# Growth and Biochemical Responses of *Dracaena Angustifolia* and *Beaucarnea Rrecurvata* to Slow-Release Fertilizers

Berivan Abdalakhalq Ghareeb[1]

[1]Department of production of Mmedicinal Plant, College of Agriculture, Raparin University, Ranya, Iraq

Email: Berivan.garib@uor.edu.krd

**Abstract**

This study evaluates the performance of two slow-release fertilizers, Hydro Complex (HC; NPK12:11:18) and PG-Mix (PG; NPK14:16:18), on the growth performance, biomass accumulation, and biochemical composition of *Dracaena angustifolia* and *Beaucarnea recurvat* (syn. *Nolina recurvata*.).The aim was to determine the optimal application rate (0, 5, 10, and 15 g / plant) of these fertilizers to achieve maximum growth vigor and ornamental quality for these indoor plants. The experiment was conducted during the 2024 growing season using a factorial randomized complete block design with three replications. Data analysis included Principal Component Analysis (PCA) to identify variance drivers and Pearson correlation to examine relationships between vegetative and biochemical variables. Findings indicated that HC at 15 g per plant brought the most significant changes in vegetative growth, including plant height (46.86% increase in *D. angustifolia*), leaf count (149.42% increase), and root development. PCA showed that root volume, leaf fresh weight, and chlorophyll had the best positive loading on Component 1. Furthermore, 15 g of HC significantly improved nutrient levels (N, P, K), chlorophyll (89% increase), and carbohydrates (80% increase). While PG-Mix improved growth compared to controls, its effects were generally less noticeable than HC.

**Conclusion:** Based on these results, applying Hydro Complex at 15 g per plant at four-month intervals is suggested as the best slow-release fertilization practice to enhance the growth and ornamental quality of these indoor ornamental plants

**Keywords:** slow-release fertilizers, indoor plants, *Dracaena angustifolia*, Nutrient management, *Beaucarnea recurvata., Nolina.*

## 1. Introduction

The management of nutrient delivery in container-grown ornamental plants has shifted significantly toward the adoption of slow-release fertilizers (SRFs) as an efficient and ecologically sound alternative to traditional liquid fertilization. In conventional overhead irrigation systems, nutrients are often applied across broad areas, leading to substantial resource inefficiency. Previous research indicates that up to 70% of applied nutrients can be lost through leaching and runoff in overhead systems [1]. These losses are further exacerbated by factors such as pot spacing, canopy density, and the volume of the nutrient solution applied. Even with high-density container placement, a significant portion of the fertilizer fails to reach the target root zone, intercepted instead by foliage or falling between containers—a

problem that intensifies as plants mature and canopy cover expands [2].

In contrast, slaw-release fertilizers (SRFs) particularly coated fertilizers such as Osmocote and Multicote, provide a regulated nutrient supply through gradual nutrient release. This mechanism can reduce nutrient leaching and improve fertilizer-use efficiency [3]. PG-Mix, however, is a soluble powdered fertilizer and should not be classified as a coated fertilizer. of applications required during the production cycle [4, 5].

The efficacy of SRFs, including organic materials and synthetic formulations like ureaform or isobutylidene diurea (IBDU), is governed by the physical properties of the pellets, coating thickness, and environmental variables such as temperature and substrate moisture [4, 6]. Among these, Hydro Complex (HC) and PG-Mix (PG) are widely utilized in commercial nurseries for a diverse range of ornamental species, typically offering nutrient release duration of three to four months [6]. While the benefits of regulated nutrition have been documented in species such as *Ficus benjamina* [7, 8], *Chrysanthemum morifolium* [9], and various woody ornamentals [10], there remains a critical need to calibrate application rates for specific indoor ornamental species to maximize their growth potential and aesthetic value.

Despite the extensive literature on SRFs, comparative studies focusing on the differential physiological and biochemical responses of slow-growing, high-value indoor plants like *Dracaena angustifolia* and *Beaucarnea recurvata* remain limited. Specifically, there is a lack of data regarding how the distinct nutrient release kinetics of HC and PG formulations interact with the specific metabolic requirements of these two species under containerized conditions. This study is built on the hypothesis that the balanced nutrient availability provided by slow-release formulations will trigger species-specific metabolic adaptations, where the more stable release pattern of HC may be more conducive to the steady biomass accumulation of *D. angustifolia*, whereas *B. recurvata* might exhibit higher plastic response to varying levels of PG-Mix due to its unique water-storing coudex morphology.

Accordingly, this study aims to: (1) determine the optimal application rates of Hydro Complex and PG-Mix for the cultivation of *Dracaena angustifolia* and *Beaucarnea recurvata*; (2) evaluate and compare the influence of these two formulations on vegetative growth, biomass partitioning, and key biochemical parameters; and (3) provide evidence-based recommendations for precision nutrient management in professional indoor plant production.

## 2. Materials and Methods

### *2.1. Experimental design and plant materials*

The experiment was conducted during the 2024 growing season at the College of Agricultural and Engineering Sciences, University of Raparin, Kurdistan Region, Iraq. Two popular ornamental species were selected for the study: *Dracaena angustifolia* and *Beaucarnea recurvata*. To ensure experimental uniformity, one-year-old *D. angustifolia* specimens with a mean height of 40 cm were selected. For *B. recurvata*, specimens were standardized based on a mean stem length of approximately 30 cm and an average leaf count of 10 leaves per plant.

### 2.2. Growing Medium and Potting Conditions

Plants were transplanted into plastic pots (height: 22 cm; diameter: 18 cm), each containing 3.5 kg of a standardized growing substrate. The medium consisted of a mixture of peat moss, perlite, and clay soil in a 2:1:1 ratio (v/v) [11]. Prior to the commencement of the study, the physical and chemical properties of the substrate were analyzed to ensure a consistent baseline for nutrient application. Standard horticultural practices, including uniform irrigation schedules and integrated pest management, were strictly maintained across all treatments throughout the experimental period.

**Table A.** Table A illustrates some physical and chemical properties of the soils

| **Other Properties** | | | **Chemical Analysis** | | | **Physical Analysis** | |
|---|---|---|---|---|---|---|---|
| **Value** | **Parameter** | | **Value (%)** | **Parameter** | | **Value (%)** | **Parameter** |
| 2.14 | EC (dS $m^{-1}$) | | 0.19 | N | | 16.24 | Sand |
| 7.54 | pH | | 0.06 | $P_2 O_5$ | | 26.40 | Silt |
| Clay | Texture | | 0.21 | $K_2 O$ | | 57.36 | Clay |

### 2.3. Fertilizer Treatments and Application

Two commercial granular slow-release fertilizers (SRFs) were evaluated:

1. **Hydro Complex (HC):** NPK ratio. 12:11:18.
2. **PG-Mix (PG):** NPK 14:16:18 ratio

The fertilizers were applied at four distinct rates: 0 (unfertilized control), 5, 10, and 15 g per pot. Fertilizer were applied at four level ( 0 no fertilizer , 5, 10, 15 g / pot). To ensure a sustained nutrient supply, the total dosage was thoroughly mixed with the substrate as a single application, at a beginning of experiment ( mid-February) covering a total observational period of four months until mid of June.

### 2.4. Experimental Design and Statistical Framework

The experiment was structured Completely Randomized Design (CRD) as a 2 × 3 Factorial combination, two fertilizer type × three application rate ) plus one control treatment(0g) giving a total of 7 treatments as following :

- Factor A (Fertilizer Type): Two levels [Hydro Complex (HC) and PG-Mix (PG)].
- Factor B (Application Rates): Three levels [5, 10, and 15 g per pot].

ISSN 2072-3857

- Control Treatment: An additional unfertilized control (0 g) was maintained independently for comparisons, resulting in total of 7 distinct treatment (6 factorial combination + 1 control )

Each of the resulting 6 factorial combinations, along with the absolute control, was assigned to three independent replicates. For each plant species, this resulted in 21 experimental units (7 treatments × 3 replicates), making a total of 42 pots for the entire study.

The data were analyzed using Two-way Analysis of Variance (ANOVA) to determine the significance of the fertilizer types, application rates, and the A × B interaction , while a one-way ANOVA was applied to compare all seven treatments with the control. [12]. When significant differences were detected, mean separation was performed using LSD test at $p \leq 0.05$.

. The detailed treatment structure is summarized in Table 1.

**Table 1. Experimental treatment layout for *D. angustifolia* and *B. recurvata*.**

| Replications | Species | Application Rate (g/pot) | Fertilizer Type | Treatment ID |
|---|---|---|---|---|
| 3 | Both Species | 0 | None | T1 (Control) |
| 3 | Both Species | 5 | Hydro Complex (HC) | T2 |
| 3 | Both Species | 10 | Hydro Complex (HC) | T3 |
| 3 | Both Species | 15 | Hydro Complex (HC) | T4 |
| 3 | Both Species | 5 | PG-Mix (PG) | T5 |
| 3 | Both Species | 10 | PG-Mix (PG) | T6 |
| 3 | Both Species | 15 | PG-Mix (PG) | T7 |

..

### 2.2. Morphological and Physiological Measurements

At the conclusion of the experimental period, a comprehensive assessment of morphological parameters was conducted. For both *D. angustifolia* and *B. recurvata*, the recorded parameters included plant height (PH, cm), leaf number (LN), leaf length (LL, cm), leaf width (LW, cm), and stem diameter (SD, cm) using a digital vernier caliper. Biomass accumulation was evaluated based on the species of each plant

for *D.angustifolia*, by measuring leaf fresh weight (LFW, g) and leaf dry weight (LDW, g) after oven-drying at 70°C until constant weight. Root volume (RV, $cm^3$) was determined using the water displacement method. For *B. recurvata*, additional measurements specific to its morphology were taken, including stem length (cm), stem fresh and dry weights (g), and root dry weight (RDW, g).

**2.3. Biochemical and Nutrient Analysis**

Total chlorophyll content was determined spectrophotometrically following the methods described by [13], with results expressed as mg $g^{-1}$ of fresh weight. For nutrient profiling, dried leaf tissues were finely ground and subjected to micro-Kjeldahl digestion to determine total nitrogen (N, %) [14]. Phosphorus (P, %) content was quantified using the molybdenum blue colorimetric procedure [15], while potassium (K, %) concentration was measured via flame photometry [16]. Total soluble carbohydrates (%) were analyzed using the anthrone-sulfuric acid method as outlined by [17].

**2.4. Statistical Analysis**

The collected data for each species separately were subjected to a Two-way Analysis of Variance (ANOVA) to evaluate the main effects of fertilizer types, application rates, and their interaction. Mean separations were performed using the Least Significant Difference (LSD) at a significance level of $p \leq 0.05$. To further explore the multivariate relationships between treatments and measured variables, Principal Component Analysis (PCA) was performed on standardized data. Additionally, Pearson correlation coefficients were calculated to identify significant associations between morphological and biochemical traits. All statistical procedures were executed using R software (version 4.2.0), utilizing the *FactoMineR* package for PCA and *corrplot* for correlation matrix visualization.

**3. Result**

**3.1. *Dracaena Angustifolia***

**3.1.1. Vegetative Growth Parameters**

The application of slow-release fertilizers (SRFs) significantly enhanced the vegetative profile of *D. angustifolia* compared to the unfertilized control (Table 2). Plant height (PH) exhibited a dose-dependent increase, reaching its peak at the 15 g HC treatment (91.54 cm), representing a 47.86% improvement over the control. Notably, while the highest dosage of HC yielded the maximum height, no statistically significant differences were observed between the 10 g and 15 g rates, suggesting a threshold effect where moderate dosages are sufficient for optimal vertical growth.

**Table 2.** Effect of slow-release fertilizer type and application rate on vegetative growth parameters of *Dracaena angustifolia*.

| Stem diameter (cm) | Leaf width (cm) | Leaf length (cm) | Leaf number | Plant height (cm) | Treatment |
|---|---|---|---|---|---|
| $0.88^{d}$ | $2.30^{c}$ | $32.60^{d}$ | $25.33^{d}$ | $62.33^{e}$ | Control |
| $1.20^{c}$ | $2.70^{ab}$ | $35.90^{cd}$ | $36.33^{c}$ | $78.66^{d}$ | 5 g PG-Mix |
| $1.35^{bc}$ | $2.66^{b}$ | $39.13^{bc}$ | $37.33^{c}$ | $82.00^{cd}$ | 10 g PG-Mix |
| $1.61^{a}$ | $2.76^{ab}$ | $41.80^{b}$ | $38.33^{c}$ | $84.50^{bc}$ | 15 g PG-Mix |

ISSN 2072-3857

| | | | | | |
|---|---|---|---|---|---|
| 1.41$^{ab}$ | 2.66$^{b}$ | 36.66$^{cd}$ | 36.86$^{c}$ | 82.66$^{cd}$ | 5 g HC |
| 1.45$^{ab}$ | 2.76$^{ab}$ | 39.13$^{bc}$ | 46.66$^{a}$ | 91.50$^{a}$ | 10 g HC |
| 1.60$^{a}$ | 2.80$^{a}$ | 47.18$^{a}$ | 46.78$^{a}$ | 91.54$^{a}$ | 15 g HC |
| 0.18 | 0.12 | 4.23 | 4.15 | 5.82 | **LSD (0.05)** |

Means followed by the same letter within a column are not significantly different at $P \leq 0.05$ according to LSD test. HC = Hydro Complex; PG = PG-Mix.

A similar trend was observed in leaf production; HC at 10 g and 15 g stimulated the highest leaf proliferation, nearly doubling the leaf count relative to control plants. Leaf dimensions (length and width) also responded more vigorously to HC formulations compared to PG-Mix, particularly at the 15 g level. Stem diameter (SD) showed significant thickening under high fertilization rates, with both HC and PG-Mix at 15 g producing statistically identical results (1.60 cm and 1.61 cm, respectively), indicating that both fertilizers are equally effective in promoting secondary growth in this species.

**3.1.2. Biomass Accumulation**

Biomass accumulation was markedly influenced by the fertilizer type and application rate (Table 3). Leaf fresh weight (LFW) and dry weight (LDW) reached their maximum values under the 15 g dosage for both fertilizers. However, the PG-Mix at 15 g showed a slight numerical superiority in foliar biomass, although it remained statistically comparable to the 15 g HC treatment. In contrast, root parameters demonstrated a clear preference for the Hydro Complex (HC) formulation. The 15 g HC treatment significantly outperformed all other treatments in root volume (206.86 cm³) and root dry weight (51.55 g), achieving over a 100% increase compared to the control. This robust root response to HC suggests a more favorable nutrient release kinetic for subterranean development in *D. angustifolia*.

**Table 3.** Effect of slow-release fertilizer type and application rate on biomass accumulation and root parameters of Dracaena angustifolia.

| **Root dry weight (g)** | **Root volume (cm³)** | **Leaf dry weight (g)** | **Leaf fresh weight (g)** | **Treatment** |
|---|---|---|---|---|
| 18.90$^{e}$ | 101.60$^{d}$ | 21.70$^{e}$ | 136.35$^{e}$ | Control |
| 25.90$^{d}$ | 136.00$^{c}$ | 24.80$^{de}$ | 165.60$^{de}$ | 5 g PG-Mix |
| 33.00$^{c}$ | 172.89$^{b}$ | 28.98$^{cd}$ | 183.90$^{cd}$ | 10 g PG-Mix |
| 38.06$^{bc}$ | 176.00$^{b}$ | 56.77$^{a}$ | 271.66$^{a}$ | 15 g PG-Mix |
| 32.00$^{c}$ | 173.35$^{b}$ | 32.66$^{c}$ | 195.13$^{c}$ | 5 g HC |
| 37.96$^{bc}$ | 171.00$^{b}$ | 36.89$^{bc}$ | 203.95$^{bc}$ | 10 g HC |
| 51.55$^{a}$ | 206.86$^{a}$ | 50.00$^{ab}$ | 251.01$^{a}$ | 15 g HC |

| | | | | |
|---|---|---|---|---|
| 5.87 | 22.34 | 8.76 | 32.45 | **LSD (0.05)** |

Means followed by the same letter within a column are not significantly different at $P \leq 0.05$ according to LSD test. HC = Hydro Complex; PG = PG-Mix.

### 3.1.3. Biochemical Composition

The metabolic activity of *D. angustifolia*, reflected by chlorophyll and carbohydrate content, was significantly bolstered by SRF treatments (Table 4). Total chlorophyll reached its highest concentration in plants treated with 15 g HC (172.05 mg/100 g FW), which was approximately 89% higher than the control. Nutrient uptake patterns (N, P, and K) followed a progressive increase with higher application rates. Nitrogen and phosphorus levels peaked under the 15 g HC treatment, significantly exceeding those observed in the PG-Mix treatments at the same dosage. Total soluble carbohydrates also mirrored this trend, with the 10 g and 15 g HC treatments maximizing carbohydrate storage (58.01%). This strong biochemical response correlates with the observed increases in biomass, confirming that the HC formulation facilitates a more efficient photosynthetic and metabolic machinery in this species.

**Table 4.** Effect of slow-release fertilizer type and application rate on biochemical composition of *Dracaena angustifolia* leaves.

| **Total carbohydrates (%)** | **K (%)** | **P (%)** | **N (%)** | **Total chlorophyll (mg/100g FW)** | **Treatment** |
|---|---|---|---|---|---|
| $32.16^{e}$ | $1.80^{d}$ | $0.30^{e}$ | $0.89^{f}$ | $90.79^{e}$ | Control |
| $36.39d^{e}$ | $1.98^{cd}$ | $0.37^{d}$ | $1.00^{e}$ | $138.84^{d}$ | 5 g PG-Mix |
| $43.85^{c}$ | $2.10^{bc}$ | $0.42^{c}$ | $1.45^{c}$ | $148.00^{cd}$ | 10 g PG-Mix |
| $50.80^{b}$ | $2.24^{ab}$ | $0.53^{b}$ | $1.80^{b}$ | $163.45^{ab}$ | 15 g PG-Mix |
| $47.55^{bc}$ | $2.00^{c}$ | $0.43^{c}$ | $1.45^{c}$ | $137.10^{d}$ | 5 g HC |
| $58.01^{a}$ | $2.45^{a}$ | $0.59^{b}$ | $1.80^{b}$ | $161.20^{bc}$ | 10 g HC |
| $58.01^{a}$ | $2.39^{a}$ | $1.00^{a}$ | $2.17^{a}$ | $172.05^{a}$ | 15 g HC |
| 5.23 | 0.18 | 0.08 | 0.15 | 12.34 | **LSD (0.05)** |

Means followed by the same letter within a column are not significantly different at $P \leq 0.05$ according to LSD test. HC = Hydro Complex; PG = PG-Mix; FW = fresh weight.

## 3.2. *Beaucarnea Recurvata*

### 3.2.1. Vegetative Growth Parameters

Consistent with the trends observed in *D. angustifolia*, all fertilizer treatments significantly enhanced the vegetative growth of *B. recurvata* compared to the unfertilized control (Tables 5 and 6). Leaf proliferation was most pronounced under HC treatments, with the 15 g rate achieving a 149.42%

increase in leaf number over the control. However, statistical parity between the 10 g and 15 g HC rates suggests that leaf initiation in this species reaches an optimum at moderate application levels. While leaf width followed a similar plateau effect, leaf length continued to increase significantly at the highest HC dosage, reaching a maximum of 65.22 cm.

The accumulation of biomass also exhibited a robust response to fertilization. Both fresh and dry leaf weights reached their zenith at the 10 g and 15 g HC levels, with no significant differences between them. Interestingly, the architectural development of the stem (length and diameter) showed a high sensitivity even to the lowest HC dose (5 g), with all HC treatments yielding statistically equivalent stem dimensions. Nevertheless, the total stem dry weight followed a progressive upward trend, peaking at 40.72 g with the 15 g HC application, indicating sustained carbon sequestration in the stem tissue at higher nutrient levels.

**Table 5.** Effect of slow-release fertilizer type and application rate on leaf parameters of *Beaucarnea recurvata*.

| Leaf dry weight (g) | Leaf fresh weight (g) | Leaf width (cm) | Leaf length (cm) | Leaf number | Treatment |
|---|---|---|---|---|---|
| $3.55^{e}$ | $18.72^{e}$ | $0.47^{d}$ | $35.37^{e}$ | $19.65^{e}$ | Control |
| $5.27^{d}$ | $27.63^{d}$ | $0.67^{c}$ | $42.37^{d}$ | $28.65^{d}$ | 5 g PG-Mix |
| $6.25^{cd}$ | $36.63^{c}$ | $0.68^{c}$ | $55.18^{ab}$ | $41.34^{c}$ | 10 g PG-Mix |
| $8.34^{bc}$ | $41.62^{bc}$ | $0.72^{bc}$ | $54.41^{b}$ | $45.00^{bc}$ | 15 g PG-Mix |
| $12.34^{a}$ | $49.78^{ab}$ | $0.72^{bc}$ | $40.34^{d}$ | $42.67^{c}$ | 5 g HC |
| $16.25^{a}$ | $60.61^{a}$ | $0.97^{a}$ | $52.90^{bc}$ | $45.67^{ab}$ | 10 g HC |
| $16.23^{a}$ | $60.62^{a}$ | $0.96^{a}$ | $65.22^{a}$ | $49.01^{a}$ | 15 g HC |
| 2.87 | 9.45 | 0.12 | 5.64 | 3.87 | **LSD (0.05)** |

Means followed by the same letter within a column are not significantly different at $P \leq 0.05$ according to LSD test. HC = Hydro Complex; PG = PG-Mix.

Root system architecture was exceptionally responsive to HC fertilization. The 15 g HC treatment triggered a dramatic 328% increase in root volume relative to the control (92.67 $cm^3$ vs. 21.67 $cm^3$). This vigorous subterranean expansion highlights the high efficiency of the HC formulation in supporting the extensive root system typical of *B. recurvata*.

ISSN 2072-3857

**Table 6.** Effect of slow-release fertilizer type and application rate on stem and root parameters of *Beaucarnearecurvata*

| Root volume ($cm^3$) | Stem dry weight (g) | Stem diameter (cm) | Stem length (cm) | .Treatment |
|---|---|---|---|---|
| $21.67^{e}$ | $9.37^{e}$ | $2.74^{d}$ | $7.67^{d}$ | Control |
| $42.66^{d}$ | $16.98^{d}$ | $3.56^{c}$ | $11.01^{c}$ | 5 g PG-Mix |
| $41.00^{d}$ | $30.00^{c}$ | $4.10^{b}$ | $14.67^{ab}$ | 10 g PG-Mix |
| $51.35^{c}$ | $35.82^{bc}$ | $4.23a^{b}$ | $14.33^{b}$ | 15 g PG-Mix |
| $60.65^{bc}$ | $32.62^{c}$ | $4.53^{a}$ | $15.50^{a}$ | 5 g HC |
| $84.00^{ab}$ | $37.24^{b}$ | $4.63^{a}$ | $15.34^{a}$ | 10 g HC |
| $92.67^{a}$ | $40.72^{a}$ | $4.77^{a}$ | $15.46^{a}$ | 15 g HC |
| 12.34 | 4.56 | 0.34 | 1.23 | **LSD (0.05)** |

Means followed by the same letter within a column are not significantly different at $P \leq 0.05$ according to LSD test. HC = Hydro Complex; PG = PG-Mix.

### 3.2.2. Biochemical Composition

The biochemical response of *B. recurvata* revealed distinct differences compared to *D. angustifolia* (Table 7). Unlike the previous species, the highest total chlorophyll content in *B. recurvata* was observed under the PG-Mix treatment at 15 g (66.26 mg/100g Fresh Weight), followed by the 10 g rate. This divergence suggests that the nutrient release profile of PG-Mix may align more closely with the specific chlorophyll synthesis requirements of *B. recurvata*.

Despite the chlorophyll trend, nutrient uptake (N, P, and K) remained superior under the HC 15 g treatment, yielding the highest tissue concentrations across all analyzed elements. This confirms that while PG-Mix might favor pigment accumulation [18], the HC formulation remains more effective for overall nutrient acquisition. Total soluble carbohydrates also followed this trend, with the 15 g HC treatment resulting in a 65.5% increase over the control (48.00% vs. 29.00%). This high carbohydrate status in HC-treated plants provides a physiological explanation for the superior biomass and root volume observed, as the plants had greater energy reserves for structural growth [19].

**Table7.** Effect of slow-release fertilizer type and application rate on biochemical composition of *Beaucarnea recurvate* leaves

| Total carbohydrates (%) | K (%) | P (%) | N (%) | Total chlorophyll (mg/100g FW) | Treatment |
|---|---|---|---|---|---|
| 29.00$^{e}$ | 1.50$^{d}$ | 0.39$^{d}$ | 0.99$^{e}$ | 41.94$^{e}$ | Control |
| 31.00$^{de}$ | 1.90$^{c}$ | 0.40$^{d}$ | 1.40$^{d}$ | 49.29$^{d}$ | 5 g PG-Mix |
| 32.93$^{d}$ | 1.95$^{bc}$ | 0.43$^{cd}$ | 1.50$^{cd}$ | 58.66$^{b}$ | 10 g PG-Mix |
| 39.90$^{c}$ | 1.99$^{bc}$ | 0.47$^{bc}$ | 1.60$^{bc}$ | 66.26$^{a}$ | 15 g PG-Mix |
| 36.99$^{c}$ | 1.95$^{bc}$ | 0.44$^{cd}$ | 1.48$^{cd}$ | 48.01$^{d}$ | 5 g HC |
| 43.31$^{b}$ | 2.00$^{b}$ | 0.47$^{bc}$ | 1.69$^{b}$ | 53.43$^{c}$ | 10 g HC |
| 48.00$^{a}$ | 2.15$^{a}$ | 0.60$^{a}$ | 1.75$^{a}$ | 57.00$^{bc}$ | 15 g HC |
| 3.45 | 0.12 | 0.05 | 0.12 | 4.56 | **LSD (0.05)** |

Means followed by the same letter within a column are not significantly different at $P \leq 0.05$ according to LSD test. HC = Hydro Complex; PG = PG-Mix; FW = fresh weight.

### *3.3. Principal Component Analysis*

To further elucidate the integrated responses of *D. angustifolia* and *B. recurvata* to the fertilization regimes, a Principal Component Analysis (PCA) was performed (Figure 1). The first two principal components (PC1 and PC2) accounted for the majority of the total variance, effectively separating the treatments based on their physiological and morphological vigor.

Variables associated with plant vigor and biomass, such as root volume (RV), leaf fresh weight (LFW), and chlorophyll content (Chl), exhibited strong positive loadings on PC1 (horizontal axis). The spatial distribution in the biplot shows these parameters clustering towards the right, aligning with the high-dosage Hydro Complex (HC) treatments [20]. Interestingly, nutrient-related variables (N, P, and K) and structural parameters like photosynthetic pigment accumulation and subterranean storage reserves. stem diameter (SD) and leaf width (LW) formed a distinct tight cluster. This pattern suggests that while all these parameters respond to fertilization, the nutrient uptake efficiency and structural thickening are closely coupled processes within the multivariate structure [21].

PC2 (vertical axis) further differentiated the responses by separating vertical growth traits, such as plant height (PH), leaf length (LL), and leaf number (LN), from dry biomass partitioning. Total carbohydrates (TC) and root dry weight (RDW) showed positive loadings on PC2, positioning them in the upper quadrants, whereas leaf dry weight (LDW) tended toward the lower-left sector. This spatial configuration reveals that the slow-release fertilizers do not merely increase size, but rather orchestrate a multifaceted shift in resource allocation, balancing between

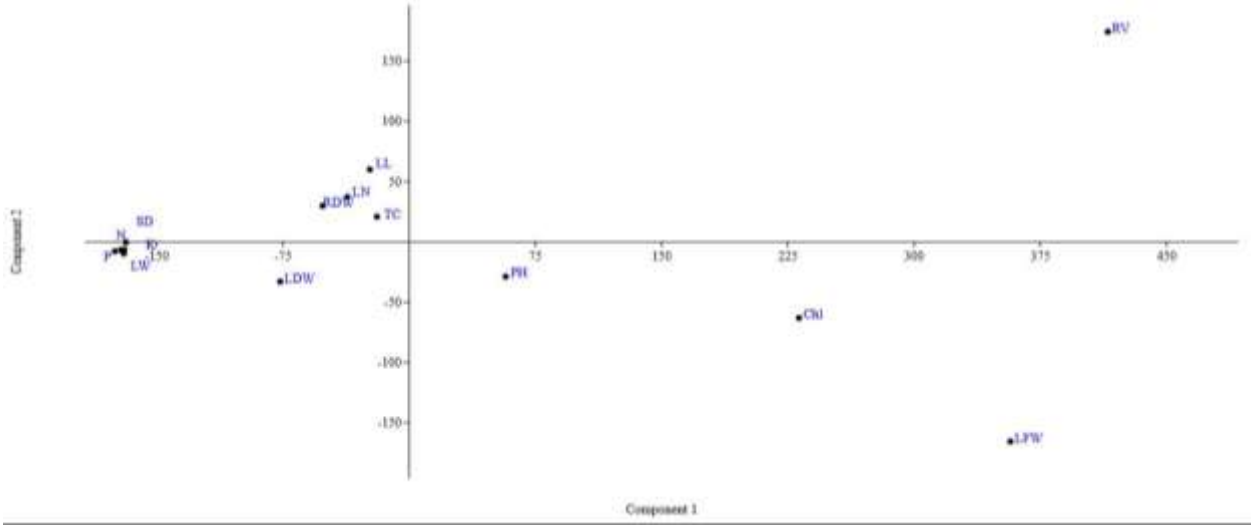



**Figure 1.** PCA biplot displays measured variables along the two main components of the data. PH = height of the plant; LN = number of leaf; LL = length of the leaf; LW = width of the leaf; SD = diameter of stems; LFW = fresh weight of leaf; LDW = dry weight of leaf; RV = volume of roots; RDW = dry weight of root; Chl = chlorophyll content; N = nitrogen; P = phosphorus; K = potassium; TC = total carbohydrates .

### 3.4. Correlation Analysis

The Pearson correlation matrix (Figure 2) revealed a comprehensive network of significant positive associations among the measured vegetative, biomass, and biochemical traits. A robust synergistic development pattern was evident, with plant height (PH) showing high-intensity correlations (r>0.80) with leaf number (LN), leaf length (LL), and stem diameter (SD). These strong interrelationships support the hypothesis that slow-release fertilization promotes a balanced architectural development rather than isolated growth spurts [22]

Biomass accumulation parameters (LFW and LDW) were intrinsically linked to the photosynthetic machinery, evidenced by their strong positive correlation with chlorophyll content (Chl, r = 0.60–0.80) and total carbohydrates (TC, r>0.75). This nexus confirms the direct physiological bridge between pigment density, carbon assimilation, and structural biomass buildup. Furthermore, the significant correlation between root volume (RV) and aboveground growth (r = 0.65–0.85) underscores a well-coordinated root-to-shoot signaling, where enhanced subterranean development, facilitated by the stable nutrient release of HC, directly supports more vigorous canopy expansion [23].

Conversely, some specific traits exhibited a more autonomous response. Leaf width (LW) showed weaker correlations with nutrient parameters, suggesting that leaf expansion in these species might be more genetically conserved or less sensitive to nitrogenous fluxes compared to leaf length or biomass [24]. Notably, the negative correlation observed between certain stem and root dry weight parameters in specific treatments (indicated by red circles) may point to an internal competition for photo-

assimilates—a "trade-off" where plants prioritize either stem thickening or root storage depending on the nutrient availability and fertilizer release kinetics.

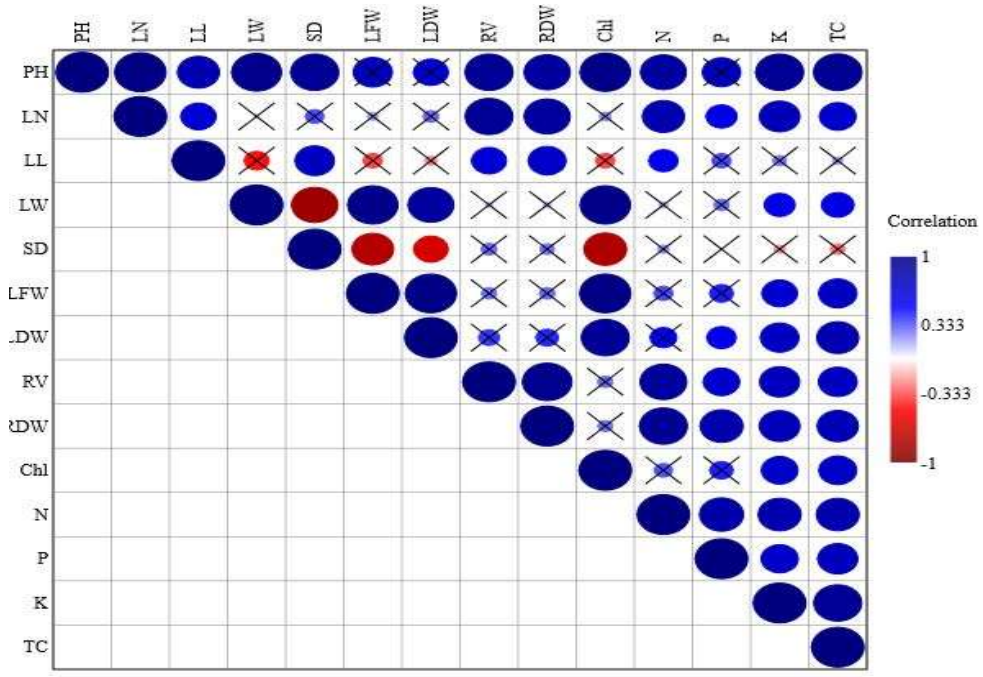



**Figure 2.** Pearson correlation heatmap of the two-way relationships between the measured variables. Blue circles show positive correlations, red circles show negative correlations, and X symbols show non-significant correlations ($P > 0.05$). The size of a circle indicates the value of the correlation coefficient. Variable abbreviations as Figure 1.

## 4. Discussion

The results of this study demonstrate that slow-release fertilization (SRF) using Hydro Complex (HC) and PG-Mix significantly optimizes the morpho-physiological and biochemical profile of *D. angustifolia* and *B. recurvata*. The superior performance observed at the 15g HC rate across most parameters validates the fundamental role of macronutrients (N, P, and K) in driving ornamental plant vigor [25]. However, the nuanced differences in species-specific responses and biomass partitioning suggest that the benefits of SRFs transcend simple nutrient addition, involving complex metabolic adjustments and resource allocation strategies.

### 4.1. Physiological Mechanisms Underlying Vegetative Vigor

The substantial increase in plant height, leaf number, and stem diameter under high SRF rates can be attributed to the sustained availability of nitrogen (N), which is a critical constituent of amino acids, proteins, and the porphyrin ring of chlorophyll [26, 28]. Our findings align with previous reports on *Brassaia actinophylla* and *Ficus benjamina* [29], where controlled nutrient

release prevented the "feast-and-famine" cycles typical of liquid fertilizers, thereby maintaining steady meristematic activity. The strong correlation found between N uptake and carbohydrate accumulation ($r > 0.75$) suggests that SRFs do not only boost chlorophyll synthesis but also enhance the efficiency of the photosynthetic electron transport system by providing the necessary nitrogen for cytochrome enzyme production [26, 30].

### 4.2. Root-Shoot Coordination and Biomass Partitioning

One of the most significant findings was the dramatic expansion of root volume (RV) and root dry weight (RDW), particularly in *B. recurvata* under HC treatments. The 328% increase in RV highlights a synergistic root-shoot development pattern, which was further confirmed by the high Pearson correlation coefficients ($r = 0.65–0.85$). From a physiological standpoint, the higher phosphorus (P) content in the HC formulation (16% vs 11% in PG-Mix) likely played a decisive role in early root primordia initiation and energy transfer (ATP), facilitating a more robust subterranean architecture [31]. The PCA biplot (Figure 1) confirms this, showing RV as a primary driver of treatment differentiation on PC1. This robust root system, in turn, provides a larger surface area for nutrient interception, creating a positive feedback loop that supports the observed increases in foliar biomass and stem thickening [32].

### 4.3. Species-Specific Metabolic Responses

A compelling aspect of our data is the divergence in chlorophyll response: *D. angustifolia* peaked under HC, whereas *B. recurvata* showed a preference for PG-Mix [33]. This "species-specific optimization" contradicts a "one-size-fits-all" fertilization approach. *B. recurvata*, characterized by its succulent-like stem and slower metabolic rate, may possess a different nutrient uptake kinetic that aligns more effectively with the release profile of PG-Mix. This metabolic plasticity is a critical finding, suggesting that for high-value indoor ornamentals, fertilizer selection must be calibrated to the specific physiological "tempo" of the species, as previously hinted at in studies on *Dracaena fragrans* [1] and other woody ornamentals [31].

### 4.4. Multivariate Integration and Resource Trade-offs

The multivariate approach through PCA and correlation matrices provided a deeper understanding than univariate ANOVA alone. The tight clustering of nutrient variables (N, P, K) away from biomass parameters in the PCA space indicates that nutrient "accumulation" and "utilization" for growth are distinct physiological phases. Furthermore, the occasional negative correlations between stem thickening and root storage in certain treatments point to an internal competition for photo-assimilate [33]. Under optimal SRF levels, the plants appear to reach a "metabolic equilibrium" where they can simultaneously invest in both structural (stem/leaf) and storage (root/carbohydrate) tissues, a key requirement for the longevity of indoor ornamental plants.

## 5. Conclusion

This study underscores the pivotal role of slow-release fertilization (SRF) in enhancing the morpho-physiological and biochemical profile of container-grown *Dracaena angustifolia* and *Beaucarnea recurvata*. Our findings confirm that the Hydro Complex (HC) formulation, particularly at the 15 g per plant rate, consistently maximizes vegetative vigor, root architecture, and

metabolic reserves. The multivariate integration through PCA identified root volume, foliar fresh weight, and chlorophyll density as the primary determinants of plant response, highlighting a well-coordinated developmental strategy under optimized nutrient flux.

While both SRF formulations outperformed the unfertilized control, the superior efficacy of HC is likely linked to its balanced N:P:K ratio, which facilitated robust subterranean expansion and sustained carbon assimilation. However, the distinct preference of *B. recurvata* for PG-Mix regarding chlorophyll synthesis serves as a critical reminder of species-specific metabolic plasticity.

**Practical Recommendation:** For commercial nursery production and indoor plant management, an application of 15 g **per plant of Hydro Complex** is recommended as the optimal fertilization regime for these species. This dosage ensures not only aesthetic quality through vigorous canopy growth but also long-term plant health by promoting extensive root systems and high carbohydrate storage. These insights into multivariate plant responses provide a foundational framework for precision nutrient management in a broader range of indoor ornamental crops, balancing agronomic productivity with resource efficiency.

**Conflict of intrestrst**

None

**Acknowledgements**

I gratefully acknowledge all the staff members at the College of Agriculture and Teaching staff , Qaladziy , Iraq for their support to this study.

**References**

[1] Xiang Y, Ji-yun J, Ping H, Ming-zao L. 2008. Recent advances on the technologies to increase fertilizer use efficiency. Agricultural Sciences in China 7(4): 469-479.

[2] Chien SH, Prochnow LI, Cantarella H. 2009. Recent developments of fertilizer production and use to improve nutrient efficiency and minimize environmental impacts. Advances in Agronomy 102: 267-322.

[3] Yuan-liang S, Zhi-jie W, Li-jun C, Xu-dong Z, Zong M. 2009. Development and application of slow release fertilizer. Agricultural Sciences in China 8(6): 10-12.

[4] Blaylock AD, Kaufmann J, Dowbenko RD. 2005. Nitrogen fertilizer technologies. In: Proceedings of the Western Nutrient Management Conference, Salt Lake City, UT, pp. 8-13.

[5] Hartrath H. 1986. Nitrogen should be released slowly. Gemüse 22(8): 332-334. 1.

[6] Kirk O. 1993. Encyclopedia of Chemical Technology: Controlled Release Technology 7(4): 251-27

[7] Collard RC, Joiner JN, Conover CA, McConnel DR. 1977. Influence of shade and fertilization on light compensation point of *Ficus benjamina*. Journal of the American Society for Horticultural Science 104(4): 447-449.

[8] Ticknor RL, Chaplin MH. 1987. Effect of slow release fertilizer sources on flower formation and nutrient composition in Rhododendrons. Combined Proceedings of the International Plant Propagators' Society 28: 101-105.

[9] Catanzaro CJ, Williams KA, Sauve RJ. 1998. Slow release versus soluble fertilization affects nutrient leaching of potted chrysanthemum. Journal of Plant Nutrition 21: 1025-1036.

[10] Worrall RJ, Lamont GP, O'Connell MA, Nicholls PJ. 1987. The growth response of container-grown woody ornamentals to controlled-release fertilizers. Scientia Horticulturae 32(3-4): 275-286.

[11] Snedecor GW, Cochran WG. 1981. Statistical Methods, 7th ed. Iowa State University Press, Ames, IA.

[12] Oliet J, Planelles R, Segura ML, Jacobs F. 2004. Mineral nutrition and growth of containerized *Pinus halepensis* seedlings under controlled-release fertilizer. Scientia Horticulturae 103(1): 113-129.

[13] Greig J, Motes J, Tikiriti A. 1968. Effect of nitrogen levels and micronutrients on yield, chlorophyll and mineral contents of spinach. Proceedings of the American Society for Horticultural Science 92: 508-515.

[14] Chapman HD, Pratt PF. 1961. Methods of Analysis for Soils, Plants and Waters. Division of Agricultural Sciences, University of California, Riverside, CA.

[15] Bringham FT. 1982. Boron. In: Page AL (ed.) Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. American Society of Agronomy, Madison, WI, pp. 431-447.

[16] Brown JO, Lilleland O. 1946. Rapid determination of potassium and sodium in plant material and soil extracts by flame photometry. Proceedings of the American Society for Horticultural Science 48: 341-346.

[17] Herbert D, Philipps PJ, Strange RE. 1971. Determination of total carbohydrates. Methods in Microbiology 5: 204-244.

[18] Lamont GP, Cresswell GC, Spohr LJ. 1988. Response of kentia palm (*Howea forsteriana*) to controlled-release fertilizer. Scientia Horticulturae 36(3-4): 293-302.

[19] Laiche AJ. 1991. Evaluation of slow release fertilizers to produce container-grown landscape plants. Research Report, Mississippi Agricultural and Forestry Experiment Station 16(7): 1-3.

[20] Klock-Moore KA. 2001. Effect of controlled-release fertilizer application rates on bedding plant growth in substrates containing compost. Compost Science and Utilization 9(3): 215-220.

[21] Jackson ML. 1973. Soil Chemical Analysis. Prentice Hall of India, New Delhi.

[22] Irish G. 2000. Agaves, Yuccas and Related Plants: A Gardener's Guide. Timber Press, Portland, OR.

[23] Hector GA, Russell DB, Timothy AV, Edwin HW, Lawrence PA. 2003. Effect of organic amendments and slow-release fertilizer on willow biomass production and soil chemical

ISSN 2072-3857

characteristics. Biomass and Bioenergy 25(4): 389-398.

[24] Huxley A. 1992. The New Royal Horticultural Society Dictionary of Gardening. Macmillan Press, London.

[25] Essa ZM. 1984. Studies on the effect of foliar nutrition on some flowering ornamental plants. MSc Thesis, Ain Shams University, Egypt.

[26] Devlin RM. 1975. Plant Physiology, 3rd ed. Affiliated East-West Press, New Delhi.

[27] Clemens J, Dennis DJ, Butler RC, Thomas MB, Ingle A, Welsh TE. 1998. Mineral nutrition of *Zantedeschia* plants affects plant survival, tuber yield, and flowering upon replanting. Journal of Horticultural Science and Biotechnology 73(6): 755-762.

[28] Marschner H. 1997. Mineral Nutrition of Higher Plants, 2nd ed. Academic Press, San Diego, CA.

[29] Conover CA, Poole RT. 1985. Comparison of a liquid fertilizer source with several slow release fertilizers on *Brassaia actinophylla* and *Ficus benjamina*. Foliage Digest 8(6): 1-3.

[30] El-Naggar AHM. 1994. Effect of different ratios and levels of some fertilizer on the vegetative growth, flowering and corms production of gladiolus. MSc Thesis, Alexandria University, Egypt.

[31] Abou-Taleb NS, Hassan SM. 1995. Effect of commercial and slow release fertilizers on the growth and chemical composition of two Dracaena species. Annals of Agricultural Science, Moshtohor 40(2): 853-865.

[32] El-Fawakhry FM, El-Naggar AH, El-Naggar AA. 2004. Physiological studies on growth and flowering of *Cyperus papyrus* L. 2- Effect of mineral fertilization and light intensity. Alexandria Journal of Agricultural Science 49(3): 107-119.

[33] El-Khateeb MA, Salem MA. 1988. Effect of chemical fertilization on growth and chemical composition of *Thuja orientalis* L. seedlings. Tanta University Journal of Agricultural Research 14(2): 925-935

ISSN 2072-3857