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Effects of NPK Mineral Fertilizers on Seedling Growth of Selected Ornamental Palm Species

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Abstract

The application of mineral fertilizers plays an important role in improving plant growth and development, particularly in ornamental palm species cultivated in nurseries and landscape systems. This study evaluated the effects of nitrogen (N), phosphorus (P), and potassium (K) fertilizers on the seedling growth of four ornamental palm species: *Trachycarpus fortunei*, *Trachycarpus wagnerianus*, *Washingtonia robusta*, and *Jubaea chilensis*. The experiment was conducted under controlled conditions using different mineral fertilizer treatments, and seedling height was measured periodically over several months to assess growth responses. The results demonstrated species-specific differences in nutrient requirements. Phosphorus fertilization significantly enhanced the growth of *Trachycarpus fortunei*, *Trachycarpus wagnerianus*, and *Jubaea chilensis*, indicating a higher demand for phosphorus during early developmental stages. In contrast, Washingtonia robusta seedlings exhibited a stronger response to nitrogen fertilization, suggesting greater nitrogen requirements for optimal vegetative growth. These findings highlight the importance of species-specific fertilization strategies for ornamental palm cultivation. The results provide practical recommendations for improving nursery production and landscape establishment of palm seedlings through optimized mineral fertilizer management.

Keywords

Ornamental Palms, Seedling Growth, NPK Fertilizers, Nutrient Requirements, Palm Cultivation

1. Introduction

In recent years, ornamental palm species such as *Washingtonia robusta* and *Trachycarpus fortunei* have gained increasing importance in urban landscaping and green infrastructure development. These species are widely planted in the courtyards of government institutions, hotels, recreational areas, and educational campuses due to their high decorative value, adaptability to diverse environmental conditions, and relatively low maintenance requirements [1] [2]. The unique morphology of palm leaves, characterized by their large size and distinctive structure, significantly enhances the aesthetic and ecological quality of urban landscapes. The successful establishment and sustainable growth of ornamental palms under nursery and field conditions are strongly influenced by proper nutrient management practices. Among essential macronutrients, nitrogen (N), phosphorus (P), and potassium (K) play fundamental roles in plant physiological and biochemical processes. Nitrogen is a key component of chlorophyll and amino acids, directly affecting photosynthesis and vegetative growth, while phosphorus is essential for energy transfer, nucleic acid synthesis, and root development. Potassium contributes to enzyme activation, osmotic regulation, and improved resistance to abiotic stresses such as drought and temperature fluctuations [3]. Numerous studies have demonstrated that the application of mineral fertilizers significantly improves plant growth parameters, including seedling height, leaf area, biomass accumulation, and overall plant vigor in ornamental and woody species. In nursery production systems, balanced fertilization is especially critical, as seedlings are grown under controlled conditions where nutrient availability directly influences growth performance and transplant success [4]-[6]. However, the response to fertilization may vary depending on species-specific nutrient requirements, substrate composition, and environmental conditions. In particular, different plant species exhibit varying sensitivity to individual macronutrients, which necessitates species-oriented fertilization approaches [7]. At the same time, the excessive and unregulated use of mineral fertilizers has raised environmental concerns. Improper fertilization practices can lead to soil salinization, nutrient imbalance, and leaching of nitrates and phosphates into groundwater and surface water systems. Additionally, volatilization and emission of nitrogen compounds may contribute to atmospheric pollution. These issues highlight the importance of developing optimized and environmentally sustainable fertilization strategies [8] [9]. Despite the growing popularity of ornamental palms, scientific information regarding their nutrient requirements, particularly during the seedling stage, remains limited. Most existing studies focus on general fertilization practices or combined NPK applications, while the individual effects of nitrogen, phosphorus, and potassium on different palm species are not sufficiently explored. Furthermore, comparative analyses of species-specific responses under controlled nursery conditions are scarce. Understanding how different palm species respond to individual macronutrients is essential for improving nursery management practices, enhancing seedling quality, and supporting sustainable urban landscaping programs. Such knowledge can contribute to the development of efficient fertilization regimes tailored to specific species and local growing conditions. Therefore, the aim of this study was to evaluate the effects of nitrogen, phosphorus, and potassium fertilizers on the seedling growth of selected ornamental palm species under controlled nursery conditions, with a particular focus on species-specific responses to individual nutrient applications.

2. Materials and Methods

2.1. Experimental Design and Plant Material

The experiment was conducted to evaluate the effects of mineral fertilizers on the early growth of selected ornamental palm species. Seedlings of four palm species—*Trachycarpus fortunei*, *Trachycarpus wagnerianus*, *Washingtonia robusta*, and *Jubaea chilensis*—were used as experimental plant material. Healthy and uniform seedlings were selected to ensure consistency in the experimental conditions. The study was carried out under controlled nursery conditions. Each species was grown in plastic pots filled with prepared soil substrate. The volume of each pot was 5L. The experiment followed a completely randomized design with four treatments: control (without fertilizer), nitrogen fertilization (N), phosphorus fertilization (P), and potassium fertilization (K). Each treatment consisted of three replicates with ten seedlings per replicate. Seedlings of each palm species were obtained from a local nursery, and their age at the start of the experiment ranged from 6 to 8 months. The initial height of the seedlings varied between 25 and 35 cm depending on the species. The experimental unit was defined as an individual seedling grown in a separate pot. The treatments were arranged in a Completely Randomized Design (CRD), and seedlings were randomly assigned to each fertilizer treatment to minimize experimental bias.

2.2. Soil Preparation and Fertilizer Application

Prior to planting, the soil substrate was homogenized and enriched with mineral fertilizers. The fertilizer rates were calculated per kilogram of soil and consisted of 0.492 g nitrogen, 0.136 g phosphorus, and 0.075 g potassium. Nitrogen was applied in the form of ammonium nitrate, phosphorus as superphosphate, and potassium as potassium sulfate. Fertilizers were incorporated into the soil before planting to ensure uniform distribution of nutrients within the substrate. The control treatment received the same soil mixture without additional fertilizer application. All fertilizers were applied once as a pre-plant treatment at fixed rates before transplanting. Nitrogen, phosphorus, and potassium were supplied separately in mineral form according to the experimental design. No additional seasonal applications were performed during the study period. Each treatment was applied consistently across all experimental units.

2.3. Growth Conditions

The experiment was conducted under greenhouse conditions where environmental factors were maintained at levels suitable for palm seedling development. The average temperature ranged between 25˚C and 28˚C, and natural daylight conditions provided approximately 10 - 12 h of photoperiod per day. Plants were irrigated regularly to maintain optimal soil moisture while avoiding waterlogging.

Seedling growth was evaluated based on absolute plant height (cm), measured from the soil surface to the tip of the highest leaf. Measurements were recorded monthly from May to November. The initial measurement taken at the beginning of the experiment was used as a baseline for subsequent comparisons.

2.4. Soil Analysis

Prior to the experiment, soil samples were collected and analyzed to determine baseline physicochemical characteristics. The soil analysis included measurements of nitrogen, phosphorus, and potassium content, as well as pH and organic matter levels. These parameters were used to evaluate the initial fertility status of the soil and to interpret the growth responses of palm seedlings under different fertilizer treatments. The experiment was conducted under controlled nursery conditions using a pot system. The soil used in the study was collected from Samarkand city and Bulung'ur district and thoroughly homogenized to form a uniform substrate. Thus, a mixed soil was used as a single growth medium for all treatments. The sampling locations were not considered as separate experimental factors.

2.5. Growth Measurements

Plant growth was evaluated by measuring seedling height at regular intervals during the experimental period. Measurements were taken monthly from the base of the stem to the tip of the longest leaf. The recorded data were used to determine growth rates and to compare the effects of different mineral fertilizer treatments on palm seedling development.

2.6. Statistical Analysis

All experimental data were statistically analyzed using Analysis Of Variance (ANOVA) to determine significant differences among treatments. Mean values were compared using appropriate post hoc tests at a significance level of $p < 0.05$. The results were expressed as mean ± standard deviation.

Only seedling height was measured and analyzed in this study. Parameters such as leaf number, leaf color, effects of organic fertilizers, pruning practices, and resistance to pests or diseases were not evaluated. Any references to these factors are discussed only in relation to previously published studies.

3. Results

3.1. Soil Physicochemical Characteristics of the Experimental Site

Prior to the establishment of the experiment, soil samples were collected from the experimental plots located in Samarkand city and Bulung'ur district to determine their physicochemical properties and nutrient status. The results of the agrochemical soil analysis are presented in Table 1. The analysis included soil pH, electrical conductivity, salinity indicators, macroelement availability, organic matter content, and mechanical composition.

Table 1. Soil environment, salinization levels, nutrient supply, and mechanical composition.

Site	Depth (cm)	pH	Electrical conductivity (mS/cm)	Dry residue (%)	Chloride (%)	Na_2O (%)	K_2O (%)	Sulfate (%)	$CaCO_3$ (%)	NO_3-N (mg/kg)	NH_4-N (mg/kg)	P_2O_5 (mg/kg)	K_2O (mg/kg)	Humus (%)	Soil texture
Samarkand city	0 - 30	7.67	586	0.32	0.0142	0.011	0.0136	0.00345	11.5	97	6.21	143	377	3.31	Heavy clay-loam
Bulung'ur district	0 - 30	7.63	151	0.12	0.0071	0.0028	0.0049	0.00286	20	9.3	13.2	154	251	3.52	Heavy clay-loam

Reference values: Optimal soil conditions for palm cultivation generally include pH 6.5 - 7.5, nitrate nitrogen 20 - 30 mg/kg, available phosphorus 31 – 45 mg/kg, exchangeable potassium 201 - 300 mg/kg, and humus content 0.8% - 1.2%.

3.2. Interpretation of Soil Analysis

The agrochemical analysis showed that the soils of both experimental sites were slightly alkaline, with pH values of 7.63 - 7.67, which is within the acceptable range for palm seedling growth. Electrical conductivity values indicated moderate salinity in the Samarkand soil compared with the Bulung'ur soil.

The nitrate nitrogen content varied significantly between the two sites. The Samarkand soil contained relatively high nitrate nitrogen levels (97 mg/kg), whereas the Bulung'ur soil showed lower concentrations (9.3 mg/kg), suggesting possible nitrogen limitation in that site. Available phosphorus content ranged from 143 to 154 mg/kg, which exceeds typical optimal levels and may contribute positively to early plant development.

Exchangeable potassium levels were also relatively high, especially in the Samarkand soil (377 mg/kg), indicating good potassium availability for plant uptake. The humus content ranged from 3.31% to 3.52%, reflecting relatively fertile soils with substantial organic matter.

Both soils were classified as heavy clay-loam in mechanical composition, which can influence water retention and nutrient availability for palm seedlings. Overall, the soil analysis provided important baseline information for interpreting the growth responses of palm species to mineral fertilizer treatments in the subsequent experiment.

For our research, we selected the following species of palm trees: *Trachycarpus fortunei*, *Wagneria-Trachycarpus wagnerianus*, *Washington-Washingtonia robusta*, and *Canary-Jubaea chiliensis*. The fertilization process starts in the third decade of March.

In our experiment, we conducted trials on these palm species, which belong to the Arecaceae family. For each species, we applied different fertilizers: a certain amount of potassium fertilizer to some, phosphorus fertilizer to another part, and nitrogen fertilizer to the remaining part, applying it several times. In the case of *Trachycarpus fortunei*, when 62 of the 250 seedlings were treated with a solid nitrogen fertilizer, I observed that the seedlings grew 2 cm taller than those growing without fertilizer. From this, it can be concluded that the *Trachycarpus fortunei* species has a very low nitrogen requirement. Even when 62 of the seedlings were fed with potassium water (three times a year—March, June, and September), the difference from those not treated with this mineral food was not significant. However, when *Trachycarpus fortunei* seedlings were treated with phosphorus-based mineral fertilizer (twice a year—in March and July), they showed a darker color and were much taller compared to those fertilized with nitrogen and potassium.

The same results were observed for *Trachycarpus wagnerianus* seedlings. In this species, the seedlings without mineral fertilization grew 3 cm taller, while those treated with nitrogen fertilizer showed a 5 cm increase. When the *Trachycarpus wagnerianus* seedlings were fed with potassium solution, their height increased to 6 cm. In the case of phosphorus fertilization, the effect of the mineral nutrients was more evident, with a growth of over 7 cm. I also observed that their color became darker.

We also studied the need for mineral fertilizers in another palm species, Washingtonia robusta. The growth rate of this species was much faster compared to other species, and it clearly demonstrated a higher nitrogen requirement. In the control group without any fertilizer, the growth reached 13 cm, while initially, the seedlings measured 28 - 29 cm. After nitrogen fertilization, the palms grew to nearly 1 meter. Seedlings treated with phosphorus-based mineral fertilizer grew up to 70 cm. In the potassium solution, their height increased to just over 0.5 meters.

Finally, looking at the mineral nutrient requirements of *Jubaea chiliensis*, the seedlings treated with phosphorus-based mineral fertilizers showed a higher growth rate. Initially, the height of *Jubaea chiliensis* seedlings was 29 cm, but after two rounds of phosphorus fertilization (in March and July), I observed that their height increased by almost 0.5 meters. Seedlings treated with potassium and nitrogen fertilizers showed similar growth rates to those treated with phosphorus, with only a small difference. Even the seedlings that were not treated with any mineral fertilizers showed a growth increase of up to 41 cm.

The growth of *Trachycarpus fortunei* seedlings showed clear responses to mineral fertilizer treatments throughout the experimental period (**Table 2**). Phosphorus-treated seedlings exhibited the most pronounced growth, reaching 34.1 ± 1.4 cm by November, which was significantly higher than all other treatments (group a). Nitrogen treatment also enhanced growth (33.0 ± 1.3 cm, group b), while potassium and control treatments showed comparatively lower growth (31.9 ± 1.1 cm and 31.5 ± 1.2 cm, both group c). Monthly dynamics indicate that phosphorus supplementation promoted faster growth from June to September, with seedlings consistently outperforming other treatments during these months. Nitrogen treatment had a moderate effect, improving growth relative to the control but lagging behind phosphorus. Potassium treatment showed a slight early advantage in July but did not significantly enhance final height compared with the control.

Trachycarpus wagnerianus exhibited slower growth overall, consistent with its smaller initial size. Phosphorus treatment significantly increased seedling height, culminating in 25.0 ± 1.0 cm by November (group a), compared to nitrogen (23.0 ± 0.9 cm, group b), potassium (23.9 ± 0.9 cm, group c), and control (20.5 ± 0.8 cm, group d).

Table 2. Monthly growth of ornamental palm seedlings under mineral fertilizer treatments (cm, mean ± SD with ANOVA letters).

Species	Treatment	May	Jun	Jul	Aug	Sep	Oct	Nov
Trachycarpus fortunei	Control	20.5 ± 0.5c	22.0 ± 0.6c	24.5 ± 0.7c	25.5 ± 0.8c	26.5 ± 0.8c	28.5 ± 0.9c	31.5 ± 1.2c
	Nitrogen (N)	21.5 ± 0.6b	23.5 ± 0.7b	25.5 ± 0.8b	27.1 ± 0.9b	29.0 ± 1.0b	31.1 ± 1.1b	33.0 ± 1.3b
	Phosphorus (P)	23.0 ± 0.7a	25.0 ± 0.8a	27.0 ± 0.9a	29.5 ± 1.0a	31.5 ± 1.1a	34.1 ± 1.2a	34.1 ± 1.4a
	Potassium (K)	20.7 ± 0.5c	22.5 ± 0.6c	25.2 ± 0.7bc	26.3 ± 0.8bc	27.5 ± 0.9bc	28.7 ± 0.9c	31.9 ± 1.1c
Trachycarpus wagnerianus	Control	17.5 ± 0.4d	18.0 ± 0.5d	18.5 ± 0.5d	19.1 ± 0.6d	19.5 ± 0.6d	20.5 ± 0.7d	20.5 ± 0.8d
	Nitrogen (N)	18.5 ± 0.5b	19.9 ± 0.6b	20.5 ± 0.6b	21.1 ± 0.7b	21.7 ± 0.7b	23.0 ± 0.8b	23.0 ± 0.9b
	Phosphorus (P)	19.0 ± 0.5a	20.6 ± 0.6a	21.5 ± 0.7a	22.5 ± 0.7a	23.7 ± 0.8a	25.0 ± 0.9a	25.0 ± 1.0a
	Potassium (K)	18.0 ± 0.5c	18.9 ± 0.5c	20.2 ± 0.6c	20.7 ± 0.7c	21.5 ± 0.7c	22.4 ± 0.8c	23.9 ± 0.9c
Washingtonia robusta	Control	29.5 ± 0.9d	31.5 ± 1.0d	34.0 ± 1.1d	35.5 ± 1.2d	37.5 ± 1.3d	39.5 ± 1.4d	42.0 ± 1.6d
	Nitrogen (N)	40.1 ± 1.5a	45.1 ± 1.7a	56.0 ± 2.1a	66.8 ± 2.4a	73.9 ± 2.7a	80.4 ± 3.0a	91.0 ± 3.2a
	Phosphorus (P)	30.5 ± 1.0c	33.4 ± 1.1c	38.7 ± 1.3c	42.5 ± 1.5c	45.3 ± 1.6c	48.4 ± 1.7c	51.5 ± 1.8c
	Potassium (K)	35.2 ± 1.2b	38.1 ± 1.3b	45.1 ± 1.6b	50.1 ± 1.8b	56.2 ± 2.0b	64.0 ± 2.3b	70.0 ± 2.5b
Jubaea chilensis	Control	30.0 ± 0.8c	31.5 ± 0.9c	33.5 ± 1.0c	35.0 ± 1.1c	36.5 ± 1.2c	39.0 ± 1.3c	41.0 ± 1.2c
	Nitrogen (N)	30.1 ± 0.8b	32.2 ± 0.9b	34.1 ± 1.0b	36.1 ± 1.1b	37.9 ± 1.2b	40.8 ± 1.3b	42.2 ± 1.4b
	Phosphorus (P)	32.5 ± 0.9a	34.8 ± 1.0a	36.9 ± 1.1a	38.5 ± 1.2a	41.1 ± 1.3a	43.4 ± 1.4a	43.4 ± 1.5a
	Potassium (K)	30.6 ± 0.8c	32.8 ± 0.9bc	34.6 ± 1.0b	36.5 ± 1.1b	38.5 ± 1.2b	39.7 ± 1.3bc	41.3 ± 1.3c

Note: The monthly growth measurements of four ornamental palm species under different mineral fertilizer treatments (control, nitrogen, phosphorus, and potassium) are presented in Table 2. The data include mean heights (cm) ± Standard Deviation (SD) and ANOVA-based Tukey HSD letters (a-d) indicating statistically significant differences among treatments for each species at $p < 0.05$.

The monthly pattern shows steady growth under phosphorus, with a marked acceleration between July and September. Nitrogen and potassium treatments demonstrated moderate improvement over the control, but only phosphorus provided a statistically significant enhancement of growth throughout the experiment. These results indicate that *T. wagnerianus* is particularly responsive to phosphorus during early vegetative development.

Among the studied species, *Washingtonia robusta* responded most dramatically to nitrogen fertilization. Seedlings under nitrogen treatment reached 91.0 ± 3.2 cm by November (group a), which was substantially higher than phosphorus (51.5 ± 1.8 cm, group c), potassium (70.0 ± 2.5 cm, group b), and control (42.0 ± 1.6 cm, group d).

The growth curves show that nitrogen treatment induced rapid elongation starting from May, with pronounced monthly gains, particularly between June and October. Potassium also enhanced growth relative to control, but to a lesser extent than nitrogen. Phosphorus treatment had minimal impact, suggesting that *W. ro-*

busta seedlings have a higher demand for nitrogen to support vegetative growth.

The growth response of *Jubaea chilensis* seedlings was moderate, with phosphorus treatment again providing the highest final height (43.4 ± 1.5 cm, group a). Nitrogen treatment slightly increased growth (42.2 ± 1.4 cm, group b) compared to control (41.0 ± 1.2 cm, group c) and potassium (41.3 ± 1.3 cm, group c). Monthly monitoring indicates that phosphorus enhanced early growth from May to August, maintaining a consistent advantage over other treatments. Nitrogen treatment accelerated growth in mid-season (June-October), while potassium treatment had minor effects on overall height (**Table 2**).

General Observations: Treatment effect: Across all species, phosphorus and nitrogen fertilization significantly promoted seedling growth compared with the control, whereas potassium generally had a lesser effect, depending on species. *T. fortunei* and *T. wagnerianus were* most responsive to phosphorus, highlighting the importance of phosphorus in early vegetative development. *W. robusta* exhibited a strong preference for nitrogen, consistent with its rapid vegetative growth habit. *J. chilensis* responded moderately to both phosphorus and nitrogen, suggesting balanced nutrient requirements. Monthly growth dynamics: Fertilizer effects were detectable from the earliest measurements in May and persisted throughout the study, demonstrating that early nutrient supplementation is critical for optimal seedling development. Statistical significance: The use of ANOVA with Tukey HSD letters allows clear visualization of treatment differences, confirming that nutrient management strategies should be species-specific for ornamental palms.

The data presented in **Figure 1** illustrate the monthly growth responses of four ornamental palm species (*Trachycarpus fortunei*, *Trachycarpus wagnerianus*, *Washingtonia robusta*, and *Jubaea chilensis*) to different mineral fertilizer treatments (control, nitrogen, phosphorus, and potassium) from May to November 2024. Each value represents the mean height (cm) ± Standard Deviation (SD) of seedlings, with ANOVA-based Tukey HSD letters indicating statistically significant differences among treatments at $p < 0.05$. Across all species, phosphorus and nitrogen significantly enhanced seedling growth compared to the control, while potassium generally produced a moderate effect. Phosphorus was particularly effective for *Trachycarpus species* and *Jubaea chilensis*, supporting the critical role of phosphorus in early vegetative development. Nitrogen showed a pronounced effect on *Washingtonia robusta*, indicating a high nitrogen demand to sustain rapid vegetative growth. *Trachycarpus fortunei* and *T. wagnerianus* seedlings responded most strongly to phosphorus, with consistently higher growth each month relative to other treatments. *Washingtonia robusta* exhibited maximal height under nitrogen treatment, achieving a final growth of 91.0 ± 3.2 cm, significantly surpassing other treatments. *Jubaea chilensis* showed moderate growth enhancement under both phosphorus and nitrogen, with potassium and control producing lower but comparable growth. Fertilizer effects were detectable from the first measurement in May and persisted throughout the growing season. Phosphorus treatments accelerated growth particularly from June to September, while nitrogen accelerated growth of *W. robusta* consistently throughout the season. Potassium treatment had limited influence, primarily affecting early-season growth in *Trachycarpus fortunei* but showing little impact on final height. Different ANOVA letters within each month indicate statistically significant differences ($p < 0.05$) among treatments. Seedlings sharing the same letter are not statistically different, whereas seedlings with different letters indicate significant variation due to fertilizer treatment. The results demonstrate that nutrient management should be tailored to each species, with phosphorus prioritized for *Trachycarpus* and *Jubaea*, and nitrogen emphasized for *Washingtonia*. Early-season fertilization is crucial for promoting consistent growth trends, as treatment effects manifest rapidly and continue throughout the season.

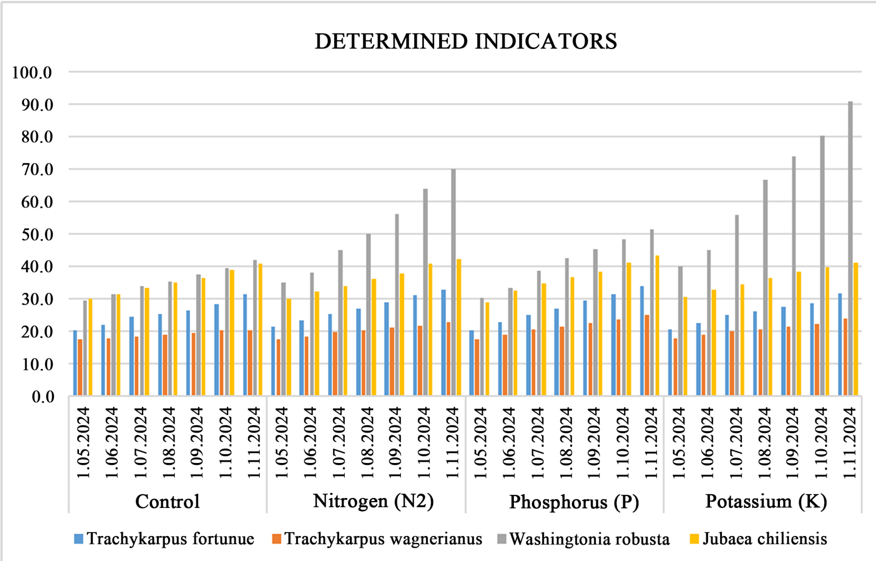

Figure 1. Monthly growth of ornamental palm seedlings under different mineral fertilizer treatments (May-November 2024).

As a result of our research, it was found that phosphorus fertilizers had a more positive effect on the growth and development of *Trachycarpus fortunei* and *Trachycarpus wagnerianus* species compared to other mineral fertilizers (potassium and nitrogen). (**Figure 2**, **Figure 3**)

In Washingtonia robusta palms, seedlings treated with nitrogen fertilizers showed a higher number of green leaves, and the leaves were somewhat smaller. Subsequently, potassium fertilizer was applied in proportion to the amount of nitrogen. Over a period of 30 - 35 days, not only was the number of leaves greater, but they also became larger, as observed in the experiment.

Similar to Trachycarpus palms, it was observed in the experiment that seedlings of *Jubaea chiliensis* also developed more rapidly when phosphorus fertilizers were applied. (**Figure 4**)

From **Figure 5**, it is clear that when the palms are grown without mineral fertilizers, their growth and development process is very slow. Palms that were fed with mineral fertilizers show better development compared to the control group of palms.

Figure 2. T*rachykarpus fortunue*.

Figure 3. *Trachykarpus wagnerianus*.

Figure 4. *Washingtonia robusta*.

Figure 5. *Jubaea chiliensis*.

The role of organic fertilizers in feeding palms is invaluable. The four palm species we examined in the experiment were planted in soils treated with organic fertilizers. If they are treated with organic fertilizers every 6 months, we can grow palms like those in coastal countries such as Mexico, Saudi Arabia, and the tourist-rich city of Dubai.

One of the important factors that accelerates the growth of palms and the process of producing new leaves is regularly cutting off the old lower leaves. Cutting the lower leaves enhances the decorative beauty of the palms.

Feeding palm trees with mineral fertilizers is done throughout the entire vegetation period during the palm growth stages. They are not fed during the winter season. From the second decade of September, fertilization is stopped because growth slows down.

It is also important to note that phosphorus fertilizers ensure the proper development of the initial roots for palm seedlings grown from seeds. Therefore, it is advisable to give phosphorus fertilizer to all young palm seedlings. In later years, nitrogen and potassium fertilizers can also be applied. The age of the palms plays an important role in their nutrition.

Mineral fertilizers also play a significant role in combating diseases and pests. The use of mineral fertilizers (NPK) causes changes in the biochemical composition of the seedlings and reduces pests on the leaves. It should also be noted that the plants' tolerance increases, the labrum and parenchyma tissue increase, the cuticles strengthen, and the plant's resistance to decay improves.

4. Discussion

The present study investigated the effects of three major mineral fertilizers—nitrogen (N), phosphorus (P), and potassium (K)—on the monthly growth of four ornamental palm species (*Trachycarpus fortunei*, *Trachycarpus wagnerianus*, *Washingtonia robusta*, and *Jubaea chilensis*) over a seven-month period (May–November 2024). The results demonstrate that species-specific responses to nutrient supplementation are evident, with phosphorus and nitrogen showing the most significant positive effects, while potassium had a moderate or minor impact depending on the species. *Trachycarpus fortunei* and *T. wagnerianus* seedlings responded most strongly to phosphorus, reaching final heights of 34.1 ± 1.4 cm and 25.0 ± 1.0 cm, respectively, under phosphorus treatment. This aligns with prior studies indicating that phosphorus is a critical nutrient for early vegetative growth, influencing root development, leaf expansion, and biomass accumulation [10]-[12]. Phosphorus likely promoted cell division and elongation, which explains the consistent growth advantage observed from June through September. Nitrogen treatment enhanced growth moderately, suggesting that these species have a lower relative nitrogen demand during early growth stages. In contrast, *Washingtonia robusta* showed a strong response to nitrogen, with seedlings achieving a maximum height of 91.0 ± 3.2 cm, significantly surpassing all other treatments (ANOVA, $p < 0.05$). Nitrogen is known to be essential for vegetative vigor, chlorophyll synthesis, and protein production, which likely contributed to the rapid height increase observed in this species [13]-[15]. Phosphorus and potassium treatments provided only moderate growth improvement, indicating that nitrogen is the primary limiting nutrient for *W. robusta* seedlings under the given soil conditions. *Jubaea chilensis* exhibited balanced responses to both phosphorus and nitrogen treatments, with final heights of 43.4 ± 1.5 cm and 42.2 ± 1.4 cm, respectively. Potassium treatment had a negligible effect, suggesting that while potassium is necessary for osmotic regulation and photosynthetic efficiency, its deficiency was not limiting under the experimental soil conditions. These results are consistent with prior studies on slow-growing palms, which indicate that nutrient demands vary according to growth rate and species physiology [16]. This study has several limitations that should be acknowledged. First, only seedling height was evaluated as a primary growth parameter, while other important morphological and physiological traits such as leaf area, biomass accumulation, root development, and chlorophyll content were not assessed. Previous studies have demonstrated that plant growth responses to fertilization are complex and multidimensional, requiring integrated evaluation of both aboveground and belowground traits to obtain a comprehensive understanding of plant performance [17] [18]. Second, the experiment focused exclusively on single-nutrient applications (N, P, or K), whereas in practical agricultural and horticultural systems, combined NPK fertilization is more commonly applied. Nutrient interactions, particularly synergistic effects among nitrogen, phosphorus, and potassium, play a crucial role in regulating plant growth and nutrient-use efficiency. Several studies have shown that balanced fertilization regimes often produce significantly higher growth responses compared to single-nutrient treatments [19] [20]. Third, the study was conducted under a single set of controlled nursery conditions using a pot experiment. While such conditions allow for better control of environmental variables, they may not fully represent field conditions where soil heterogeneity, climate variability, and biotic interactions influence plant growth. It has been reported that plant responses observed under controlled environments may differ substantially from those in open-field systems [21]. Furthermore, the use of a homogenized soil mixture limits the ability to evaluate site-specific soil effects, which are often critical in determining nutrient availability and plant response. Soil properties such as texture, pH, and organic matter content can significantly influence nutrient dynamics and plant uptake efficiency [22]. Therefore, future studies should incorporate multiple growth parameters, combined fertilization regimes, and diverse environmental conditions to provide a more comprehensive understanding of nutrient effects on ornamental palm species.

The monthly data highlight that fertilizer effects were apparent early in the season, with differences among treatments emerging from the first measurements in May. Phosphorus treatment accelerated growth in *Trachycarpus species* and *Jubaea chilensis*, while nitrogen promoted rapid growth in *Washingtonia robusta*. These trends persisted throughout the experimental period, indicating that early nutrient supplementation is critical for maximizing growth potential. The control groups in all species exhibited slower, steady growth, confirming that baseline soil nutrient levels were insufficient to support optimal growth. Monthly monitoring allowed the detection of species-specific growth dynamics, emphasizing the importance of nutrient management tailored to each palm species. These findings have important practical implications for the cultivation of ornamental palms: Phosphorus-rich fertilization should be prioritized for *Trachycarpus species* and *Jubaea chilensis*, particularly during early vegetative stages. Nitrogen fertilization is crucial for fast-growing species such as *Washingtonia robusta*, where nitrogen strongly influences stem elongation and leaf development. *Potassium supplementation*, while essential for physiological functions such as turgor maintenance and photosynthesis, may be applied as a secondary measure, particularly when soil levels are adequate. The timing of fertilizer application is critical: early-season application ensures sustained growth and maximizes height gain across species.

The results corroborate earlier research on palm nutrient management. Kultiasov [23] and Dart [24] reported that phosphorus is a limiting nutrient in early palm development, while nitrogen availability primarily affects fast-growing species. The observed patterns are also consistent with the ecological principle that nutrient requirements are species-specific, influenced by growth rate, morphology, and physiological characteristics.

5. Conclusions

This study evaluated the effects of nitrogen (N), phosphorus (P), and potassium (K) mineral fertilizers on the growth of four ornamental palm species (*Trachycarpus fortunei*, *Trachycarpus wagnerianus*, *Washingtonia robusta*, and *Jubaea chilensis*) over a seven-month period (May-November 2024). The results clearly demonstrate species-specific nutrient requirements and the importance of tailored fertilization strategies. Phosphorus significantly enhanced growth in *Trachycarpus species* and *Jubaea chilensis*, supporting early vegetative development, while nitrogen was the primary growth-limiting nutrient for *Washingtonia robusta*, resulting in the highest total height gain. Potassium had a moderate or limited effect across all species. Fertilizer treatments produced measurable growth differences from the first month, with effects persisting throughout the season, emphasizing the importance of early and timely nutrient application. These findings highlight that effective palm cultivation requires nutrient management adapted to species-specific demands: phosphorus-rich fertilization for *Trachycarpus* and *Jubaea*, and nitrogen-focused fertilization for *Washingtonia*. Properly applied mineral fertilizers not only maximize vegetative growth but also support sustainable use of soil nutrients and reduce the risk of nutrient leaching.

Overall, this study provides evidence-based guidelines for the cultivation of ornamental palms, demonstrating that species-specific fertilization enhances growth performance and can serve as a practical reference for nurseries and landscape management.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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