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Early growth of imperial palm (Roystonea oleracea) in tropical environments

Crecimiento temprano de la palma imperial (Roystonea oleracea) en ambientes tropicales

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ABSTRACT

The imperial palm (*Roystonea oleracea* (Jacq.) O.F.Cook) was first introduced to Brazil in 1809 as a gift to King Dom João VI, subsequently becoming a favored ornamental species. Its aesthetic appeal, grandeur, and adaptability have contributed to its widespread use in urban landscaping across the country. Despite its prominence, scientific studies on its physiological development under tropical conditions remain limited. Therefore, the objective of this work was to evaluate the growth of plants and the chlorophyll content of the imperial palm leaves. The experiment was carried out at the Federal University of Jataí, where 56 plants of *Roystonea oleraceae* transplanted to the university's central seedbed at 95 months in 2017 were evaluated. Plant growth data were collected on 11/14/2017, 06/28/2017, 2018, and 11/24/2018, and the plants were evaluated for height, diameter, and number of leaves. Analyses were also carried out regarding the chlorophyll content on 08/18/2018 and 11/24/2018 using a completely randomized design with 56 replications. Through descriptive statistics, the growth and chlorophyll content data were analyzed. The initial development of Roystonea oleracea under tropical conditions demonstrated a vigorous growth pattern, particularly in plant height, which increased from an average of 86.36 cm to 151.19 cm over seven months. Stem diameter exhibited a consistent upward trend, with averages progressing from 22.04 cm to 36.64 cm, and reaching 37.08 cm in the final assessment. These findings suggest that *R. oleracea* adapts well to the environmental conditions of the study site, showing promising potential for ornamental and ecological applications in tropical urban landscapes.

Keywords: afforestation; Arecaceae; conservation; landscaping; ornamental; species

RESUMEN

La palmera imperial (*Roystonea oleracea* (Jacq.) O.F.Cook) se introdujo por primera vez en Brasil en 1809 como regalo al rey Dom João VI, convirtiéndose posteriormente en una especie ornamental muy apreciada. Su atractivo estético y su adaptabilidad han contribuido a su uso generalizado en el paisajismo urbano de todo el país. A pesar de su importancia, los estudios científicos sobre su desarrollo fisiológico en condiciones tropicales siguen siendo limitados. Por tanto, esta investigación tuvo como objetivo evaluar el crecimiento de las plantas y el contenido de clorofila de las hojas de la palmera imperial. El experimento se llevó a cabo en la Universidad

Federal de Jataí, donde se evaluaron 56 plantas de *Roystonea oleraceae* trasplantadas al semillero central de la universidad a los 95 meses de 2017. Los datos de crecimiento de las plantas fueron recolectados en tres ocasiones: el 14 de noviembre de 2017, el 28 de junio y el 24 de noviembre de 2018, evaluando la altura, el diámetro y el número de hojas. También se realizaron análisis sobre el contenido de clorofila el 18 de agosto y el 24 de noviembre de 2018 con un diseño completamente aleatorizado con 56 repeticiones. Mediante estadística descriptiva se analizaron los datos de crecimiento y contenido de clorofila. El desarrollo inicial de *R. oleracea* en condiciones tropicales mostró un patrón de crecimiento vigoroso, especialmente en la altura de las plantas, que aumentó de una media de 86,36 cm a 151,19 cm en un periodo de siete meses. El diámetro del tallo mostró una tendencia al alza constante, con promedios que pasaron de 22,04 cm a 36,64 cm y alcanzaron los 37,08 cm en la evaluación final. Estos resultados sugieren que *R. oleracea* se adapta bien a las condiciones ambientales del lugar de estudio, lo que muestra un potencial prometedor para aplicaciones ornamentales y ecológicas en paisajes urbanos tropicales.

Palabras clave: Arecaaceae; conservación; especies; forestación; ornamentales; paisajismo

INTRODUCTION

The Arecaceae family consists of approximately 189 genera and 3,000 species worldwide. Due to their botanical characteristics, species in this family have significant economic, nutritional, and ornamental value (Soares *et al.*, 2020). They also exhibit a great diversity of uses and a strong capacity to adapt to different climates and soil types (Souza *et al.*, 2021).

Ornamental palm trees are widely used in urban afforestation due to their beauty, and the tropical appeal they bring to the environment. It is well known that one of the most valued qualities in afforestation is the shade provided by vegetation, which help protect the urban environment (Weirich *et al.*, 2015). In addition, afforestation positively influences the microclimate quality of urban environments, thereby improving the quality of life for the population (Souza *et al.*, 2019).

The first imperial palm (*Roystonea oleracea*) (Jacq. O.F.Cook) was introduced to Rio de Janeiro in 1809 as a gift to Emperor Dom João VI. It became his favorite species and is now widely used in urban afforestation projects (Nascimento *et al.*, 2013). This palm belongs to a group of the most imposing and majestic ornamental palms. Native to the Caribbean and northern South America, it is found throughout Brazil in the landscaping of botanical gardens, farms, squares, avenues, museum gardens, and public buildings (Colonnello *et al.*, 2016). The indigenous people of Venezuela named the imperial palm the “queen of all palm trees” due to its majestic height and beauty. The first imperial palm planted in Brazil by Dom João VI lived for 163 years and reached approximately 38 meters in height (Araújo & Silva, 2010).

A large part of the world's population lives in an urban environment, and therefore, it is necessary to create conditions that favor the coexistence of society in this environment (Weirich *et al.*, 2015). One way to alleviate problems related to urbanization is to plant trees in public squares, preservation areas, and parks, since this allows urban permanence and vitality. Planting trees in urban areas not only improves quality of life by reducing temperature fluctuations and producing oxygen but also increases biodiversity and enhances human health in the surrounding region (Gonçalves *et al.*, 2018).

“Green Parks” began to be implemented in Brazil at the end of the 18th century, but municipalities started developing public parks more widely in the mid-20th century due to population growth and the need for leisure and well-being spaces (Gonçalves *et al.*, 2018). The introduction of exotic species in Brazil is related to socioeconomic interests, and many palm trees were brought to the country for economic and ornamental purposes.

Urban afforestation is essential for thermal control, humidity regulation, oxygen production, shade control, and city landscaping. However, such initiatives must be carefully planned, as species with large canopies and surface roots systems can cause problems with wiring, cables, visibility of signs and traffic lights, as and damage to asphalt and sidewalks, resulting in costs for both the population and the government (Firmo *et al.*, 2019; Bacelar *et al.*, 2020; Rocha *et al.*, 2018). Therefore, the imperial palm tree presents great potential for landscaping avenues and more signposted environments since it has a smaller crown compared to other trees, minimizing issues with visibility in urban spaces.

An exotic species can be considered invasive when it is widely cultivated due to its ornamental characteristics or when it spread extensively through natural propagation (by wind or animals) (Silva, 2017). Factors such as fast vegetative growth, easy fruit dispersal, and high seed longevity contribute to the invasiveness of a species (Oliveira *et al.*, 2016). Due to its widespread use in landscaping metropolitan areas, the imperial palm can be considered invasive species.

Light plays a fundamental role in the plant vegetative growth, as it is drives photosynthesis, stomatal opening, and chlorophyll synthesis. The amount of light a plant receives varies depending on daylight hours and seasons. Studies on forest species have shown that low light conditions can reduce the quality and productivity of some species (Schmidt *et al.*, 2017). However, specific studies on the influence of light on the development of imperial palms are lacking.

Plants with high chlorophyll content are estimated to have greater photosynthetic efficiency, and photosynthetic pigments are correlated with nitrogen content, as approximately 50% of total leaf nitrogen is associated with chloroplasts (Santos *et al.*, 2019).

The incidence of solar radiation, cloudiness, water availability, and developmental stage directly influence the photosynthetic capacity of leaves. In addition, solar radiation, ambient temperature, and mineral nutrition affect leaf longevity, which in turn can delay or impair plant development (Marenco *et al.*, 2019). Despite the magnificence and exuberance of this species, studies remain scarce. Given this, the objective of this study was to evaluate the growth and chlorophyll content of the leaves of the imperial palm (*Roystonea oleracea*).

MATERIALS AND METHODS

The experiment was carried out at the Federal University of Jataí, located at 17º55'S, 51º42'W, and 680 meters above sea level. According to the Köppen classification, the region's climate is Aw, with a dry period from May to September and a rainy period from October to April. The average temperature is 23.3 °C, and the average annual precipitation is 1,541 mm (Melo & Dias, 2019).

Fifty-six plants from a commercial nursery were evaluated. They were planted in January 2017, in an area with soil covered by brachiaria (*Urochloa decumbens*), arranged in two rows spaced 9 × 8 m apart, with a weekly irrigation system during dry periods. Invasive plants were controlled manually, without the use of herbicides.

Seedling growth data were collected between November 11, 2017, and May 28, 2018. Measurements were taken at 316, 542, and 695 days after sowing (DAS), evaluating plant height, stem diameter, and leaf count. Chlorophyll content was analyzed at 606 and 704 DAS.

To determine plant height, measurements were taken from the soil surface to the insertion of the last leaf, using a topographic ruler. Steam diameter was measured at the midpoint of each plant using a tape measure. To determine the number of leaves per plant, fully expanded leaves were counted, excluding those still enclosed in the leaf sheath. Chlorophyll content was assessed using a Falker® CFL1030 chlorophyll meter. Measurements were conducted between 08:00 and 09:00 a.m., targeting the first, second, and third fully expanded leaves of each plant. For each leaf, three readings were taken using the sensor, and the mean value was calculated to represent the chlorophyll level per plant.

The experimental design employed was a completely randomized design with two treatments (planting lines), each with 28 replicates, totaling 56 plants. Data on plant growth and chlorophyll content were analyzed using descriptive statistics. Measures of central tendency (mean) and measures of dispersion (standard deviation and coefficient of variation) were calculated to summarize the data. All statistical analyses were performed using the AgroEstat software (Barbosa & Maldonado, 2015).

RESULTS

Plant Growth

Plant growth was evaluated at 316, 542, and 695 days after sowing (DAS), focusing on plant height, stem diameter, and leaf count. The results revealed progressive growth over time, accompanied by fluctuations in variability (Table 1). Plant height increased from an average of 86.36 cm at 316 DAS to 151.19 cm at 542 DAS, followed by a slight decline to 139.26 cm at 695 DAS (Table 1). The coefficient of variation (CV) decreased from 42.02% to 30.60%, indicating reduced variability in height as the seedlings matured (Table 1).

Table 1. *Height, diameter, and number of leaves of imperial palm trees.*

Characteristics evaluated	Days after sowing	Average	Standard deviation	CV (%)
Height (cm)	316	86.36	36.29	42.02
	542	151.19	58.63	38.78
	695	139.26	42.62	30.60
Diameter (cm)	316	22.04	7.97	36.15
	542	36.64	9.55	26.06
	695	37.08	10.50	28.31
Number of leaves (direct count)	316	2.50	0.93	37.36
	542	5.32	1.68	31.67
	695	3.51	1.17	33.41

CV: Coefficient of variation.

Stem diameter showed a consistent upward trend, rising from 22.04 cm at 316 DAS to 36.64 cm at 542 DAS and 37.08 cm at 695 DAS. The CV also declined from 36.15% to 28.31%, suggesting increasingly uniform stem growth over time (Table 1).

Leaf count peaked at 542 DAS, with an average of 5.32 leaves, compared to 2.50 at 316 DAS and 3.51 at 695 DAS. Despite these changes, the CV remained relatively high across all stages (ranging from 31.67% to 37.36%), indicating substantial variability in leaf production among seedlings (Table 1).

Chlorophyll content

Chlorophyll content was quantified in the first, second, and third leaves at 606 and 704 days after sowing (DAS). The data revealed a general increase in chlorophyll concentration over time, with differences in magnitude and variability depending on leaf position (Table 2). In the first leaf, the average chlorophyll content increased from 70.39 at 606 DAS to 88.91 at 704 DAS. The coefficient of variation (CV) showed a slight decrease, from 27.52% to 26.49%, indicating relatively stable and consistent accumulation. The second leaf followed a similar pattern, with chlorophyll levels rising from 72.85 to 91.02. The CV decreased from 30.42% to 24.43%, suggesting improved uniformity in chlorophyll distribution among samples (Table 2).

Table 2. *Chlorophyll content in three central leaves of the imperial palm.*

	Chlorophyll content					
	1^{rst} leaf		2nd leaf		3rd leaf	
	606 DAS	704 DAS	606 DAS	704 DAS	606 DAS	704 DAS
Average	70.39	88.91	72.85	91.02	54.66	78.03
Standard deviation	19.38	23.55	22.16	22.24	20.65	35.64
CV (%)	27.52	26.49	30.42	24.43	37.78	45.67

CV (%): Coefficient of variation, given as a percentage. DAS= Days After Sowing

In contrast, the third leaf exhibited lower overall chlorophyll values, increasing from 54.66 at 606 DAS to 78.03 at 704 DAS. However, the CV increased from 37.78% to 45.67%, reflecting greater variability in chlorophyll content at the later stage (Table 2). These findings indicate that chlorophyll accumulation tends to increase over time across all leaf positions. Nonetheless, the degree of variability appears to be influenced by leaf age or position, with older leaves showing less uniformity in chlorophyll content.

The observed increase in chlorophyll content over time suggests enhanced photosynthetic capacity as seedlings mature, which may contribute to improved growth and biomass accumulation. The lower variability in younger leaves (first and second) highlights their potential as reliable indicators for physiological assessments in nursery or field conditions. Conversely, the higher variability in older leaves (third leaf) may reflect senescence or environmental stress, underscoring the importance of leaf selection when monitoring plant health. These insights can inform best practices in seedling management, fertilization strategies, and the timing of physiological measurements in forestry and agricultural systems.

DISCUSSION

Plant Growth

The observed trends in seedling growth have several practical applications for nursery management and field establishment strategies. The consistent increase in stem diameter and plant height up to 542 DAS, followed by a slight decline in height at 695 DAS, suggests that optimal growth conditions may be achieved before the final evaluation period. This highlights the importance of timely transplantation or intervention to maintain growth momentum. *Roystonea oleracea*, when mature, reaches between 18 and 40 meters in height, with steam diameter ranging from 46 and 66 cm (Silva, 2017). The data collected reveal that the palm trees evaluated still have great potential for growth in both height and diameter.

The growth characteristics of *R. oleracea* have been investigated in the Atlantic Forest of Brazil, with emphasis on population dynamics, vital rates, and management strategies (Zucaratto *et al.*, 2021). However, limited information is available regarding on direct comparisons of its growth rate with other palm species, as well as the specific economic implications associated with its growth performance.

The decreasing coefficient of variation (CV) in height and diameter over time indicates increasing uniformity among seedlings, which is beneficial for standardizing planting material and ensuring predictable field performance. In contrast, the persistently high CV in leaf count suggests that leaf production remains variable, potentially influenced by environmental factors or genetic diversity. This variability should be considered when selecting seedlings for physiological assessments or productivity predictions.

Overall, these findings support the use of intermediate growth stages (around 542 DAS) as a reliable point for evaluating seedling vigor and uniformity, aiding in decision-making for thinning, fertilization, or transplantation schedules in forestry and agroforestry systems. Extending the evaluation period beyond 695 days could provide insights into late-stage growth dynamics, including potential stabilization, decline, or secondary growth phases. This would help determine the optimal timing for transplantation or harvesting in long-cycle species.

When evaluating palm tree height in a farm setting, Lima *et al.* (2003) reported that adult individuals of *Syagrus comosa* ranged from 89 to 380 cm in height. This finding is particularly relevant when compared to the young *Roystonea* (imperial palm) specimens assessed in the present study, as some of these juvenile individuals already exhibit heights comparable to the lower range of adult *Syagrus comosa*. However, when contrasted with mature *Roystonea* palms, the seedlings evaluated in Table 1 are still in early developmental stages and will require several more years to reach the typical adult size of the species. This growth trajectory is consistent with the known ontogeny of *Roystonea*, which is characterized by a prolonged juvenile phase before reaching full stature.

These results underscore the importance of species-specific growth benchmarks when interpreting seedling performance. The comparison with *Syagrus comosa* provides a useful reference point, highlighting the need to consider interspecific differences in growth rates and final size. Understanding these dynamics is crucial for developing effective long-term management strategies in ornamental or reforestation contexts involving palm species.

The diameter of palm trees is a key morphological trait that reflects their overall growth and developmental status. According to Bovi *et al.* (2002), the development of fruit-bearing palms is directly correlated with stem diameter, making it a reliable indicator of plant vigor and productivity. These authors also emphasize the practicality of measuring diameter, noting its widespread use in growth assessments within the Arecaceae family due to the simplicity and consistency of data collection.

In the context of *Roystonea* (imperial palm), stem diameter not only serves as a proxy for physiological development but also contributes to the visual impact and structural robustness of the plant. Larger diameter values are generally associated with more vigorous individuals, which tend to exhibit greater architectural exuberance—an important trait in ornamental and landscape applications. The results presented in Table 1 align with these observations. The progressive increase in stem diameter over time, coupled with a decreasing coefficient of variation, suggests a trend toward more uniform and vigorous growth among the seedlings. This reinforces the utility of diameter as a practical and informative parameter for evaluating seedling quality and predicting future performance in both commercial and ecological planting programs.

In a study conducted on a farm, Lima *et al.* (2003) reported a maximum stem diameter of 17.5 cm in adult individuals of Syagrus comosa (Mart.). This value provides a useful benchmark for comparing growth performance across palm species.

In contrast, Amaral *et al.* (2016) documented *Roystonea* (imperial palm) specimens in Ramos de Azevedo Square, São Paulo, with heights of 3.0 m and stem diameters of 27 cm. These values are notably 10 cm smaller than the diameters observed in the present study (Table 1), suggesting that the palms evaluated here exhibit superior growth. This discrepancy may be attributed to differences in phytosanitary management, as Amaral *et al.* (2016) noted the absence of adequate care in the urban setting, which likely limited the development of those individuals.

The results of the present study indicate that young *Roystonea oleracea* ((Jacq.) O.F.Cook) palms, at 95 months of age, have already achieved more than half of the maximum diameter reported for mature individuals of the species. This suggests a robust growth trajectory and highlights the species' potential for rapid structural development under favorable conditions. These findings reinforce the importance of stem diameter as a reliable indicator of palm vigor and underscore the influence of management practices on growth outcomes. Moreover, they position *Roystonea oleracea* ((Jacq.) O.F.Cook) as a species with promising ornamental and ecological value, especially when cultivated under optimal nursery or field conditions.

The number of leaves in palm trees is closely linked to irrigation and fertilization practices, playing a fundamental role in plant development. As highlighted by Bischoff *et al.* (2017), leaves are the primary organs responsible for converting solar energy into chemical energy through photosynthesis, an essential process for sustaining the metabolic activities of plants. Furthermore, leaves are key sites for the production of plant hormones and photo assimilates, which contribute to growth regulation and biomass accumulation.

In this context, the leaf count serves not only as a morphological indicator but also as a proxy for physiological performance. Variations in leaf number may reflect differences in resource availability, environmental conditions, or management practices. The results presented in Table 1, which show fluctuations in leaf count and a relatively high coefficient of variation across sampling periods, suggest that leaf production in *Roystonea oleracea* seedlings is sensitive to external factors and may vary significantly among individuals.

Chlorophyll content

Chlorophyll content plays a fundamental role in plant development and growth, as it is directly associated with photosynthetic efficiency. Higher chlorophyll levels typically enhance the plant's ability to convert solar energy into chemical energy, which is essential for metabolic processes and biomass accumulation. According to Dias *et al.* (2020), chlorophyll concentration can also serve as an indicator of the plant's nutritional status, particularly in relation to nitrogen availability, and is influenced by environmental factors such as climate, irrigation, and soil fertility.

Additionally, Engel and Poggiani (1991) observed that shaded leaves often exhibit higher chlorophyll concentrations. This phenomenon is explained by the dynamic balance between chlorophyll synthesis and degradation, which is accelerated under high light intensity, leading to lower pigment levels. In shaded conditions, the rate of degradation slows, allowing chlorophyll to accumulate.

The results of the present study, which show increased chlorophyll content over time across different leaf positions, may reflect favorable environmental conditions and adequate nutrient availability during the evaluation period. The variation in chlorophyll levels among leaves also suggests differential light exposure or physiological age, which could influence pigment concentration and photosynthetic capacity.

These findings support the use of chlorophyll content as a practical and non-destructive indicator of plant health and vigor, with potential applications in monitoring fertilization efficiency, irrigation management, and early detection of stress in nursery and field conditions.

The growth of the palm trees observed in this study, as reflected in the morphological traits presented in Table 1, was likely influenced by the increase in chlorophyll concentration across the three evaluated leaves. Over two months, a significant increase in chlorophyll content was recorded, suggesting enhanced photosynthetic capacity during this interval.

Chlorophyll content is closely associated with the nitrogen status of plants and has been proposed as a reliable indicator for refining nitrogen fertilization strategies (Argenta *et al.,* 2001). Since chlorophyll is the primary pigment involved in capturing light energy for photosynthesis, its concentration directly affects the plant's ability to produce energy and support metabolic functions essential for growth.

Furthermore, the distribution of chlorophyll within leaves is influenced by environmental conditions such as light intensity. As noted by Engel and Poggiani (1991), shaded leaves tend to accumulate higher chlorophyll levels due to a slower degradation rate, whereas leaves exposed to intense light experience faster turnover, resulting in lower concentrations. This dynamic may partially explain the variation in chlorophyll content among the different leaf positions evaluated.

Taken together, these findings suggest that the observed increase in chlorophyll content may have contributed to the improved growth performance of the seedlings, particularly in terms of height and stem diameter. Monitoring chlorophyll levels could therefore serve as a useful tool for assessing plant health and optimizing fertilization and light management practices in palm cultivation systems.

Investigating the role of environmental factors (e.g., light intensity, soil moisture, nutrient availability) on the observed variability in leaf production and growth parameters could clarify the sources of heterogeneity and inform precision management practices. Additionally, exploring the relationship between morphological traits (height, diameter, leaf count) and physiological parameters such as chlorophyll content, photosynthetic rate, or nutrient uptake could enhance understanding of growth efficiency and stress tolerance.

CONCLUSIONS

The initial development of *R. oleracea* under tropical conditions demonstrated a vigorous growth pattern, particularly in plant height, which increased from an average of 86.36 cm to 151.19 cm over a seven-month period. Stem diameter exhibited a consistent upward trend, increasing from an average of 22.04 cm to 36.64 cm, and reaching 37.08 cm in the final assessment. These findings suggest that *R. oleracea* adapts well to the environmental conditions of the study site, indicating promising potential for both ornamental and ecological applications in tropical urban landscapes. Data from the analysis of growth and chlorophyll content in the palm trees indicated that chlorophyll content increases in direct proportion to the plant's developmental characteristics, positively influencing overall growth

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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