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Anthurium plowmanii growth in translucent and opaque pots under different photo-selective nets

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ABSTRACT

Indoor green plants, such as the *Anthurium plowmanii* (Anthurium Bird Nest group), are used to balance the domestic environment in large cities and stand out in this market. This study aimed to evaluate *in vitro* plantlets of *Anthurium plowmanii* cultivated under 30% photo-selective nets in the red, blue, and black spectra, and two kinds of pots, opaque and translucent. After one year of cultivation, plants under the red net showed a higher number of leaves per pot, fresh mass, and leaf length, regardless of the pot type. The roots were influenced by the type of pot, with a higher thickness of velamen in the roots grown in opaque pots. The presence of chloroplasts and chlorophyll in the cortical parenchyma of the roots is exclusively in translucent pots. No root escape was observed in either treatment at the end of the 12-month cultivation period.

Keywords: *Anthurium plowmanii*, ornamental, velamen, indoor, chlorophyll.

RESUMO

Crescimento de *Anthurium plowmanii* em vaso translúcido e opaco sob diferentes malhas fotosselativas

Plantas verdes de interior, como o *Anthurium plowmanii* (grupo dos Anthurium Bird Nest), são utilizadas para equilibrar o ambiente doméstico em grandes cidades e se destacam neste mercado. Assim, o objetivo do presente estudo foi avaliar mudas *in vitro* de *Anthurium plowmanii* cultivadas sob telas fotosselativas de 30% nos espectros vermelho, azul e preto, e em dois tipos de vasos, opaco e translúcido. Após um ano de cultivo, as plantas sob a tela vermelha apresentaram maior número de folhas por vaso, massa fresca e comprimento de folhas, independentemente do tipo de vaso. As raízes foram influenciadas pelo tipo de vaso, com maior espessura de velame nas raízes cultivadas em vasos opacos. A presença de cloroplastos e clorofila no parênquima cortical das raízes ocorreu exclusivamente em vasos translúcidos. Não foi observado escape de raízes dos vasos ao final do período de 12 meses de cultivo.

Palavras-chave: *Anthurium plowmanii*, ornamental, velame, indoor, clorofila.

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It is estimated that the urban population spends between 80% and 90% of their time indoors, with this percentage being even higher for children, the elderly, the sick, and people with disabilities, thus increasing the importance of the indoor environment (Samudro *et al.*, 2022; Liu *et al.*, 2022). In this context, indoor environmental pollution is often more severe than outdoor pollution due to the type of construction, use of synthetic materials, equipment, furniture, and human presence (Gao *et al.*, 2021). This condition, known as Sick Building Syndrome (SBS), is associated with symptoms of poor indoor air quality, including eye, nasal, and skin irritations, allergies, respiratory dysfunctions, headaches, fatigue, and metabolic disorders (Mentese *et al.*, 2020).

One of the main strategies to mitigate the effects of SBS is the introduction of green plants (Liu *et al.*, 2022). Additionally, the absence of green plants indoors has negative psychological effects that compromise the occupants' mental health (Samimi & Shahhosseini, 2021). The central question concerns which plant species are involved in and the magnitude of their impacts, as these factors directly influence ecological outcomes. In this context, the use of native species represents a suitable strategy for designers, as it can minimize local environmental impacts while enhancing plant acclimatization and long-term establishment (Abbasoglu & Kahramanoglu, 2025).

Among the species used indoors, *Anthurium* species are notable for their aesthetic effect and leaf shape, with eccentric veins contrasting with the color of the leaf blade, with varying shades and textures (Guimarães *et al.*, 2017; Maitan & Jasmim, 2020).

Anthurium species with a Bird Nest habit are found in tropical and subtropical environments, with 30 genera endemic to Brazil. The Bird Nest group is generally epiphytic, with a densely rooted caudex, rosulate leaves, commonly short-petiolate leaves, leaf blades typically thick, oblong, lanceolate to obovate, mostly coriaceous with usually free ending primary lateral veins (Morais *et al.*, 2017; Camelo *et al.*, 2021). It is adapted to indoor environments, rustic plants, and with great commercial potential been recommended sales height for Araceae foliage in 15/20 cm pots, ranging from 30 to 40 cm (FMA & FNGA, 2016).

Light quality and intensity are important inputs for horticultural production and photo-selective nets can be used to vary these parameters during greenhouse production (Almeida *et al.*, 2021). Colored shade nets were evaluated on foliage plants such as *Codiaeum variegatum* and *Aglaonema commutatum*. In this study, applying shading in yellow, green, and red colors, it was shown that high levels of anthocyanins and carotenoids were gained using the red net indicating a significant influence of light spectral modification on plant pigment composition (Abbasnia Zare *et al.*, 2020).

Light availability can significantly influence root development and, consequently, may determine the most suitable type of container used during cultivation. This effect is particularly evident in orchids of the genus *Phalaenopsis*, whose roots are capable of photosynthetic activity. In such cases, the use of translucent pots is recommended to enhance light penetration to the root system, thereby promoting improved growth and physiological performance (Wang *et al.*, 2007).

Despite their potential, there are no descriptions in the scientific literature about the cultivation and management of these species. The present study aims to evaluate the development of *in vitro* propagated plantlets of *Anthurium plowmanii* in two types of pots, under three different photo-selective nets, over a one-year protected cultivation cycle.

MATERIAL AND METHODS

Plant material and parameters

The plant material used consisted of *in vitro* propagated *Anthurium plowmanii* plantlets, acclimatized in 64-cell trays containing medium-textured coconut fiber substrate (AMAFIBRA). A total of 120 plantlets, with heights ranging from 3.0 to 4.0 cm and four leaves, were selected. The plantlets were transferred to two types of 15 cm Ø pots: translucent (TP) and opaque (OP), both filled with 250 g of the same substrate used for acclimatization. The experiment began on May 30, 2022 and lasted for 12 months in a greenhouse measuring 6.4 m in width and 36 m in length, oriented north-south, and covered with a polyethylene diffuser film with 100% transmissivity. Photo-selective nets (Polysak® Plastic Industries Ltd, Negev, Israel) with 5 mm thickness and 30% shading index were positioned 3.5 m above the ground. The photo-selective net treatments were red (RN), blue (BN), and black control (CN).

The photosynthetically active radiation (PAR) during the period evaluated in the protected environment was monitored using a Pyranometer sensor (LI-COR LI-200), and the temperature was measured with a 1400-101 sensor

(Figure 1), both connected to a data acquisition system consisting of a data logger (SultronXlite 9210). Pots were placed centrally within each treatment area to minimize spectral interference. The east side of the greenhouse was shaded with the corresponding spectrum to minimize the influence of early morning sunlight. Plants were irrigated with a drip-type irrigation system (flow rate of 8 L/h) and fertirrigated every two weeks with 30 mL of 6.0 g/L NPK solution (14-30-14) per pot.

The following parameters were evaluated at 12 months: number of leaves, leaf length (mean of three youngest leaves, in cm), plant height (from the base of the stem to the last open leaf in cm), fresh plant mass (kg), levels of chlorophyll a, b, and total, and root escape from the pot. Leaf chlorophyll levels were read on the last two mature leaves produced by each plant, obtaining three measurements at different points on each leaf, totaling six readings per experimental unit (ClorofiLOG CFL2060 – Falker™). The mean of the values obtained was considered for analysis. Fresh plant mass was determined by subtracting pot weight from the total.

Histological analysis

Histological analyses were conducted on the roots from all treatments to assess the presence and distribution of chloroplasts and chlorophyll. Root cross-sections segments (elongation zone) were excised, fresh-sectioned using a sliding microtome (SM200 R; Leica, Heidelberg, Germany) with disposable blades (Leica 818), and mounted directly in glycerin. Sections were observed under a microscope (Axioskop 2, Carl Zeiss, Jena, Germany). The diameter measurements of 10 sections of each treatment were evaluated using the Image J 1.46r software (<https://imagej.nih.gov/ij/>).

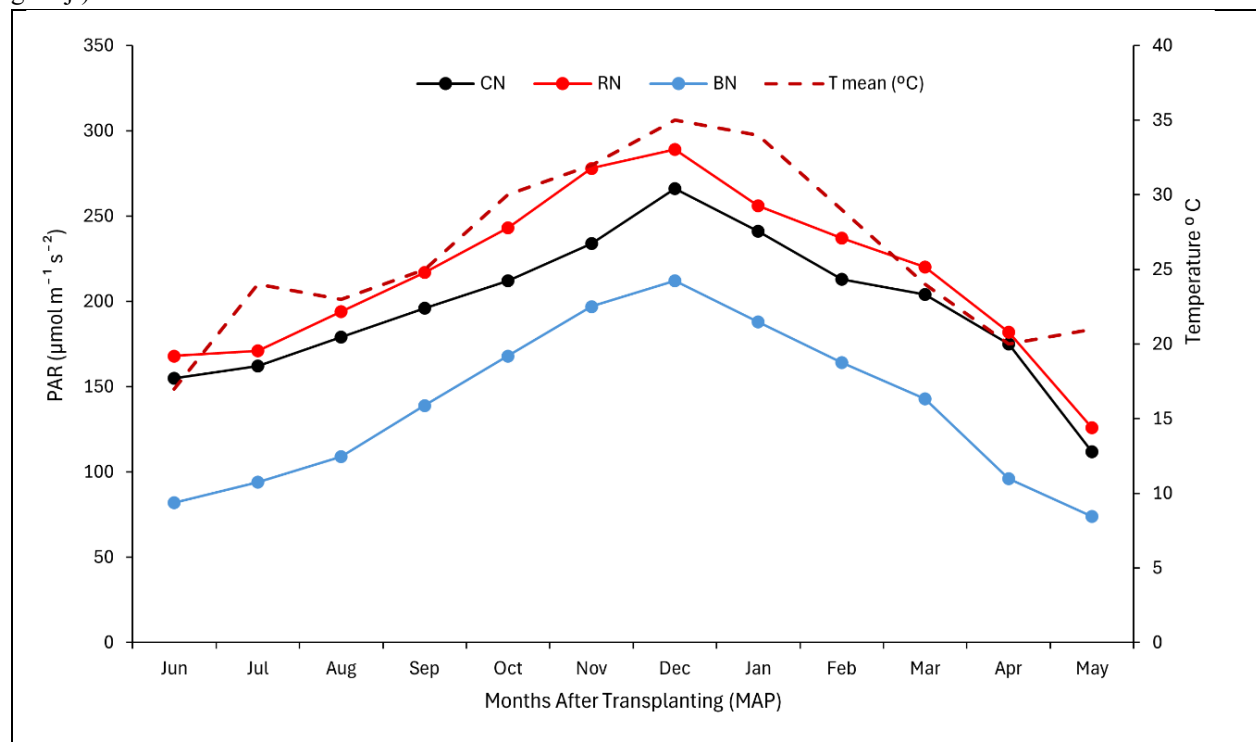


Figure 1. Monthly mean air temperature (°C) and photosynthetically active radiation PAR ($\mu\text{mol}/\text{m}^2/\text{s}$) recorded inside the greenhouse under photo-selective (red and blue) and control (black) shade nets in Piracicaba, São Paulo state, Brazil. Piracicaba, ESALQ, 2022-2023.

Statistical analysis

The experimental design was a completely randomized design (CRD), with treatments arranged in a 2x3 factorial scheme (two pot types and three photo-selective net spectra), totaling six treatments with 20 replicates (pots) per treatment, each containing one plant. For data that did not meet the assumptions of variance analysis (number of leaves and chlorophyll a), non-parametric Kruskal-Wallis and Dunn's multiple comparisons tests were conducted to compare

net colors within each category of pot type. Mann-Whitney non-parametric tests were used to compare pot types within each category of net color. The variables height, fresh mass, leaf length, total chlorophyll, chlorophyll b, and velamen density were analyzed using analysis of variance (ANOVA), followed by Tukey's test for multiple comparisons, with the R software and a significance level of 5%.

RESULTS AND DISCUSSION

After one year of cultivation, all plants met the commercial criterion (FMA & FNGA, 2016), and significant differences were observed between pot types or net treatments. In translucent pots (TP), plants grown under the red net (RN) exhibited both a higher mean leaf number and greater fresh mass compared to those under the blue net (BN) or black control net (CN) (Table 1). Conversely, under BN and CN, plants cultivated in opaque pots (OP) showed higher fresh mass than those in TP. Leaf length responses varied with pot type and net color: in OP, plants under RN had shorter leaves compared to BN and CN, whereas in TP, RN promoted longer leaves than CN. Overall, the longest leaf lengths were observed in TP under RN (Table 1).

Under BN, total chlorophyll and chlorophyll b levels were higher in OP (Table 1). Specifically in OP, under BN total chlorophyll values were higher than under other net colors, while in TP under RN, total chlorophyll values were lower compared to BN and CN (Table 1). Regardless of the pot type, plants under BN had higher chlorophyll a value compared to other treatments (Table 1). Chlorophyll b was higher under BN in OP, and, in TP, chlorophyll b was higher under BN than under RN.

Most scientific studies on anthurium have focused on *Anthurium andreaeanum* Lindel, widely explored as a cut flower and potted plant. However, there is a lack of scientific information on the cultivation of Araceae used for foliage, which does not possess commercial flowering characteristics. In the cultivation of *Dieffenbachia amoena* under different photo-selective nets, Khomami *et al.* (2023) found that blue nets resulted in plants with greater height, growth index, root fresh mass, and iron concentration. Conversely, in the cultivation of *Philodendron Xanadu* under blue, red, gray, and black nets, the greatest leaf production was observed under the red net and the lowest under the blue net (Stamps, 2009).

In this study, plants grown in TP under RN showed a higher number of leaves and fresh mass compared to other nets, greater leaf length compared to CN and OP, and lower chlorophyll levels. Plants under BN in TP had fewer leaves and lower fresh mass than those under RN, but exhibited higher chlorophyll a, b, and total levels than those under RN. Plants under BN in OP had longer leaf lengths compared to those under RN and higher chlorophyll a, b, and total values. The greater number of leaves and fresh mass under RN is closely related to the environmental conditions under RN in the greenhouse. Figure 1 shows that PAR radiation was higher under RN, followed by CN, and lower under BN. Adaptation to the environmental light spectra conditions in the greenhouse is associated with the plant's photosynthetic efficiency. These physiological responses will result in greater overall plant development (Almeida *et al.*, 2021).

In plants grown in TP, the presence of chloroplasts (green regions) in roots indicates chlorophyll occurrence, suggesting that these roots are photosynthetically active (Figure 2A and 2B). This was not observed in plants grown in OP (Figure 2I and 2J). Histological analysis revealed the presence of green chloroplasts beneath the velamen and epidermis, as well as within the cortical parenchyma of roots collected from translucent pots (TP) across all net treatments (Figure 2C–2H). In contrast, chloroplasts were absent in roots from opaque pots (OP) under all net treatments (Figure 2K–2P). Additionally, roots from OP exhibited a thicker, multilayered velamen compared to TP across all net treatments (Table 1).

The enhanced velamen in OP likely contributed to higher fresh mass, leaf number, and leaf length under BN and CN. Velamen radicum is a spongy rhizodermal tissue, either uni- or multilayered, composed of dead cells with thickened walls (Hauber *et al.*, 2020). Its functions include mechanical protection, reducing water loss, facilitating nutrient absorption, and UV protection (Rodriguez *et al.*, 2023). Araceae have adaptations for forming adventitious roots, which are advantageous for vegetative propagation. Furthermore, the evolution of adventitious roots has led to morphological and functional differences, including aerial roots for climbing and support, and soil-absorbing roots for water and nutrients (Croati & Ortiz, 2020; Liz Filartiga *et al.*, 2021).

Table 1. *Anthurium plowmanii* cultivation under red net (RN), blue net (BN), and black net (CN), and different pot types (translucent (TP) and opaque (OP). Means (standard deviation) of the variables studied: plant height (cm), leaf length (cm), fresh mass (kg), velamen thickness (μm), total chlorophyll, and b, and median (minimum; maximum) of leaves number and chlorophyll a, after one year of greenhouse production. Piracicaba, ESALQ, 2022-2023.

	Plant height (cm)		Leaves number		Leaf length (cm)		Fresh mass (kg)	
	Mean (standard deviation)		Median (minimum: maximum)		Mean (standard deviation)		Mean (standard deviation)	
	OP	TP	OP	TP	OP	TP	OP	TP
RN	42.95	43.03	100	9.5	21.83	24.60	0.32	0.32
	(6.88)	(5.12)	(5.0; 17.0)	(8.0; 25.0)	(5.42)	(4.64)	(0.07)	(0.14)
	Aa	Aa	Aa	Aa	Bb	Aa	Aa	Aa
BN	45.11	42.72	7.5	8.0	24.47	23.93	0.30	0.23
	(8.96)	(6.84)	(4.0; 33.0)	(5.0; 12.0)	(6.26)	(4.36)	(0.04)	(0.07)
	Aa	Aa	Aa	Ab	Aa	Ba	Aa	Bb
CN	42.11	41.56	9.0	8.0	23.37	22.50	0.31	0.21
	(5.50)	(4.34)	(6.0; 29.0)	(6.0; 11.0)	(4.87)	(2.14)	(0.04)	(0.06)
	Aa	Aa	Aa	Aa	Aa	Ab	Aa	Bb
	Velamen thickness (μm)		Total chlorophyll		Chlorophyll a		Chlorophyll b	
	Mean (standard deviation)		Mean (standard deviation)		Median (minimum: maximum)		Mean (standard deviation)	
	OP	TP	OP	TP	OP	TP	OP	TP
RN	100.97	25.56	61.18	58.91	33.5	33.8	27.52	25.43
	7.88	3.74	(5.47)	(6.06)	31.3; 35.4)	(29.9; 35.6)	(4.55)	(4.66)
	Ab	Bb	Ab	Ab	Ab	Ab	Ab	Ab
BN	94.14	49.65	75.11	68.85	36.0	35.5	39.17	33.49
	(2.41)	(15.98)	(7.44)	(7.52)	(34.2; 37.3)	(33.3; 36.6)	(6.89)	(7.01)
	Ab	Ba	Aa	Ba	Aa	Aa	Aa	Ba
CN	171.78	64.22	63.75	64.15	34.6	34.5	29.66	30.10
	(8.72)	(10.60)	(7.49)	(8.73)	(30.3; 35.5)	(30.0; 36.1)	(6.37)	(7.18)
	Aa	Ba	Ab	Aa	Aa	Ab	Ab	Aa

Means followed by distinct letters differ from each other by analysis of variance (Tukey test), while medians followed by distinct letters differ from each other by nonparametric tests (Dunn test). Uppercase letters compare treatments horizontally, while lowercase letters compare treatments vertically.

Despite the high velamen density in OP (Table 1), plants under RN in TP exhibited significantly superior leaf length, fresh mass, and plant height, although no significant differences were observed when compared to other treatments. The presence or absence of chloroplasts and chlorophyll in the roots, along with significant differences in velamen thickness across different pot types, demonstrates the adaptability of Araceae roots to environmental conditions. These results may contribute to studies on the origin of velamen in the *Anthurium* genus. It appears that the presence of velamen in this genus is not ancestral, having been lost and reacquired multiple times during its diversification (Werner *et al.*, 2024).

Regarding root escape from pots, no such phenomenon was observed during the cultivation of *Anthurium plowmanii* in this study (Figure 2 A and 2I). In some epiphytes, such as Phalaenopsis orchids, roots avoid dark environments and seek light, as they contain chloroplasts and are photosynthetically active. This behavior complicates cultivation management, causing root damage and reduced nutrient absorption (Blanchard & Runkle, 2008).

Transparent pots allow light penetration, which is believed to help maintain epiphytic roots in the substrate for *Phalaenopsis* cultivation (Wang *et al.*, 2007).



Figure 2. Plants and roots cross-sections of *Anthurium plowmanii*. A-B= Plant and roots in Translucid Pots (TP); C-D= general view and detail of root cross-section from TP under Red Net (RN); E-F: general view and detail of root cross-section from TP under Blue Net (BN); G-H= general view and detail of root cross-section from TP under Black Control Net (CN); I-J= Plant and roots in Opaque Pots (OP); K-L= general view and detail of root cross-section from OP under (RN); M-N= general view and detail of root cross-section from OP under (BN); O-P= general view and detail of root cross-section from OP under (CN). cl: chloroplasts; co: cortex; ep: epidermis; ve: velamen.

CONCLUSIONS

In conclusion, the use of photo-selective nets in the cultivation of *Anthurium plowmanii* influenced plant development, as did the pot types, with significant alterations in root characteristics. These results offer new insights into the cultivation and morphological adaptability of epiphytic Araceae.

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