, and a maximum of 71.24% to 85.14% respectively.

Pollination was performed manually three days per week between 22:00 and 24:00. The details regarding the shading net application and pollination process are given in Figure1.



Figure 1. From left to right: Images showing the trellising system, shading net application, and pollination process.

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2.2. Observation of morphological characteristics in plants

After planting, all lateral shoots were removed until the plants reached 100 cm in height. When the plant reached 100 cm, the top part was cut to encourage lateral shoot formation (Figure 2). The number of days that plants took to reach 100 cm height, and the first flowering and the number of days that took from flowering to harvest were determined for each species.

2.3. Investigation criteria of fruit physical characteristics

Fruit weight was measured by using a precision balance in grams. The circumference and length of the fruits were measured in centimeters using a measuring tape.

2.4. Fruit quality characteristics

2.4.1. Flesh firmness

Flesh firmness was determined using a Loyka GY-3 handheld penetrometer with an 8 mm diameter tip. Measurements were taken from three different points on the surface of each fruit and expressed in N.

2.4.2. Soluble solid content

The soluble solid content of the fruits was measured as a percentage (%) using a digital refractometer. The measurements were conducted on juice extracted from the fruits using a fruit juicer.

2.4.3. Fruit peel color (L, a, b*)*

The peel color of the fruits was determined by measuring the L, a*, and b* values at three equidistant points around the circumference of each fruit. L indicates lightness (white/black), a* represents the red/green axis, and b* represents the yellow/blue axis. A 3NH-NR60CP colorimeter was used for these measurements.

2.5. Yield

Yield was calculated in tons per hectare (ton ha^{-1}) by multiplying the average fruit weight, the average number of fruits per plant, and the number of plants per hectare (approximately 1850 plants per hectare).

2.6. Data evaluation and statistical analyses

The experiment was laid out in a completely randomized design and 36 plants were used for each cultivar. A t-test was employed to determine differences between the cultivars, and the data were analyzed using the Minitab 17 statistical software package.

3. Results and Discussion

3.1. Plant's morphological characteristics

The results regarding the plant's morphological characteristics of the pitaya cultivars are given in Table 1. The days from planting to reach 100 cm, days from planting to first flowering, and days from flowering to harvest were not found to be statistically significant between the cultivars (P>0.05). Days from planting to reaching 100 cm in height was found to be 163.9 days on average for the White Jaina cultivar and 182.1 days for the Red Jaina cultivar respectively. The first flowering after planting occurred on June 19, 2022 for the White Jaina cultivar, and May 25, 2022 for the Red Jaina cultivar. However, flowering predominantly occurred in July and August for both cultivars. The days from planting to the first flowering was recorded as 619.40 days for White Jaina and 621.20 days for Red Jaina respectively. The duration from flowering to harvest was 44.18 days for White Jaina and 45.10 days for Red Jaina.



Figure 2. Removal of lateral shoots and apical pruning in pitaya plants.

Table 1. The results of plant morphological traits in pitaya cultivars

Trait	White Jaina (Mean)	Red Jaina (Mean)	P Value
Time to reach 100 cm height (days)	163.9	182.1	>0.05
Time to first flowering (days)	243.5	258.3	>0.05
Time from flowering to harvest (days)	40.2	41.1	>0.05

No statistically significant differences were found between the cultivars for the examined morphological traits (P>0.05).

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Based on our findings, it could be claimed that flowering in both pitaya cultivars began at the end of May, with a peak in flowering occurring in July and August and continued until September. The results were found to be similar with some of the previous studies. Gübbük et al. (2017) reported that flowering in pitaya began in May-June and continued until September. Trivellini et al. (2020) carried out another study on pitaya under protected cultivation in Pisa, Italy. The researchers reported that 8% of the total flower buds were formed in July, 77% in late August, and the remaining 15% in September. Rodeo et al. 2018 found that the fruit harvest started in May, reached its peak between July and October, and continued until November in the Philippines.

In this study, the number of days from flowering to harvest were found to be around 44-45 days for both cultivars. The number of days from flowering to harvest was reported as 35-40 days in Türkiye (Gübbük et al. 2017), 30-35 days in the Philippines (Rodeo et al. 2018), 40-45 days in Italy (Trivellini et al. 2020), and 35, 41, and 96-110 days in three different studies conducted in Brazil (Costa et al. 2014; Menezes et al. 2015; Rabelo et al. 2020).

3.2. Fruit physical characteristics

3.2.1. Fruit weight

The average fruit weight was found to be statistically significant (P<0.05) for both cultivars (Figure 3). The fruit weight was recorded as 264.60 g for the White Jaina cultivar and 344.00 g for the Red Jaina cultivar respectively. Parmar and Karetha (2020) reported that the fruit weight was 265.86 g for S1 (*Hylocereus undatus*) and 260.27 g for S2 (*Hylocereus polyrhizus*). Trivellini et al. (2020) reported as 273 g for Clone 1 (*H. Undatus*) (white-fleshed cultivar) and 315 g for Clone 2 (*H. undatus* × *H. polyrhizus*) (red-purple-fleshed cultivar). Our results were found to be similar to previous studies. Menezes et al. (2015) and Magalhães et al. (2019) reported higher fruit weight values than that of our study as 442.47 g (*Hylocereus undatus*), and 436.84 g (*Hylocereus polyrhizus*) respectively. This difference is believed to have resulted from ecological and varietal differences.

3.2.2. Fruit circumference and length

Average fruit circumference and fruit length differences were found to be statistically insignificant for both cultivars (P>0.05) (Figure 4). The fruit circumference was determined to be 20.58 cm for the White Jaina cultivar and 21.99 cm for the Red Jaina cultivar respectively. On the other hand, the fruit length was 13.07 cm for the White Jaina and 12.22 cm for Red Jaina. As reported in previous studies, the fruit width was 7.19 cm for *Hylocereus undatus* (Parmar and Karetha 2020), 8.34 cm for *Hylocereus undatus* (Menezes et al. 2015), and 10.66 cm for *Hylocereus polyrhizus* (Magalhães et al. 2019). Fruit length was recorded as 9.51 cm for *Hylocereus undatus* by Parmar and Karetha (2020) 9.87 cm for *Hylocereus undatus* by Menezes et al. (2015), and 8.45 cm for *Hylocereus polyrhizus* by Magalhães et al. (2019). The values for fruit circumference and length were consistent with some studies, while some of them were found to be different from our study. The variations observed in fruit weight might be attributed to differences in ecological conditions and the cultivars used.

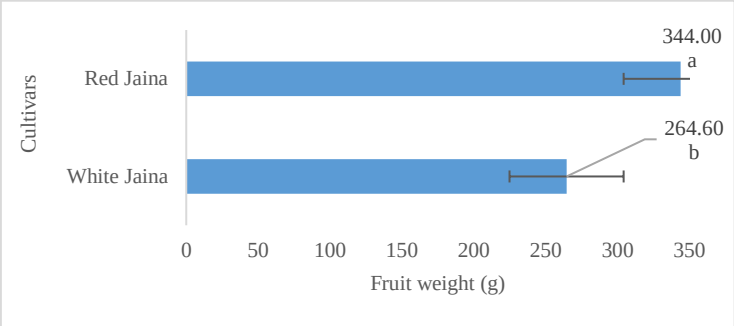


Figure 3. Fruit weight (g) values were determined for White Jaina and Red Jaina cultivars.

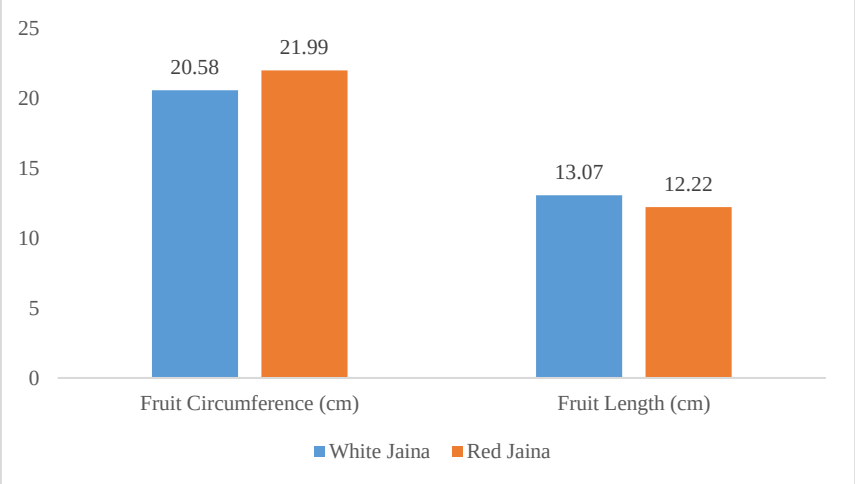


Figure 4. Fruit circumference and fruit length values were determined for White Jaina and Red Jaina cultivars.

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3.3. Fruit quality characteristics

3.3.1. Fruit flesh firmness

The differences in fruit flesh firmness between pitaya cultivars were found to be statistically insignificant ($P>0.05$) (Figure 5). The fruit flesh firmness was determined to be 1.11 N for the White Jaina cultivars and 1.13 N for the Red Jaina cultivars. Menezes et al. (2015) reported a pulp firmness of 6.16 N for Hylocereus undatus and noted that firmness significantly decreases during ripening due to water loss. Centurión et al. (2008) observed a firmness of 6.3 N in fruits harvested 31 days after flowering. In Hawaii, Wall and Khan (2008) harvested mature fruits 45 to 50 days after flowering and reported a firmness of 5.7 N. Enciso et al. (2011) also noted that firmness is a relatively underexplored variable in postharvest studies of pitaya.

3.3.2. Soluble solids content

The difference in soluble solids content between pitaya cultivars was found to be statistically significant ($P<0.05$) (Figure 6). The soluble solids content was determined as 10.98% for the White Jaina cultivar and 12.35% for the Red Jaina cultivar respectively.

The soluble solids content in pitaya has been reported with varying values across different studies and cultivars. Menezes et al. (2015) reported an soluble solids content of 19.58% in *Hylocereus undatus*, while Ortiz and Takahashi (2015) recorded a value of 12.2% for *Hylocereus undatus*. Magalhães et al. (2019) reported a maximum soluble solids content of 15.44% in white-fleshed cultivars of *H. undatus*. Brar et al. (2023) observed soluble solids content values ranging from 8.63% to 9.31% in three dragon fruit species grown under subtropical conditions in northwestern India—one white-fleshed (*H. undatus*, DG-I) and two red-fleshed (*H. polyrhizus*, DG-II; *H. costaricensis*, DG-III). Özyici et al. (2024) reported the highest soluble solids content as 13.70% for the white-fleshed Costa Rica White cultivar, and the lowest as 8.50% for the red-fleshed Philippines Purple cultivar. Our findings are in agreement with those reported by Özyici et al. (2024).

3.3.3. Fruit skin color (L, a*, b*)

The differences in the fruit skin color parameters (L, a*, b*) between pitaya cultivars were found to be statistically insignificant ($P>0.05$) (Figure 7). The L value for the fruit skin color of pitaya cultivars was found to have ranged between 32.30 and 35.30, the a* value between 19.90 and 21.96, and the b* value between 7.46 and 8.15. The L and a* values obtained in this study were lower than those reported by Menezes et al. (2015), who reported an L value of 51.23 and an a* value of 35.50 for the species *Hylocereus undatus*. Similarly, Özyici et al. (2024) reported L values ranging from 22.65 to 57.44, a* values from 0.51 to 40.72, and b* values from-5.55 to 11.84 across two white and six red pitaya cultivars.

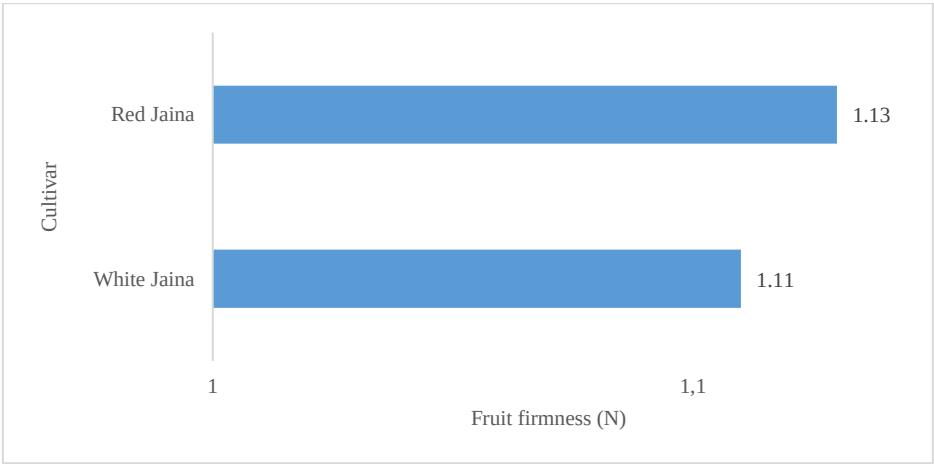


Figure 5. Fruit flesh firmness (N) values were determined for White Jaina and Red Jaina cultivars.

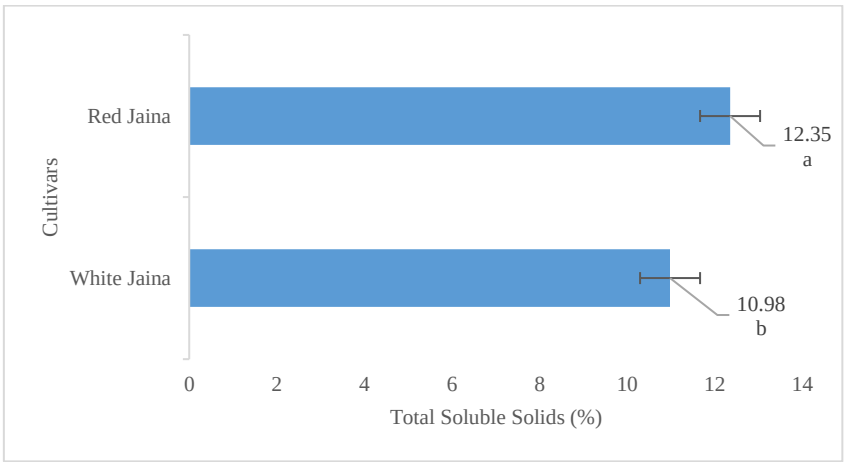


Figure 6. Soluble solids content (%) determined for White Jaina and Red Jaina cultivars.

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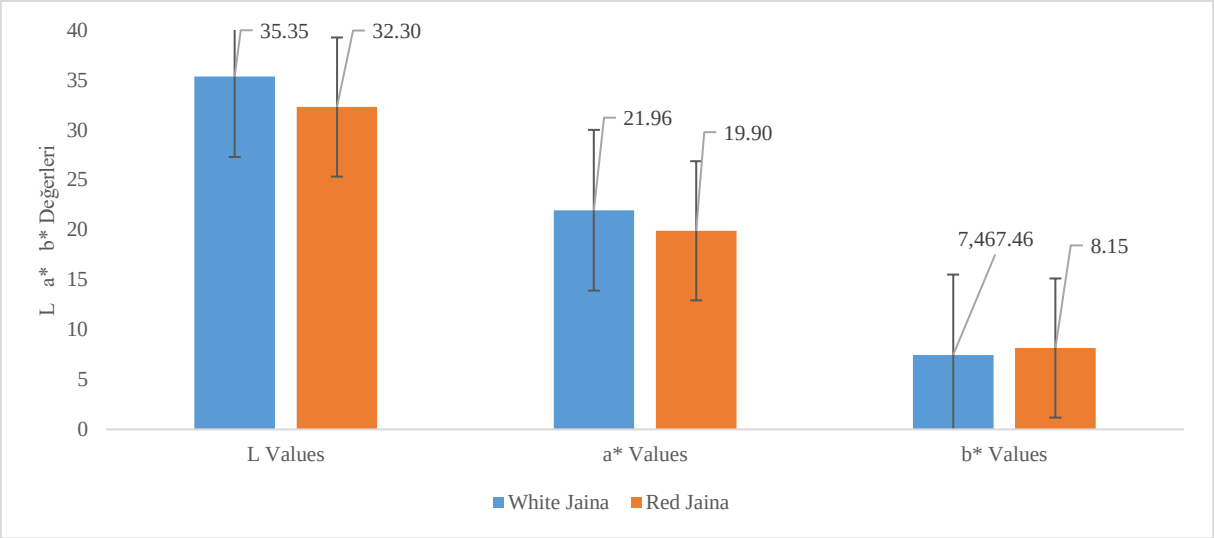


Figure 7. L, a*, b* values determined for the White Jaina and Red Jaina cultivars.

3.4. Yield

The differences observed in yield per hectare among pitaya varieties were found to be statistically insignificant ($P>0.05$). The yield per hectare of the White Jaina variety was determined to be 1.74 t ha^{-1}, while that of the Red Jaina variety was 1.65 t ha^{-1}. A study conducted in Brazil showed that the yield values obtained in the first year were consistent with the current study; however, it was observed that the yield increased substantially over the years (Alves et al. 2021). Nevertheless, the results obtained in this study were lower than those of many other studies, as they reflect data from the initial years (Sibut et al. 2023).

4. Conclusion

In conclusion, both cultivars are recommended for cool subtropical areas when the yield and some investigation criteria are considered. Furthermore, when we consider the water shortage problem in the Mediterranean climate, pitaya can be seen as an alternative crop in this region.

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