EFFECT OF LIGHTING SYSTEM ON THE GROWTH RATE OF TWO CULTIVARS OF DRAGON FRUIT (*HYLOCEREUS UNDATUS* AND *HYLOCEREUS COSTARICENSIS*) IN ASIR REGION SAUDI ARABIA

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Abstract. The cultivation of dragon fruit (Hylocereus spp.) in the Asir region has gained momentum, prompting a shift towards sustainable agricultural techniques. This research delves into the intricate relationship between lighting systems and plant growth parameters, specifically, shoot length and the number of branches, spanning from September 2022 to April 2023. Through rigorous analysis of variance, significant treatment effects were discerned across different months. During the initial phase (September to December 2022), variations in lighting systems markedly influenced the number of branches. Notably, October emerged as a pivotal month, eliciting a substantial increase in branch development. However, the effects witnessed in November and December were relatively subdued, possibly attributed to nuanced environmental factors. The subsequent period (January to April 2023) focused on shoot length. January and February exhibited conspicuous impacts, shaping shoot growth significantly. March maintained a consistent influence, while April witnessed a decline in the observed effects. This study underscores the paramount importance of comprehending both seasonal fluctuations and lighting conditions in the quest to optimize plant growth. The findings offer pivotal insights into agricultural practices and indoor cultivation methodologies, serving as a cornerstone for future research endeavors in this domain.
Keywords: *dragon fruit plants, light effect, cultivation, growth rate, number of branches*

Introduction

Dragon fruit, also known as pitaya, is a tropical fruit belonging to the Hylocereus genus and is renowned for its exotic appearance, nutritional value, and economic importance (Attar et al., 2022). In recent years, the cultivation of dragon fruit has been on the rise, both for local consumption and export markets in various regions, including the Abha region (Morgouno et al., 2022). The cultivation of dragon fruit has gained considerable attention globally due to its adaptability to various climates and soil types (Jia et al., 2022).

In recent years, controlled environment agriculture (CEA) techniques, such as artificial lighting systems, have been pivotal in enhancing plant growth, yield, and fruit quality in various crops (Modarelli et al., 2022). However, the impact of different lighting systems on the growth of dragon fruit cultivars, particularly on *Hylocereus undatus* and *Hylocereus costaricensis*, in the unique climatic conditions of Abha region, Saudi Arabia, remains a topic of significant interest and investigation (Nangare et al., 2020). The Abha region, characterized by its specific environmental conditions,

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including temperature fluctuations and limited sunlight hours, poses challenges to traditional agricultural practices (Khan et al., 2022). As a result, there is a growing need to explore innovative methods to optimize the growth and yield of dragon fruit cultivars in this region (le Bellec et al., 2006).

Artificial lighting systems, such as light-emitting diodes (LEDs) and high-intensity discharge (HID) lamps, have demonstrated their efficacy in supplementing natural sunlight and promoting plant growth, especially in areas with limited sunlight exposure (Dutta Gupta and Agarwal, 2017). However, the successful cultivation of dragon fruit, especially in regions with challenging environmental conditions, requires innovative agricultural practices (Krauser et al., 2022). The Abha region in Saudi Arabia presents a distinctive set of environmental challenges for agriculture (Al-Raddady, 1977). With temperature fluctuations, limited sunlight hours, and specific climatic nuances, traditional farming methods often face limitations (Alexander, 2016).

CEA techniques, particularly the utilization of artificial lighting systems, have emerged as a promising solution to overcome these challenges (Neo et al., 2022). Artificial lighting, (LEDs) and (HID) lamps, offers the potential to supplement natural sunlight, providing plants with the required light spectrum for photosynthesis and growth (Dutta Gupta and Agarwal 2017). This study aims to bridge this knowledge gap by investigating the effect of lighting systems on the growth rate, plant development, and productivity of two dragon fruit cultivars (*Hylocereus undatus* and *Hylocereus costaricensis*) in the unique agricultural setting of the Abha region. By comprehensively assessing growth parameters, photosynthetic efficiency, flowering patterns, fruit development, nutrient uptake, and economic viability, this research endeavors to provide valuable insights into optimizing dragon fruit cultivation methods tailored to the specific conditions of the Abha region.

Material and methods

Study area

The study was conducted for *Hylocereus undatus* and *Hylocereus costaricensis*, petaya fruit, in the Asir region, located in the southwestern part of the Kingdom of Saudi Arabia, according to *Figure 1*. It is located between latitudes 17.25 and 19.50 north, and longitudes 50.00 and 41.50 east and has an area of 76,693 km^2 (Mohamed et al., 2019). It rises about 2000 m above sea level, and Asir climate is characterized by a unique character on a global level, which is illustrated in *Figure 2,* where the temperature in the middle of summer does not exceed 24°C in mountain parks, and the average temperature in the region is 10°C lower than other regions in the Kingdom, exceeding the global average of thermal comfort in the best tourist. The topography of Asir and its vegetation contributed to an increase in the rate of rain, as the region is characterized by precipitation during most seasons of the year, reaching 500 mm annually, increasing during the spring and summer seasons (Youssef and Pourghasemi, 2021). *Table 1* shows the name and GPS location of the two sites used as farms for planting the samples under examination.

Study sample

The plant used in this study is the red and white petaya plant, which bears the scientific name, *Hylocereus costaricensis* and *Hylocereus undatus.* Two farms were chosen to conduct this study, and experiments using light in each farm.

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This study investigates the impact of different lighting systems on the growth of two dragon fruit cultivars, *Hylocereus undatus* and *Hylocereus costaricensis*, in the Abha region. Three lighting systems, natural sunlight, high-pressure sodium (HPS) lamps, and light-emitting diode (LED) grow lights, were employed over six months.

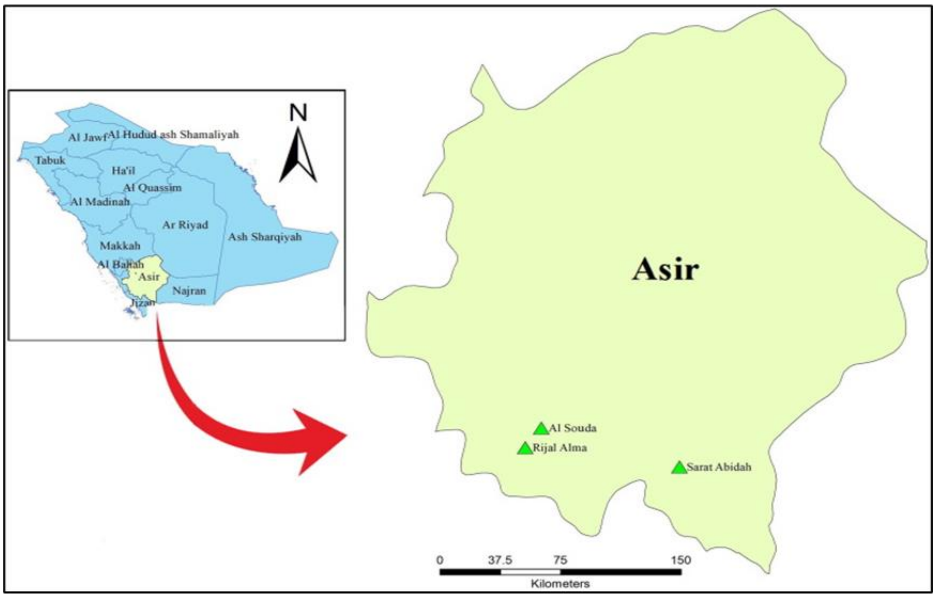

Figure 1. *Asir region, located in the southwest of the Kingdom of Saudi Arabia*

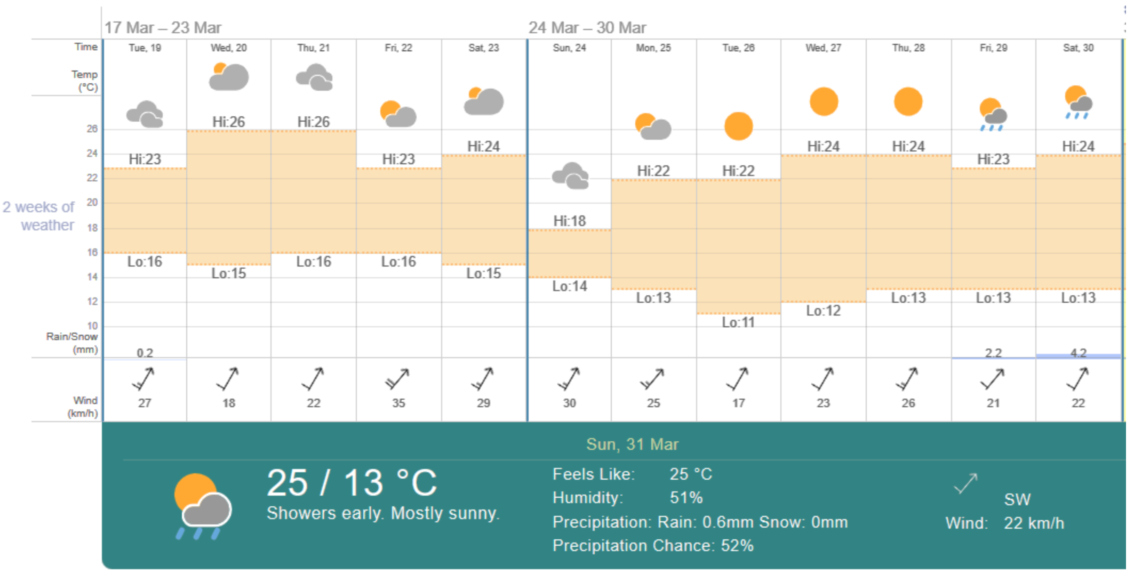

Figure 2. *The weather in the Asir region for 2 weeks by Custom Weather, © 2024*

Treatment and experimental design

This study investigated how different lighting systems affect the growth of two dragon fruit varieties, *Hylocereus undatus*, and *Hylocereus costaricensis*, in the Abha region of the Asir province, Saudi Arabia, over six months. Three lighting methods were used: natural sunlight, high-pressure sodium (HPS) lamps, and light-emitting

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diode (LED) grow lights. At Ali Sarhan's farm in Al-Sha'af, twenty plants of each variety were exposed to these lighting systems. Similarly, at the pilot farm in Wadi Bin Hashbel, twenty plants of each variety underwent the same treatments.

Table 1. *Name and GPS location of the study area*

1	Farm name	Ali Sarhan farm in Shaaf	The pilot farm using treated water in Wadi Bin Hashbel
2	Coordinates	(18.1788370, 42.6748580)	(18.6102240, 42.6968990)
3	QR		

The experiment was conducted in a greenhouse with dimensions of 5 m wide and 25 m long. Lighting was distributed by placing an artificial illumination source every 2 m on both sides at a height of 2.5 m. *Table 2* shows the types of lighting systems applied on the two examined Dragon fruit plant cultivars. The lamps used had specific parameters. The LED lamps were from the Philips floodlight series, had a voltage of 220 volts, consumed 50 watts of power, had an IP66 external reflector, and had an intensity of 5000 lumens. The HID lamps were manufactured by Philips, had a power consumption of 100 watts and an EX39 base. They had an intensity of 4300 lumens. The study strategy is to break up the dark period by supplementing lights in the middle of the night between 10 pm and 2 am. The night break can induce plant growth. The pitaya plants were cultivated in soils that were mostly moderately fine in texture having a pH of about 6.5. They were irrigated once a week with Fert through a drip system during spring and early summer. However, during the hot summer months (i.e. end of July and August), the plants were irrigated twice a week. *Figure 3* illustrates treated Dragon plants.

Table 2. *Lighting systems were applied on the two examined dragon fruit plant cultivars*

Treatment type	**Location**	**The number of individuals that have been treated at the location**
Natural sunlight	Ali Sarhani farm symbolized by (A)	Twenty plants
High-pressure sodium (HPS) lamps		Twenty plants
Emitting diode (LED) grow lights		Twenty plants
Natural sunlight	The pilot farm using treated water in Wadi Bin Hashbel symbolized by (B)	Twenty plants (two plants in each hole)
High-pressure sodium (HPS) lamps		Twenty plants (each hole contains three plants)
Emitting diode (LED) grow lights		Twenty plants (each hole contains three plants)

Recorded data

In this study, we meticulously examined the growth patterns of two dragon fruit cultivars, *Hylocereus undatus* and *Hylocereus costaricensis*, at distinct agricultural

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sites. At Ali Sarhan's farm in Al-Sha'af, individual *Hylocereus undatus* and *Hylocereus costaricensis* plants were observed over a span of six months. The timing and frequency of measuring plant phenological parameters were carefully recorded. A bi-weekly assessment of plant height (using a ruler) and number of branches was carried out throughout the duration of the study. This systematic approach ensured thorough monitoring of the growth and developmental stages of the dragon fruit cultivars. As a result, comprehensive data was obtained for analysis and interpretation.

Figure 3. *Cultivated dragon plants*

Data analysis

At the two sites of the experiment, random samples were taken from two dragon fruit cultivars. The samples were analyzed for morphological measurements which were plant length and the number of branches, and the results were recorded and organized into tables. Thorough statistical analysis was performed on the datasets using Excel and R statistical software version 4.3.0 (Oksanen et al., 2019). The results from both farms were systematically analyzed and comprehensively documented, providing valuable insights into the vegetative growth of *Hylocereus undatus* and *Hylocereus costaricensis*. We employed a range of statistical methods to thoroughly examine the growth patterns of two dragon fruit cultivars, *Hylocereus undatus,* and *Hylocereus costaricensis,* across different agricultural sites. Initially, descriptive statistics, including measures such as

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mean, standard deviation, and range, were utilized to summarize the collected data on plant length and the number of branches for each cultivar at both locations of study. Subsequently, inferential statistical test analysis of variance (ANOVA), was conducted to compare the growth patterns between the two cultivars and identify any significant differences.

Results

The analysis of variance for shoot length and number of branches from September 2022 to April 2023 revealed significant findings. In summary of the research trail, the analysis of variance indicates significant and highly significant treatment effects on both shoot length and the number of branches for various months, emphasizing the critical role of treatments in influencing these growth parameters. Coefficient of variation (CV) values indicated consistent and reliable results throughout the study period. Overall, treatments significantly influenced both shoot length and the number of branches, with varying degrees of significance observed across different months. The coefficient of variation (CV) values represents the variability within the data, showcasing the consistency and reliability of the results (*Table 3A* and *B*).

Table 3A. *Analysis of variance of shoot length from September 2022 to April 2023*

Source	DF	SL Sep 2022	SL Octo 2022	SL Nov 2022	SL Dec 2022	SL Jan 2023	SL Feb 2023	SL Mar 2023	SL Apr 2023
Replicate	2	2	2	2	2	2	2	2	2
Treatment	2	1201.25**	1085.36**	8.02ns	0.05ns	73.4722ns	116.806ns	186.05ns	544.272**
Error	176	176	176	176	176	176	176	176	176
CV	35.99	35.99	26.69	30.1	32.16	24.57	23.36	24.05	25.32

Table 3B. *Analysis of variance of the number of branches from September 2022 to April 2023*

Source	DF	NB Sep 2022	NB Octo 2022	NB Nov 2022	NB Dec 2022	NB Jan 2023	NB Feb 2023	NB Mar 2023	NB Apr 2023
Replicate	2	2	2	2	2	2	2	2	2
Treatment	2	1.51250**	35.99**	7.60556**	2.03498**	5.1657**	12.0236**	36.45**	13.2297**
Error	176	176	176	176	176	176	176	176	176
CV	26.69	26.69	33.17	36.92	33.18	33.33	36.71	42.88	35.64

P > 0.0.1 ** shows high significance at 0.001 probability level, P > 0.0.5 * shows significant, and ns shows non-significant
SL Sep, shoot length September, SL Octo, shoot length October, SL Nov, shoot length November, SL Dec, shoot length December 2022, SL Jan, shoot length January, SL Feb, shoot length February, SL Mar, shoot length March, SL Apr, shoot length April 2023. NB Sep, number of branches September, NB Octo, number of branches October, NB Nov, number of branches November, NB Dec, number of branches December 2022, NB Jan, number of branches January, NB Feb, number of branches February, NB Mar, number of branches March, NB Apr, number of branches April

The effect of the lighting system on the number of branches from September to December 2022

The objective of the study was to examine the impact of the lighting system on the quantity of branches. The findings indicate that various factors related to light, such as

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intensity, quality, duration, and source type (e.g., natural sunlight or artificial lighting systems), have an influence on the growth and development of plants. It was observed that as the size of the plant increased, the effect of light on biomass allocation and leaf morphological traits decreased. In September 2022, the greatest impact of light on the number of branches was observed on day 10 compared to the control group, while the least effect was observed on day 1. In October, the results showed that the highest effects of light on the number of branches were recorded on days 13, 14, and 26 compared to the control group. In November, day 17 exhibited the maximum effects on the number of branches compared to the control group. Similarly, in December, the highest effect of the lighting system on the number of branches was observed on day 14 compared to the control group (*Fig. 4*). The plant showed a greater effect of light in October (*Fig. 4,* NB Octo) in comparison with other plants that were grown in September, November, and December. The effect of light was observed mainly in the number of branches and Length of branches. In comparison with the all-grown plants, the lesser effect of light intensity was observed in the plants of September (*Fig. 4*, NB Sep). The more and lesser effect of light indicated that there was a greater intensity of light in October that plants absorbed and increased the number of branches with length and in September, there was a lesser amount of light or reduced intensity of light due to which the roots of plant showed not as much growth.

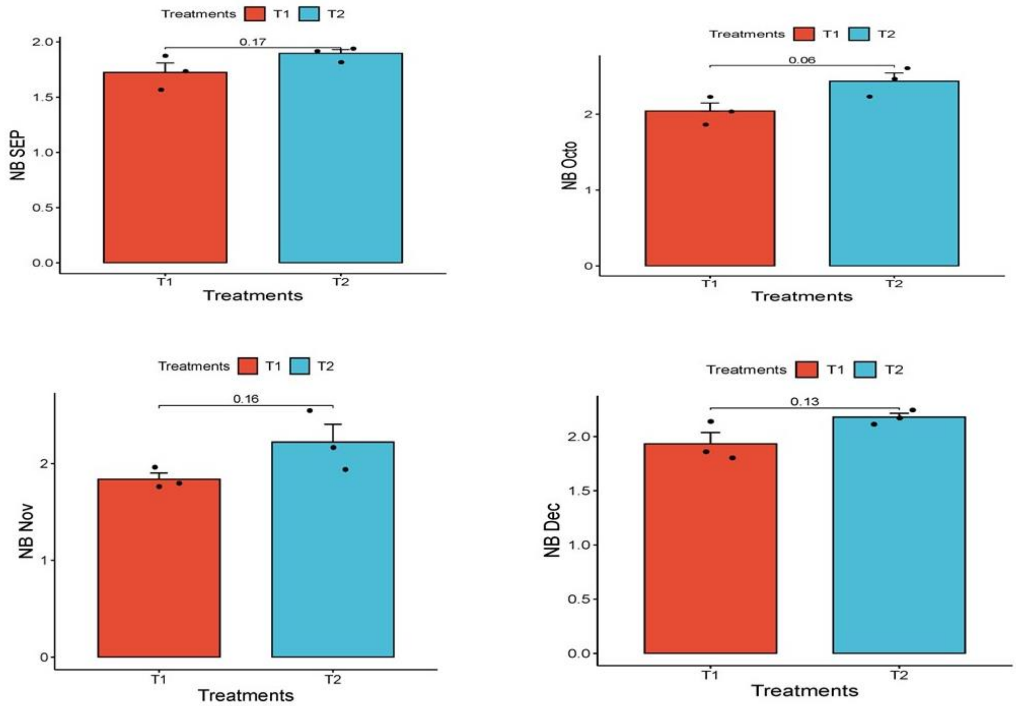

Figure 4. *Effect of lighting system on the number of branches from September to December 2022. Comparatively, all plants show their effect of light like Octo > Nov > Dec > Sep*

The effect of the light system on shoot length from September to December 2022

The impact of light systems on shoot length is a multifaceted subject that is influenced by various factors, including the specific light system employed, the plant species under investigation, and the prevailing environmental conditions. In our

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research study, we conducted an examination of the influence of light on shoot length over different months, collecting daily data. In September, our findings revealed that the maximum effect of light on shoot length occurred on day 4, surpassing the control condition. Similarly, in October, the greatest impact of light on shoot length was observed on day 2, compared to the control condition (see *Fig. 5*). However, during the months of November and December 2022, we observed minimal effects of light in comparison to the control condition. Specifically, in November, the effect of light on shoot length was minimal on day 17, while the maximum effect was recorded on day 29, relative to the control condition. Likewise, in December, we observed that light on day 21 influenced shoot length compared to the control condition (see *Fig. 5*). In comparison with all other plants, the plants that were grown in October showed the greater effect of light by their shoot growth, length, and width is shown in (*Fig. 5,* SL Oct). The plants that were grown in November showed a lesser effect of light intensity (*Fig. 5*, SL Nov).

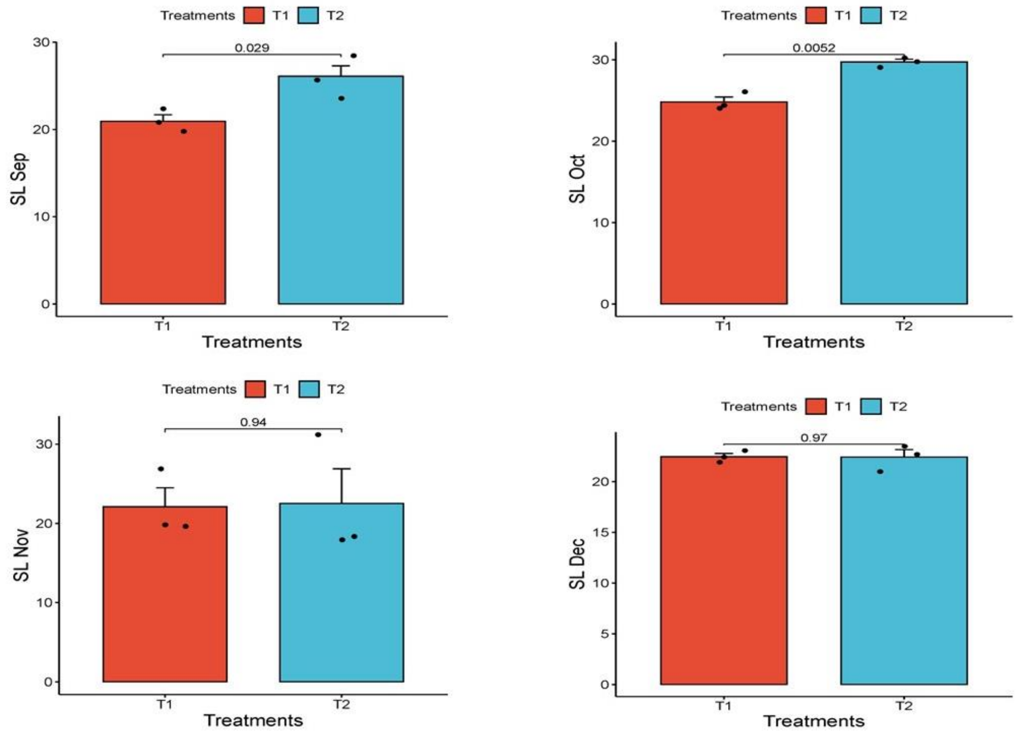

Figure 5. *Effect of lighting system on the shoot length from September to December 2022. Comparatively, the chart shows the growth of plant shoot length like Oct > Sep > Dec > Nov*

The effect of the lighting system on the number of branches from January to April 2023

In our study, we have discovered that the lighting system had a substantial impact on the number of branches in January. Specifically, on day 14, there was a significant increase in the number of branches affected by the lighting system, whereas, on day 1, the effect of light on the number of branches was minimal. Similarly, in February, we observed the effect of light on the number of branches. On day 1, the impact of light was less pronounced, while on day 14, the maximum effect was observed. In the months

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of March and April, we observed significant effects of light on the number of branches. In March, day 14 exhibited the highest impact on the number of branches, while in April, days 12 and 13 showed the maximum effect (see *Fig. 6*). The total analysis in *Figure 6* showed the effect of light intensity on the plant's number of branches. The greater effect of light was analyzed in the plants that were grown in March and this effect was mainly observed in the number and length of the branches. (*Fig. 6*, NB Mar). In Comparison with all other plants, the plants that were grown in January showed a lesser effect of light on the number of branches and length.

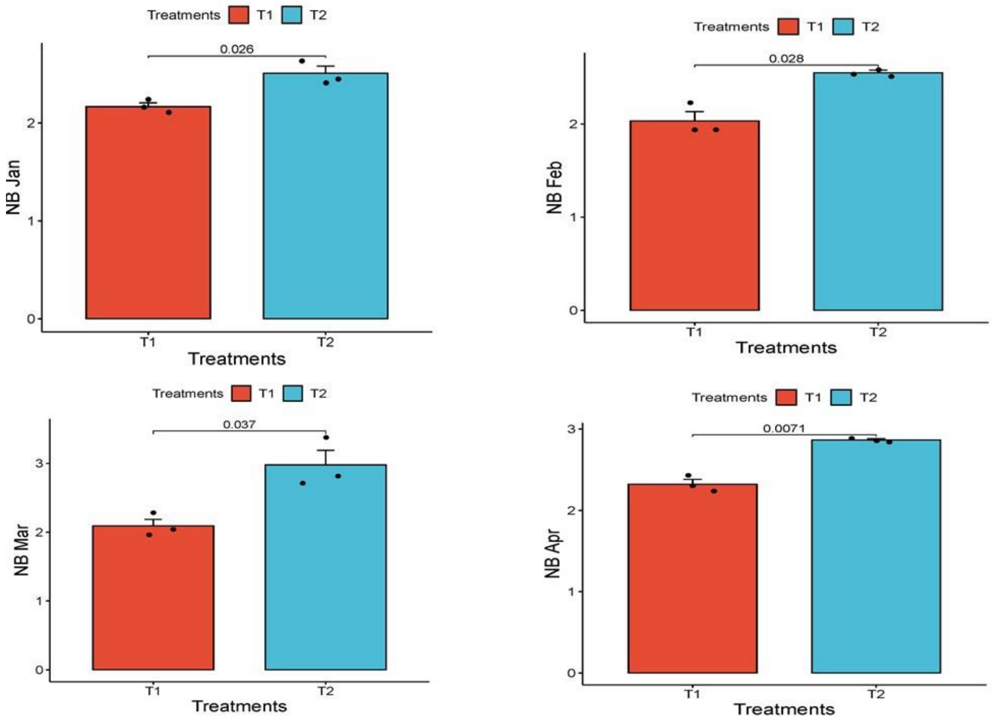

Figure 6. *Effect of lighting system on the number of branches from January to April 2023. The Chart of this figure shows the comparative analysis for the growth of branch numbers like Mar > Apr > Feb > Jan*

The effect of the light system on shoot length from January to April 2023

In our research study, we observed a significant influence of light on the length of plant shoots. To further investigate this phenomenon, we extended our research trial until 2023. Our findings indicate that light has a noticeable effect on shoot length, particularly in the month of January (see *Fig. 7*). Additionally, we observed that both January and February exhibited a significant impact of light on shoot length when compared to the control group. Specifically, we identified January 13 and February 14 as the days with the greatest influence of light on shoot length. In the month of March, we observed that light influenced shoot length on days 15, 14, 13, 12, and 11, in comparison to the control group. However, in April, we found a reduced effect of light on shoot length when compared to the controlled conditions. Notably, the day with the highest recorded impact of light on shoot length in April was day 14, while the day with the lowest recorded impact was April 8 (see *Fig. 7*). The plants of April have shown an effect greater than all other plants in their shoot length (*Fig. 7*, SL Apr). However, the

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plants that were grown in January showed not as much effect of light in the shoot length (*Fig. 7*, SL Jan). Comparatively, analysis showed that the effect of light was mainly observed in these two plants in January and April.

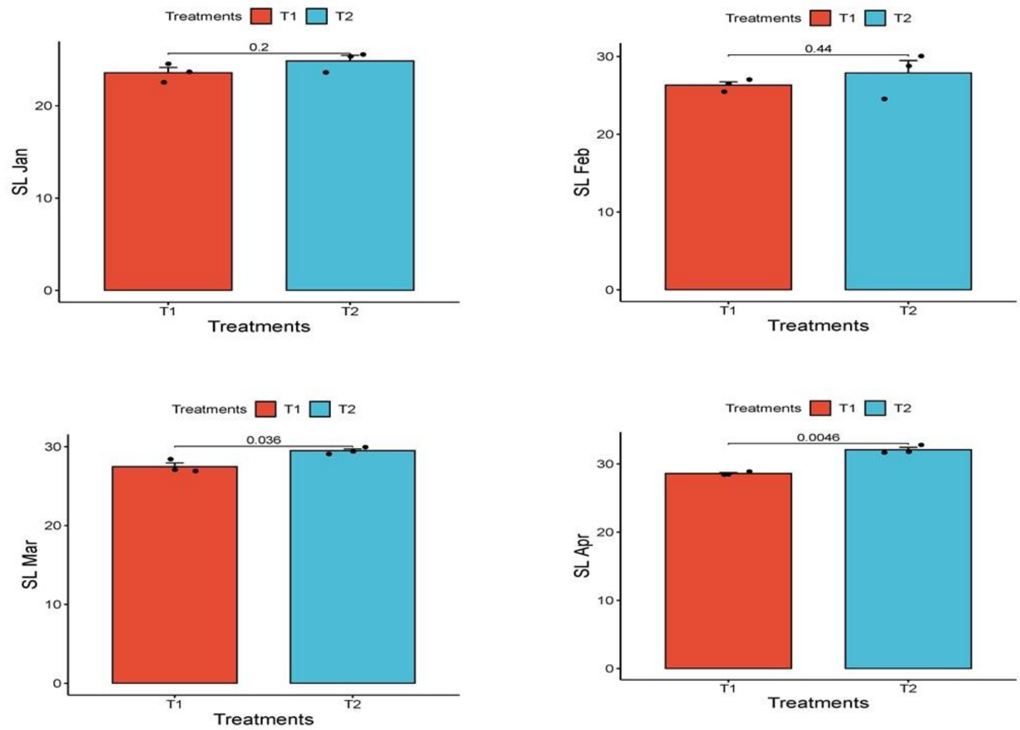

Figure 7. *Effect of the lighting system on the shoot length from January to April 2023. Analysis in this figure shows the shoot length affected by light in this manner Apr > Mar > Feb > Jan*

Discussion

Light is an essential factor in the growth and development of plants, exerting a significant influence on the number of branches and shoot length. The shoot length of a plant is affected by various factors, including the intensity, duration, and quality of light (Paradiso et al., 2022). The presented results offer valuable insights into the influence of lighting systems on plant growth, specifically focusing on shoot length and the number of branches from September 2022 to April 2023. The study aimed to understand the impact of different lighting conditions on these growth parameters, emphasizing the variations observed across different months. Light exposure significantly influences various physiological processes crucial for pitaya growth and yield. Optimal light intensity fosters photosynthesis, supporting biomass accumulation, whereas inadequate or excessive illumination may hinder growth and diminish yield (Smith et al., 2020). The timing of flowering in pitaya is regulated by photoperiodic responses, allowing growers to synchronize fruit production by manipulating light duration (Johnson and Lee, 2018). Additionally, the quality of light, as influenced by its spectral composition, has notable effects on plant morphology, metabolism, and developmental pathways (García-Muñoz et al., 2019). Growers can improve pitaya growth, flowering, and fruit quality by employing techniques such as shading, supplemental lighting, and spectral manipulation to optimize light conditions. These practices are essential for maximizing yield potential and commercial marketability in pitaya cultivation.

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The study revealed a significant effect of lighting systems on the number of branches during the initial period of plant growth (September to December 2022). Notably, October exhibited the most pronounced effect, with plants showing substantial increases in both the number and length of branches (Van Ieperen, 2012). This could be attributed to the higher light intensity experienced in October, leading to enhanced photosynthesis and biomass allocation (Katabaro et al., 2022). In contrast, plants grown in September experienced reduced light intensity, resulting in limited growth, especially in the root system (Chen and Sumida, 2018). November and December showed intermediate effects, indicating varying responses based on the available light intensity during these months.

The impact of lighting systems on shoot length varied throughout the months under study (Chandel et al., 2023). In September, light had a substantial effect, especially on day 4, suggesting the critical role of light in early shoot development (Yang et al., 2022). October exhibited the most significant impact, with plants displaying substantial shoot growth, both in length and width. However, in November and December, the influence of light on shoot length was comparatively reduced, indicating potential environmental factors affecting plant growth during these months (Vaast et al., 2006).

Moving into the next year, the study found significant effects of lighting systems on the number of branches from January to April 2023. March emerged as the month with the most substantial impact, particularly on day 14, indicating optimal conditions for branch development (Niinemets, 2010). February showed intermediate effects, while January experienced a relatively lower influence of light, leading to fewer branches. In April, the effect of light on branches decreased compared to the previous months, signifying a potential shift in environmental factors affecting plant growth as spring progressed (Han et al., 2020).

Regarding shoot length from January to April 2023, the study highlighted a noticeable influence of light on plant growth (Kong et al., 2019). January and February exhibited significant impacts, especially on days 13 and 14, indicating the importance of light during these winter months. March displayed consistent effects across several days, emphasizing the sustained impact of light on shoot length (Wassink et al., 1956). In April, although there was a noticeable effect, it was comparatively reduced, suggesting a decline in the significance of light as plants transitioned to the spring season. Understanding these effects can assist growers in optimizing plant growth and development by providing the appropriate amount and quality of light. Our findings align with Nangare et al. (2020) study, which demonstrated that illumination has a positive impact on the growth of dragon fruit plants. LED grow lights can promote flower and fruit development, prolong the growth season, raise yields, and generate higher profits when used to provide supplemental light during the night. Therefore, lighting duration is a limiting factor in the production of pitaya. Overall, while illumination is crucial for pitaya growth and production, other factors such as temperature, soil quality, water availability, and proper pollination also play significant roles in ensuring successful cultivation (Rashid et al., 2021). Illumination plays an important role in photosynthesis and is a perfect fit for the growth of dragon fruit plants. Furthermore, the right amount of light intensity and duration provided by illumination allows for the year-round production of dragon fruit plants. These findings are in line with the studies conducted by Adams et al. (2001) and Boss et al. (2004) who demonstrated the significance of photoperiodism in promoting plant growth and flowering.

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Conclusion

In conclusion, the study underscores the dynamic nature of plant responses to lighting systems, with varying effects observed across different months. While October and March exhibited the most substantial impacts on both the number of branches and shoot length, respectively, other months displayed varying degrees of influence. These findings highlight the importance of understanding seasonal variations and their interaction with lighting conditions, providing valuable insights for optimizing agricultural practices and indoor cultivation methods. Further research into the specific environmental factors influencing plant growth during these periods could enhance our understanding of these observed patterns.

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Conflicts of interest. The authors declare no competing financial interests.

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