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RESEARCH ARTICLE

Impact of control release fertilizers on vegetative, gas exchange attributes and nutrient status of *Philodendron erubescens*

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Abstract

Philodendron erubescens, commonly known as the Red-leaf Philodendron or Blushing Philodendron, is a popular ornamental plant species belonging to the family Araceae. Due to the bright red colour, this species is one of the leading indoor plants in commercial market. The current study investigated the efficacy of controlled-release fertilizers (CRFs) in accelerating the growth of tissue-cultured *Philodendron erubescens* (Pink Princess) to commercial saleable size in a nursery setting. Two CRF treatments - Basacote high K 6 M + hydrospeed CaB-Max and organic CRF + hydrospeed CaB-Max were compared against control using conventional water-soluble fertilizer. Forty-five-day-old tissue-cultured plantlets were evaluated over 60 days for morphological parameters, root development, physiological responses and nutrient uptake. A CI-340 Handheld photosynthesis machine was employed to measure photosynthetic rate, transpiration rate and stomatal conductance. Inductively Coupled Plasma-Mass Spectrometry (ICP -MS) was used for precise quantification of foliar macro- and micronutrient concentrations. Results demonstrated that Basacote high K 6 M + hydrospeed CaB-Max significantly outperformed both organic CRF + hydrospeed CaB-Max and the control in accelerating plant growth to commercial standards. Basacote high K 6 M + hydrospeed CaB-Max treated plants reached a mean height of 28.48 cm and spread of 27.09 cm after 60 days, approaching the target saleable size of 25 to 30 cm. Root morphology analysis using WinRHIZO software revealed enhanced root system development in Basacote high K 6 M + hydrospeed CaB-Max plants, indicating improved establishment. Physiological measurements showed higher photosynthetic rates (11.46 µmol m^{-2} s^{-1}), transpiration rates (1.32 mmol m^{-2} s^{-1}) and stomatal conductance (30.97 mmol m^{-2} s^{-1}) in Basacote high K 6 M + hydrospeed CaB-Max plants. ICP-MS analysis indicated superior nutrient uptake and accumulation in T1-treated plants, particularly for calcium, potassium, magnesium and iron. Strong positive correlations between physiological parameters and morphological traits suggest that enhanced nutrient availability from CRFs contributed to accelerated growth and improved plant quality. This study elucidates the potential of tailored CRF formulations to optimize the rapid establishment of tissue-cultured *P. erubescens* into marketable plants, offering valuable insights for commercial nursery production practices.

Keywords

Stomatal conductance; transpiration rate; photosynthetic rate; root morphology; control release fertilizer

Introduction

Philodendron of the Araceae family is the second largest and most diverse genus, consisting of more than 500 species. *Philodendron* species are native to tropical and subtropical regions of the Americas and the West Indies and their morphological characteristics range from small to large, with heart-shaped to palm-like, green to red and burgundy foliage. Furthermore, the plant's colourful heart-shaped leaves, which are dark purplish green with contrasting pink variegation, serve as a visual appeal to the buyers. Their growth tendencies range from climbing to arborescent or tree-like structures, making them perfect for decorative desk plants, hanging baskets, totems and potted plants. *Philodendron* species are the most popular foliage plants on the market, particularly in Thailand, due to their gorgeous leaves and capacity to grow indoors (1). *Philodendron erubescens*, often known as Philodendron Pink Princess is one of the most popular decorative variegated foliage plants. It is rare and expensive. Philodendron pink princess is mostly propagated through micro propagation. Control release fertilizers are usually applied at time of planting in containerized production system because of their long-term nutrient release. The release mechanism of coated fertilizers, which is the movement of nutrients from the fertilizer polymer interface to the polymer soil interface by swelling, degradation of the polymer coating, fracture or dissolution, depends on the kind of coating (2). Since nitrogen is typically the most significant component in coated fertilizers, the rate at which this nutrient releases from these substances determines how long the fertilizers will last (3). The temperature of the substrates has a positive relationship with the rates of nutrient release from different coated fertilizers (4). Hence, each manufacturer's formulation and coating, which are made of polymeric material, affect how the CRF reacts to environmental factors (5). The varied nutritional needs of plants which rely on the crop and its cycle phases, overall nutrient requirement and particular times of demand peaks (6), have contributed to the development of numerous types of CRFs with varying lifespans (7). As a result, various species should have varied substrate physical and chemical characteristics, nutrient requirements and fertilizer sources and rates. Studies assessing the impact of fertilization on the philodendron pink princess have not been reported so far. This study examines an efficient fertilization technique for rapid development of tissue-cultured Philodendron pink princess plants into substantial commercial plants in a nursery. Therefore, control release fertilizers were used for potting for efficient growth and to maximize labor efficiency. The current study aimed i) To investigate the impacts of different kinds of control release fertilizers on nutrition, morphology and physiology in Philodendron pink princess; ii) To compare the effect of CRFs and conventional fertilizers on nutrition, morphological and physiology in Philodendron pink princess and to evaluate the best treatment to reach quick commercial saleable size.

Materials and Methods

2.1. Preparation of potting substrate mixtures, plant material and treatments

This experiment was conducted at the Department of Floriculture and Landscape Architecture, Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. 45 days old tissue cultured Philodendron pink princess with an average height of 3.5 to 4 cm in giffy bags were used for this experiment. The potting media included vermiculite, perlite, coco chips and coir pith. Physical parameters of the media composition was: pH (6.68), EC (0.83 dsm^{-1}), bulk density (0.15 g/cc), particle density (0.50 g/cc), water holding capacity (420 %). During planting, all the fertilizers were applied directly under rhizosphere region. Two treatments and a control were evaluated with seven replications respectively. Treatment 1- Basacote high K 6 M, treatment 2 - organic CRF were used and a common spray of hydrospeed CaB-Max was given at 10 days interval time. 19-19-19 was used as control. Basacote high K 6 M + hydrospeed CaB-Max and organic CRF + hydrospeed CaB-Max were applied along with the potting media near the giffy bags in the pots. Control was applied at 3 g per plant at a 15 days interval. Observations were recorded at a 15 days interval. Mist blower was used for irrigation. 45 days old tissue cultured plants shown in Fig. 16 were transplanted. The experiment was carried out until the plant reaches a commercial size of around 25-30 cm in terms of height and 5-6 well developed leaves.

2.2. Sample nutrient analysis

To quantify the accurate value for the elements, present in different samples which directly alter the mineral composition of leaves, plant samples before fertilization and after fertilization were analysed using Inductively Coupled Plasma-Mass Spectrometry (8), Thermo Scientific™ iCAP™ RQ, equipped with micro mist borosilicate glass nebulizer; quartz cyclonic spray chamber; ICP torch, nickel sampler cone and skimmer cone, quadrapole mass analyser and mass spectrometry detector. All the samples were analzyed in Kinetic Energy Discrimination (He KED) mode using pure He as the collision gas in the collision/reaction cell (CRC) under optimized auto-tune conditions of the equipment directly from quality control with Qtegra™ Intelligent Scientific Data Solution™ (ISDS) Software. To automate the sampling process, an ASX 560 auto sampler (Omaha, NE, USA) was used. Sample digestion was performed through a closed-vessel microwave digestion system - Multiwave GO (Anton Paar) with a multi-wave pro rotor, temperature and pressure sensor, provided with an auto pressure vent PTFE vessel.

2.2.1. Preparation of calibration standard solutions

Accurately 1 mL of mixed standard reference solution was pipetted into a 100 mL volumetric flask and diluted to the volume to 100 mL using HPLC grade water. This was taken as the stock solution used for the preparation of calibration standard solutions and was stored under suitable conditions. Appropriate aliquots taken and further diluted with 5 % nitric acid in HPLC grade water to give a series of calibration standard solutions having the concentration range of 1.0, 20.0, 50.0 and 100.0 µg/L respectively.

2.2.2. Preparation of sample solutions

Approximately 0.20 ± 0.01 g, accurately weighed, dried homogenized powder samples (already milled with Teflon mortar to avoid metal contamination) of each soil and plant leaf sample were taken at the end of 45 days in 6.0 mL of concentrated ultra-pure HNO_3 in a tightly closed PTFE vessel and digested in a microwave digester separately. The digestion was carried out in three steps with constant microwave power. The program was set to increase the temperature to 160 °C in 10 min, maintain it for 5 min and then cool the digester to room temperature. The digested samples were then diluted with HPLC-grade water up to 50 mL. Plant leaf samples before and after fertilisation of the best treatment based on morphological parameters was analysed along with Basacote high K 6 M, organic CRF and hydrospeed CaB-Max fertilizer samples.

2.3. Physiological parameter analysis

Photosynthetic rate measurement was performed by using CI-340 Handheld photosynthesis machine. The leaf sample was placed into the chamber of the CI-340 Handheld photosynthesis machine. The sample was allowed to adjust to the light for 2 min before commencement. Then, the CI-340 Handheld photosynthesis machine automatically calculated photosynthesis and transpiration rates by comparing the levels of carbon dioxide and water vapour (respectively) inside the chamber and the atmosphere. Each analysis was conducted for 5 counts, which roughly equates to 10 min. The readings were taken between 9 am to 11.30 am. Measurements of photosynthesis, transpiration, stomatal conductance and internal CO_2 could be taken with minimal sample degradation because the chamber was connected directly to the CO_2/H_2O differential gas analyser. The short distance between the analyser and the leaf chamber decreases the possibility of leaks, water vapour change, or temperature change; therefore, keeping the integrity of the sample high. The unit is designed to perform several measurements, such as photosynthesis rates (µm/m^2/s), transpiration rates (mmol/m^2/s) and stomatal conductance (mmol /m^2/s), as well as measure the absolute and differential CO_2 concentrations of a leaf or plant.

2.4. SPAD value

SPAD readings were recorded by using a chlorophyll meter (SPAD 502) designed by the soil plant analytical development (SPAD) section, Minolta, Japan. The Minolta SPAD-502 measures chlorophyll content as a ratio of transmittance of light at wavelengths of 650 nm and 940 nm. Five readings were taken from each treatment and the average value was computed using the method described by Monje and Bugbee (1992).

2.5. Assessment of morphological parameters

2.5.1. Assessment of root morphology by using Win RHIZO software

The control and treatment root samples were collected from the experiment field without damaging the root and then washed thoroughly with distilled water to remove the soil, dust and debris. The washed root samples were placed in the tray filled with water and the roots were arranged without overlapping. The tray was placed in the dual-scan optical scanner attached to the system. The instrument WinRHIZO optical scanner (version 5.0) software was used to acquire the roots sample and the images were taken at 400 dpi resolution with color scale. The scanned root images of *Philodendron erubescens* were analyzed for various root growth and developmental parameters including total root length (TRL), surface area (SA), average diameter (AD), root volume (RV), number of tips (TP), forks (FR) and crossings (CR).

2.5.2. Shoot morphological parameter

Measurements were taken every 15 days until the plant achieved its commercial saleable size. The parameters included plant height (cm), leaf thickness (mm), leaf length (cm), leaf breadth (cm) and plant spread (cm).

3.1. Statistical analysis

Collected data were analysed by R software one-way ANOVA, to assess significant (P ≤ 0.05, 0.01 and 0.001) differences among treatments statistics and graphics were supported by Prism10 (GraphPad Software, Inc., La Jolla, California USA).

Results and Discussion

4.1. Morphological growth attributes

4.1.2. Plant height, width and number of leaves/plants

From the Table 1, it is clear that the impact of Basacote high K 6 M + hydrospeed CaB-Max, organic CRF + hydrospeed CaB-Max on vegetative growth traits of *Philodendron erubescens* had significant effects in comparison to the control plants. Fig.e1 showed that Basacote high K 6 M resulted in better growth parameters compared with any treatments followed by organic CRF + hydrospeed CaB-Max, while the control treatment was the least. The highest increase in plant height and plant width after 60 days was achieved by plants treated with Basacote high K 6 M + hydrospeed CaB-Max. Additionally, Basacote high K 6 M + hydrospeed CaB-Max were found to be more effective in increasing the plant spread after 60 days. From the Fig. 2 highest values in the plant spread after 60 days were recorded at Basacote high K 6 M + hydrospeed CaB-Max (28.48 cm), while the lowest values (19.20 cm) were recorded with the control.

4.1.3. Leaf dimensions (length and width of leaf blades)

The data in Table 2 reveals the response of length and width of leaves to the treatments. It followed a similar direction in height and plant spread. Most treatments

Table 1. Effect of different treatment on height (cm) and plant spread (cm) of *Philodendron erubscens.*

	Height (cm)				Plant spread (cm)			
Treatment	**15 days**	**30 days**	**45 days**	**60 days**	**15 days**	**30 days**	**45 days**	**60 days**
Basacote high K 6 M + hydrospeed CaB-Max	6.785 (2.605)[b]	15.191 (3.896)[a]	21.649 (4.652)[a]	28.48 (5.336)[a]	13.186 (3.631)[b]	19.224 (4.384)[a]	23.882 (4.887)[a]	27.092 (5.205)[a]
SE d	0.008	0.015	0.028	0.0224	0.017	0.013	0.014	0.019
CD (0.05)	0.018	0.032	0.056	0.045	0.036	0.029	0.03	0.04

Square root transformed values are given along the mean values. In a column, means followed by common letter(s) are not significantly different at P=0.05. The values are the mean values of replications at different day intervals respectively.

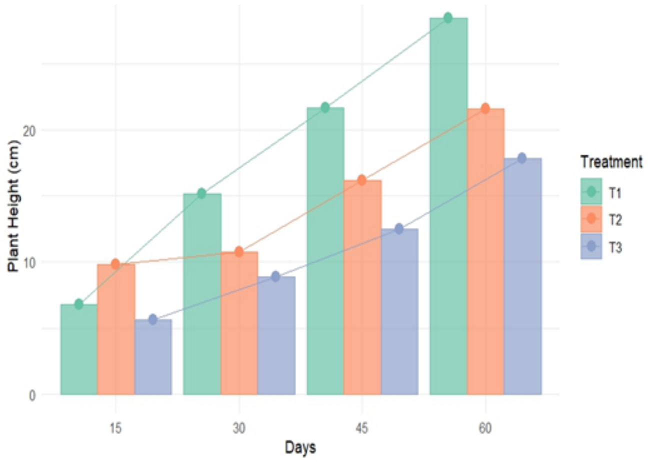


Fig. 1. Shows the graph of plant height in relation to 15, 30, 45, 60 days

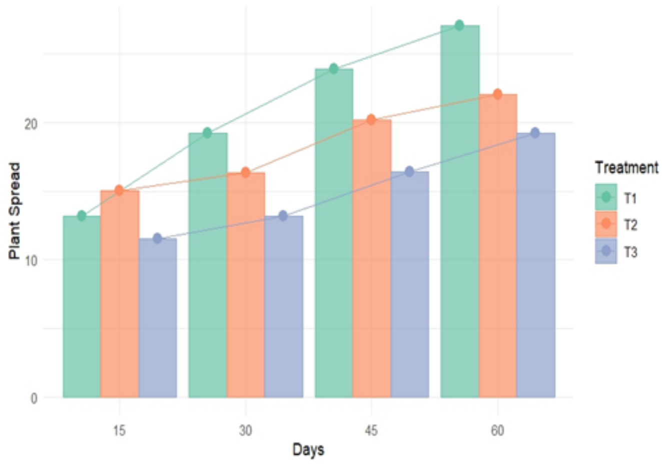


Fig. 2. Shows the graph of plant spread in relation with 15, 30, 45, 60 days

Table 2. Effect of different treatment on length and breadth of *Philodendron erubscens* leaf blades.

	Leaf length (cm)				Leaf breadth (cm)			
Treatment	**15 days**	**30 days**	**45 days**	**60 days**	**15 days**	**30 days**	**45 days**	**60 days**
Basacote high K 6 M + hydrospeed CaB-Max	5.802 (2.409[b]	12(3.543)[a]	15.484 (3.998)[a]	17.895 (4.23)[a]	3.307 (1.818)[b]	6.895 (2.717)[a]	7.493 (2.827)[a]	8.807 (2.968)
Organic CRF + hydrospeed CaB-Max	6.508 (2.551)[a]	9.0753 (3.013)[b]	12.1782 (3.561)[b]	14.773 (3.843)	4.000 (2.000)[a]	4.497 (2.235)[b]	5.904 (2.532)[b]	6.494 (2.548)
Control	4.493 (2120)[c]	7.4636 (2.740)[c]	9.3306 (43.135)[c]	11.189 (3.345)	2.808 (1.676)[c]	3.507 (2.002)c	4.497 (2.141)[c]	4.086 (2.121)
SE d	0.009	0.017	0.014	0.009	0.008	0.012	0.012	0.013
CD (0.05)	0.021	0.036	0.031	0.02	0.019	0.036	0.026	0.028

Square root transformed values are given along the mean values. In a column, means followed by common letter(s) are not significantly different at P=0.05. The values are the mean values of replications at different day intervals respectively.

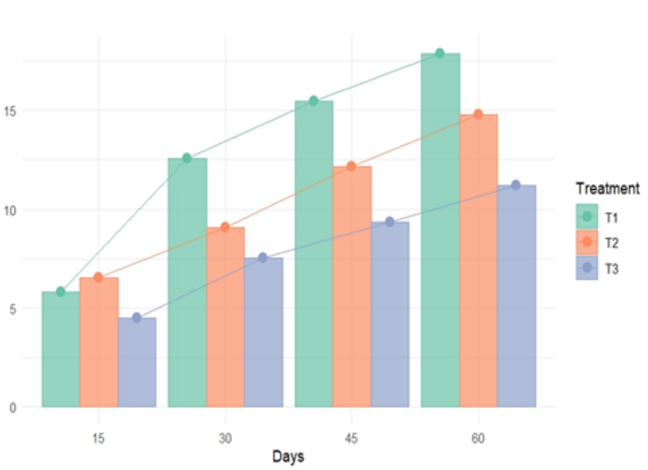


Fig. 3. Shows the curve of leaf length in relation to 15, 30, 45, 60 days

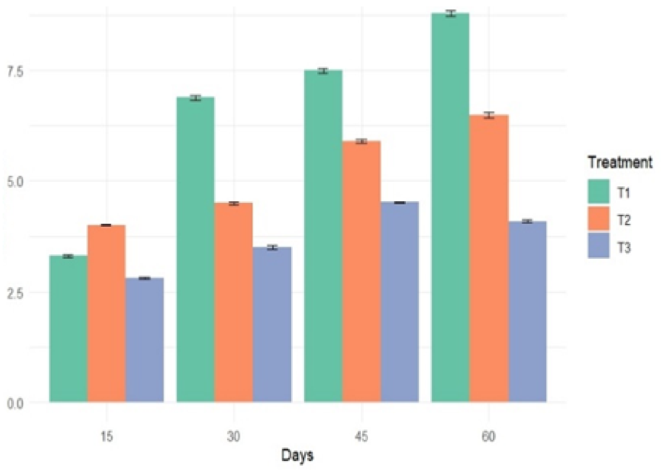


Fig. 4. Shows the curve of leaf breadth in relation with 15, 30, 45, 60 days

significantly increased the width of the leaf more than the untreated control plants after 60 days. Fig. 3 and 4 it can be summarised that application of Basacote + hydrospeed CaB-Max was most effective in increasing leaf parameters, giving the greatest mean blade length, blade width and at the end of 60 days. Plants treated with Basacote high K 6 M + hydrospeed CaB-Max, had significantly higher lengths compared to control plants after 60 days.

4.1.4. Leaf thickness

From Table 3 it could be summarised that Basacote high K 6 M + hydrospeed CaB-Max has better leaf thickness than organic CRF + hydrospeed CaB-Max and control. Basacote high K 6 M + hydrospeed CaB-Max measured the highest leaf thickness of 0.48 mm. Plants treated with organic CRF + hydrospeed CaB-Max had leaf thickness measurements of 0.65 mm and 0.48 mm for control treated plants shown in Fig. 5.

4.1.5. Root morphology

Among the tested treatments, there was a significant difference in root morphology in all the treated plots at 60 days. Total root length (230.95 cm), surface area (142.26 cm^2), average diameter (1.96 mm), root volume (6.37 cm^3), number of tips/plant (972), number of forks/plant (1761) and crossings (114) were observed as the best from organic CRF + hydrospeed CaB-Max plants. Least values of root morphology were observed in the control plot.

Following treatment 1, organic CRF + hydrospeed CaB-Max shows better root morphological parameters which include total root length (195.15 cm), surface area (80.183 cm^2), average diameter (1.87 mm), root volume (3.57 cm^3), number of tips /plant (748), number of forks /plant (565) and crossings (39) as mentioned in Table 4. The control has the least number in root morphological parameters which include total root length (136.33), surface area (131.04 cm^2), average diameter (0.56 mm), root volume (0.40 cm^3), number of tips /plant (458), number of forks / plant (350) and crossings (21). Effect of different CRF on *Philodendron erubescens* root morphology by using winRHIZO root image analyser is shown in (Fig. 12-14).

4.2. Nutrient content in leaves

The outcomes achieved using the He collision technique in ICP-MS, combined with MDS, provide detailed information on both micro and macronutrients in various matrices, including water, soil and plants. The data, presented in parts per million (ppm), represents the elemental composition of leaves under 2 treatments (treatment 1 and treatment 2).

4.2.1. Macro nutrients

In the present study the concentration of calcium in Basacote high K 6 M + hydrospeed CaB-Max treated leaves were 34352.546 ppm and in Basacote high K 6 M + hydrospeed CaB-Max is 26667.233 ppm. The potassium concentration in Basacote high K 6 M + hydrospeed CaB-Max was 46446.322 ppm and in organic CRF + hydrospeed CaB-Max, applied with organic CRF it was 26677.812 ppm.

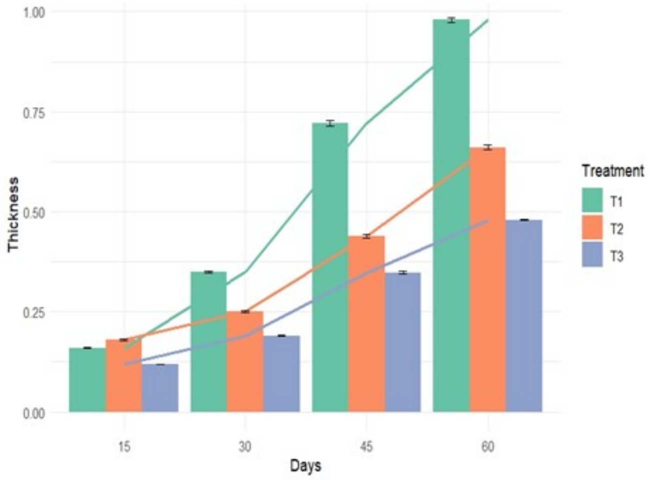


Fig. 5. shows the curve of leaf thickness in relation with 15, 30, 45, 60days axis -leaf thickness

Table 3. Effect of different treatment on thickness (mm) of *Philodendron erubscens* leaf blades.

	Leaf thickness (mm)			
Treatment	**15 days**	**30 days**	**45 days**	**60 days**
Basacote high K 6 M + hydrospeed CaB-Max	0.1603(0.400)[b]	0.3501(0.592)[a]	0.7156(0.846)[a]	0.9811(0.990)[a]
Organic CRF + hydrospeed CaB-Max	0.1803(0.425)[a]	0.2516(0.502)[b]	0.4407(0.664)[b]	0.6577(0.811)[b]
Control	0.1200(0.346)[c]	0.1901(0.436)c	0.3511(0.592)[c]	0.4800(0.693)[c]
SE d	0.001	0.001	0.003	0.002
CD (0.05)	0.004	0.006	0.009	0.008

Square root transformed values are given along the mean values. In a column, means followed by common letter(s) are not significantly different at P= 0.05. The values are the mean values of replications at different day intervals respectively.

Table 4. Effect of different treatment on root morphology of *Philodendron erubscens* leaf blades.

Treatment	Length (cm)	Proj. area (cm^2)	Surf. area (cm^2)	Avg. diam (mm)	Len. per. Vol (cm/m^3)	Root volume (cm^3)	Tips	Fork	Crossings
Basacote high K 6 M + hydrospeed CaB-Max	230.954	45.282	142.260	1.960	230.954	6.973	972	1761	114
Organic CRF + hydrospeed CaB-Max	195.151	9.883	31.049	0.506	195.151	0.393	748	565	39
Control	136.326	25.523	80.184	1.872	136.326	3.753	458	350	21

The readings are tabled using the data obtain from using winRHIZO root image analyser software. The roots were collected from each one best performed plant in terms of morphology of each Basacote high K 6 M + hydrospeed CaB-Max, organic CRF + hydrospeed CaB-Max and control respectively.

The magnesium content of leaves in Basacote high K 6 M + hydrospeed CaB-Max was 43422.412 ppm while in organic CRF + hydrospeed CaB-Max it was 27422.822 ppm. The concentration of phosphorus in the Basacote high K 6 M + hydrospeed CaB-Max leaf sample was 5882.071 ppm. In the leaf sample collected from the plant treated with organic CRF + hydrospeed CaB-Max was 5403.366 ppm.

4.2.2. Micronutrients

The boron level in the leaves after 60 days transplanting in the Basacote high K 6 M + hydrospeed CaB-Max leaf sample S1 was 65.686 ppm. In organic CRF + hydrospeed CaB-Max treated was 40.596 ppm which is well within the optimal range of 20 to 100 ppm found in plant leaves (9). The iron concentration in Basacote high K 6 M + hydrospeed CaB-Max was 25589.121 ppm and in organic CRF + hydrospeed CaB-Max 15512.779 ppm. The zinc concentration in Basacote high K 6 M + hydrospeed CaB-Max was 12.584.38 ppm while in organic CRF + hydrospeed CaB-Max it was 9.612 ppm.

4.3. The gas exchanges analysis

The effect of treatments on plant performance was evaluated by monitoring the leaf exchanges. The control plants showed a photosynthetic rate of 3.18 µmol m^{-2} s^{-1} on average (Table 5). The Basacote high K 6 M + hydrospeed CaB-Max treatments induced higher photosynthetic activity with values that ranged from to 11.46 µmol m^{-2} s^{-1} (Table 5). Second highest photosynthetic rate was found in organic CRF + hydrospeed CaB-Max treated plants of 5.09 µmol m^{-2} s^{-1} on average (Table 5). The Basacote high K 6 M + hydrospeed CaB-Max and organic CRF + hydrospeed CaB-Max showed statistically significant higher values compared to the control. The transpiration rate in the control plant was 0.34 mmol m^{-2} s^{-1} on average and all treatments showed relatively higher values. The transpiration rate was the highest in the Basacote high K 6 M + hydrospeed CaB-Max with an average of 1.32 mmol m^{-2} s^{-1}. The highest stomatal conductance was found in the Basacote high K 6 M + hydrospeed CaB-Max with a value of 30.97 mmol m^{-2} s^{-1}. Transpiration rate, stomatal conductance and photosynthetic rate at different day interval are shown in Fig. 6-8 respectively.

4.4. Chlorophyll index (SPAD)

There was a significant difference between control and treatments (Table 6). Basacote high K 6 M + hydrospeed CaB -Max had higher chlorophyll index of 47.143 followed by treatment 2 which had a chlorophyll index of 46.23. The control was recorded to maintain lower chlorophyll index of 34.20.

Referring to the results shown in Table 1, Basacote high K 6 M + hydrospeed CaB-Max was categorized to be much more efficient in stimulating the growth of the plant than the organic CRF + hydrospeed CaB-Max. At the end of 60 days Basacote high K 6 M + hydrospeed CaB-Max plants grew up to a height of 28 cm. Basacote high K 6 M + hydrospeed CaB-Max exhibited the highest value (48 cm) compared with organic CRF + hydrospeed CaB-Max which recorded the lowest averaging 21.56 cm. The plants grown under control treatment exhibited the lowest value with 17.80 cm. This is actually 60 % more than the control and 32 % more than the organic CRF + hydrospeed CaB-Max. The spread of plant in Basacote high K 6 M + hydrospeed CaB-Max was highest with a mean value of 27. 092 cm and this was 41 % more than the control and 23 % more than organic CRF + hydrospeed CaB-Max. Fig. 1 and 2 revealed that a rich exponential plant growth curve for plant height and spread was observed in plants treated with + hydrospeed CaB-Max. This pattern showed that the plant nutrient requirement was determined to be in steady relation with the supply from the CRF, as depicted (2). Nutrient release may possibly proceed at steady to higher rates and thus, supporting good vegetative growth through continued cellular division and enlargement. Notably Basacote high K 6 M + hydrospeed CaB-Max grew even better than organic CRF + hydrospeed CaB-Max and this proves that the supply of nutrients in Basacote high K 6 M along with the supplementary calcium and boron from hydrospeed CaB-Max is a better format for efficient growth

Table 6. Effect of different treatment on chlorophyll content of *Philodendron erubscens.*

Treatment	Chlorophyll index
Basacote high K 6 M + hydrospeed CaB-Max	47.143(6.866) [a]
Organic CRF + hydrospeed CaB-Max	40.207(6.340) [b]
Control	38.322(6.190) [c]
SE(d)	0.136
CD (0.05)	0.286

In a column, means followed by common letter(s) are not significantly different at P=0.05. The values are the mean values of replications at different day intervals respectively. These are the reading taken from the chlorophyll meter (SPAD 502)Square root transformed values are given along the mean values. In a column, means followed by common letter(s) are not significantly different at P=0.05. The values are the mean values of replications.

Table 5. Effect of different treatment on Pn, E, C of *Philodendron erubscens.*

Treatment	Photosynthetic rate Pn (umol/m²/s)	Transpiration Rate E (mmol/m²/s)	Stomatal conductance C (mmol/m²/s)
Basacote high K 6 M + hydrospeed CaB-Max	11.46[a]	1.32[a]	30.97[a]
Organic CRF + hydrospeed CaB-Max	5.09[b]	0.54[b]	23.28[b]
Control	3.18[c]	0.34[c]	5.44[c]
SE(d)	0.068	0.010	0.276
CD (0.005)	0.144	0.022	0.580

In a column, means followed by common letter(s) are not significantly different at P=0.05. The values are the mean values of replications at different day intervals respectively. These are the readings taken from the CI-340 Handheld photosynthesis machine. Square root transformed values are given along the mean values. In a column, means followed by a common letter(s) are not significantly different at P=0.05. The values are the mean values of replications.

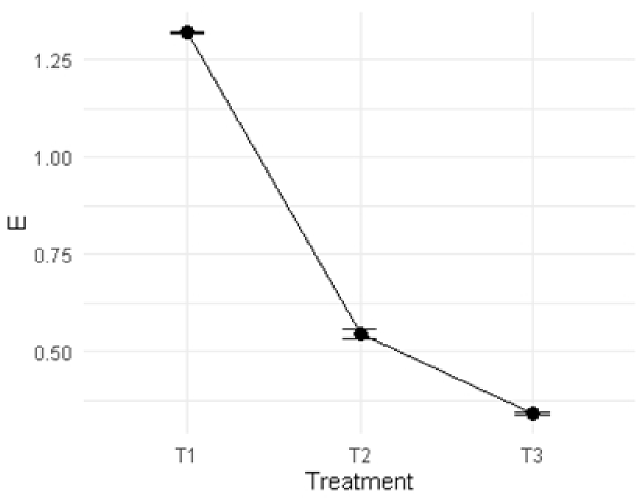


Fig. 6. shows the graph of the transpiration rate of T1, T2, T3(control). Y Axis E – Transpiration rate **(**mmol/m^2/s)

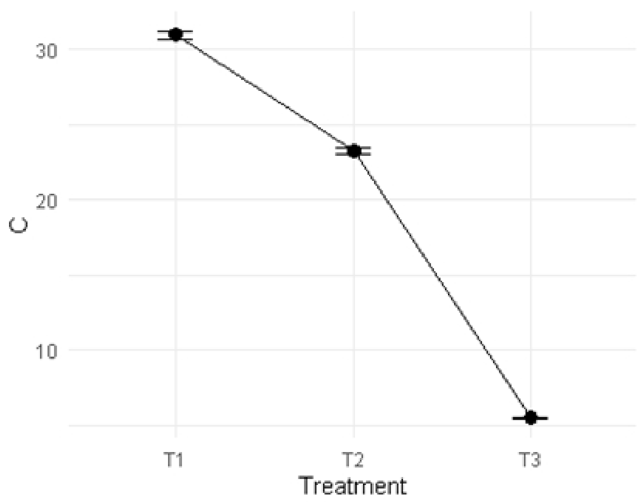


Fig. 7. shows the graph of the transpiration rate of T1, T2, T3 (control). Y Axis E – Stomatal conductance **(**mmol/m^2/s)

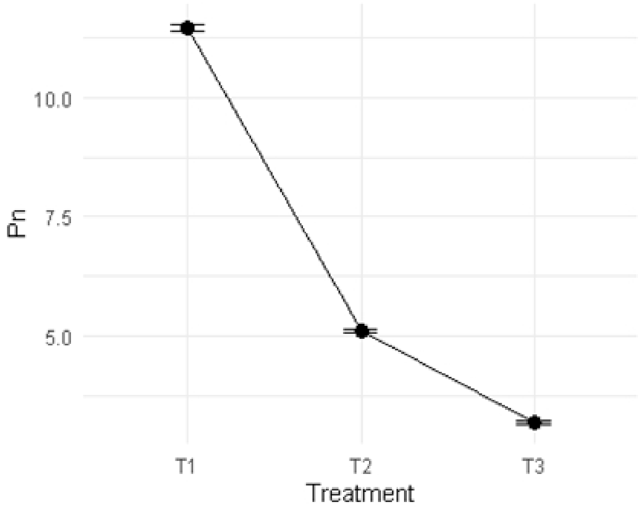


Fig. 8. shows the graph pf transpiration rate of T1,T2,T3 (control).Y Axis E - Photosynthetic rate (umol/m2/s)

of *P. erubescens*.

The enhancement in leaf size is mostly-important for ornamental plants like *P. erubescens* as size of the leaves primarily contributes to their beauty. Big leaves are not only aesthetic but increase the energy-producing area of the plant, thus may improve the general health of the plant. This increase in the size of the leaves is in accordance with the studies noting that application of CRFs on woody ornamental plants would lead to improved size of the leaves (10). The inequality of the changes in the length and breadth may point to the fact that CRFs can affect different facets of leaf growth in different ways. The relative increase in the breadth of the leaves as compared to its length might point to a definite influence on the mechanisms of leaf expansion, specifically, the processes of cell enlargement or the formation of secondary veins. This aspect deserves further investigation at the cellular and molecular levels in order to explain the fundamentals of the phenomenon under study. Table 3 revealed that Basacote high K 6 M + hydrospeed CaB-Max increased the size of the leaves in comparison to organic CRF + hydrospeed CaB-Max and control where leaves of Basacote high K 6 M + hydrospeed CaB-Max was recorded to be (0. 9811 mm) bigger than organic CRF + hydrospeed CaB-Max (0. 6577 mm) and control (0. 4800 mm) at 60 days.

Higher Leaf Area Index (LAI) figures are usually related to increased water use efficiency and increased mechanical characteristics of the leaf (11). Whereas in the case of ornamental plants larger leaves to some extent could be helpful enhancing the duration of leaf's life span and increase its ability to withstand physical stress that stems from handling or transporting the plants. However, it was observed that increased leaf thickness is associated with higher chlorophyll level per unit area of the leaf which could also be the reason of improved photosynthesis in Basacote high K 6 M + hydrospeed CaB-Max treated plants. The significant increase of leaf thickness also indicates that the CRF treatment might affect internal structures of leaf presumably due to the enhanced differentiation of palisade parenchyma or increased amount of cell layers in it. This structural enhancement could help with better light capture in many or all the functions served by the leaf. The root morphology data of the seedlings given in Table 4 shows clear and strong evidence for the enhanced root system in the plants through the application of CRFs especially Basacote high K 6 M + hydrospeed CaB-Max. Basacote high K 6 M + hydrospeed CaB-Max treated plants showed superior performance across all measured parameters. Parameters of Table 4 suggest a greater and more probing tap root system development which would be endowed with the potentiality of sampling a greater volume of soil and may possibly be able to establish in a more efficient manner in the heterogeneous distribution of nutrients in the growth media. Fig. 9-11 shows the plants treated with treatment 1, treatment 2 and control respectively.

In this study, plants that were treated with Basacote high K 6 M + hydrospeed CaB-Max contained the highest photosynthetic rate (Pn) of 11 µm/m^2/s. The Basacote high K 6 M + hydrospeed CaB-Max has higher photosynthetic rate, accounting to a better carbon assimilation rate, leading to enhanced biomass accumulation and consequently increasing the vigor of the plants (12). Perhaps the gradual mobilization of nutrients held in the CRF perhaps boosted the making and efficiency of the photosynthetic enzymes, especially Rubisco. Higher SPAD values recorded in Basacote high K 6 M + hydrospeed CaB-

Fig. 9

Fig. 10

Fig. 11

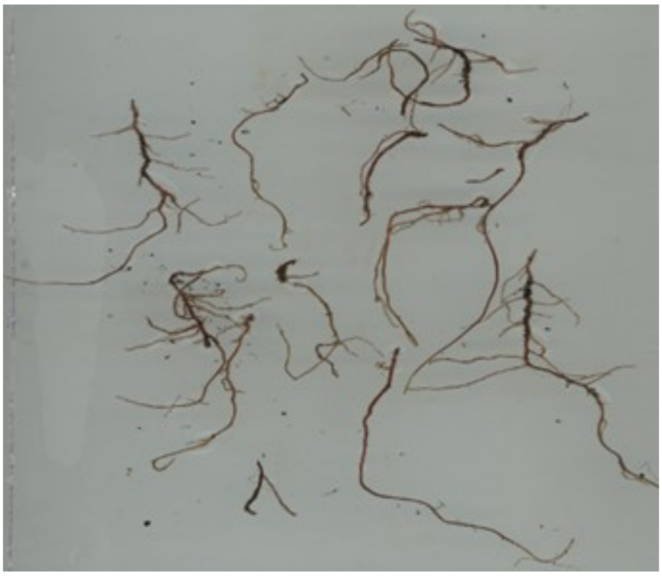


Fig. 12

Fig. 13

Fig. 14

Fig. 9-11 represents the plant images of *Philodendron erubecens* treatment 1, treatment 2 and control respectively at 60th day. **Fig. 12-14** represents the root images of WinRHIZO optical scanner (version 5.0) software taken at 400 dpi resolution with colour scale of Basacote high K 6 M + hydrospeed CaB-Max, treatment 2 and control respectively. The roots were collected from each one best performed plant in terms of morphology of each Basacote high K 6 M + hydrospeed CaB-Max, treatment 2 and control respectively

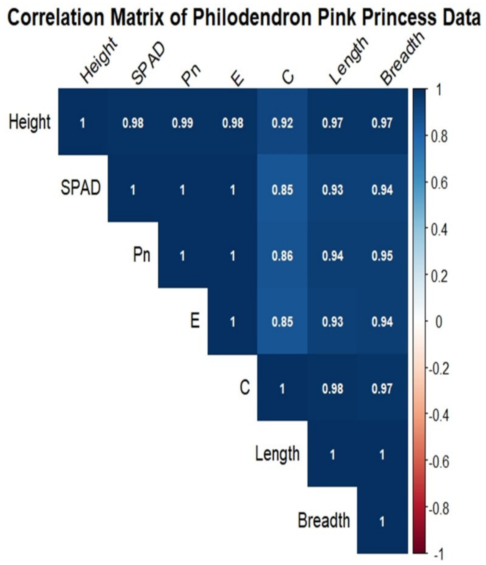
Fig. 15

Fig. 16

Fig. 16. showing the tissue cultured plants of *Philodendron erubescens* in giffy bags. **Fig. 15** represents the analysed root images in WinRHIZO optical scanner (version 5.0) software of Basacote high K 6 M + hydrospeed CaB-Max treated *Philodendron erubescens.*

Max plants confirm the increased chlorophyll level in plants, which are known to directly enhance light capture ability and better expression of photosynthesis (13). Since nitrogen is involved in the manufacture of chlorophyll and Rubisco the higher leaf N content in Basacote high K 6 M + hydrospeed CaB-Max plants may have allowed a higher potential photosynthetic rate as indicated (14). Energy balance through transpiration rate was also influenced by the fertilizer treatments. Basacote high K 6 M + hydrospeed CaB-Max exhibited the highest value of transpiration rate of 1.32 mmol m^{-2} s^{-1} followed by organic CRF + hydrospeed CaB-Max with a value of 0.54 mmol m^{-2} s^{-1} and the control treatment with 0.34 mmol m^{-2} s^{-1}. Increased proportion of absorbed water perhaps is a result of changes in root morphology (15). Specifically, stomatal conductance responsible for the uptake of CO_2 and the loss of water vapour was significantly affected by the treatment regimes. Stomatal conductance in Basacote high K 6 M + hydrospeed CaB-Max plants was 30. 97 mmol m^{-2} s^{-1} which is significantly higher as compared to organic CRF + hydrospeed CaB-Max plants (23. 28 mmol m^{-2} s^{-1}) and control (5.44 mmol m^{-2} s^{-1}). This increased stomatal conductance in Basacote high K 6 M + hydrospeed CaB-Max plants indicates more chances to allow CO_2 diffusion into the leaf, according to the higher photosynthesis rate (16). Better water status and turgor preservation might be because of the increased ability of roots to absorb water (17). It is also evident from the analysis employing Pearson's correlation that most physiological parameters exhibited a strong positive relationship with one another. Also, SPAD values that represent chlorophyll content had higher positive relationships with photosynthetic rate (r = 0. 995 µm/m^2/s), transpiration rate (r = 0. 996 mmol m^{-2} s^{-1}) and stomatal conductance (r = 0. 851 mmol m^{-2} s^{-1}) at 0. These correlations show that there is compatibility between photosynthesis, water and nutrients in *P. erubescens*. The close relationship between SPAD values and Pn (0. 995 µm/m^2/s) adds to the fact that chlorophyll pigments are key in photosynthetic capacity. This relationship is already known in the literature although chlorophyll content is often used as an index of photosynthetic capacity (18). It can be seen that E and C are highly positively correlated with a coefficient of 0.851, which indicates that the waters vapour loss is affected by CO_2 taken up through stomatal mechanism. This relationship is crucial in determining the water use efficiency of plants and other strategies of carbon acquisition (19). Notably, the research also established considerable relationships between these physiological values and the morphological features including plant height, length of the leaf and the breadth of the leaf. This implies that the increase in the physiological performance that results from Basacote high K 6 M + hydrospeed CaB-Max treatment results in better growth and development of *P. erubescens*. Concerning the accurate available macronutrients present in the leaf samples, it is observed here that Basacote high K 6 M + hydrospeed CaB-Max treatment exhibited better accumulation of calcium in the leaves as compared to organic CRF + hydrospeed CaB-Max with a mean value of 34,352.546 ppm on first treatment and 26,667.261 ppm in second treatment. High Ca content in plants may improve the cell wall properties, membrane functions and the signalling properties in Basacote high K 6 M + hydrospeed CaB-Max plants. As the result of the higher Ca levels the enhancement of significant morphological characteristics of Basacote high K 6 M + hydrospeed CaB-Max plants has been revealed such as increased thickness of leaves and height of plants which could indicate the involvement of Ca in the support of the main physiologic structure of plants. The recorded K level in plants exposed to Basacote high K 6 M + hydrospeed CaB-Max was relatively high 46,446.3 ppm than organic CRF + hydrospeed CaB-Max (26,677.871 ppm). Potassium has multifunctional role especially in osmotic regulation and activation of enzymes and stomatal (Wang et al., 2013). The higher K content in Basacote high K 6 M + hydrospeed CaB-Max plants is as per the increased stomatal conductance (30.97 mmol m^{-2} s^{-1}) and transpiration rate. The amount of Mg content was found to be significantly higher in Basacote high K 6 M + hydrospeed CaB-Max than that of organic CRF + hydrospeed CaB-Max that contained only 27,422.822 ppm.

The enhancement of Mg in chlorophyll molecule showed a great positive relation with the elevated SPAD values (47. 143) in Basacote high K 6 M + hydrospeed CaB-Max plants. This relationship explains the observed increased in photosynthetic rate in the Basacote high K 6 M + hydrospeed CaB-Max plants at 11. 46 μmol m^{-2} s^{-1}; Mg is vital in chlorophyll biosynthesis and consequently photosynthesis (20). Although the variation in P content between Basacote high K 6 M + hydrospeed CaB-Max (5,882. 07 ppm) and organic CRF + hydrospeed CaB-Max (5,403. 366 ppm) was not fairly high compared to the other macronutrients, a little percentage of increased P content in Basacote high K 6 M + hydrospeed CaB-Max helped to enhance the energy transport and metabolic activities. This may have contributed to higher growth parameters and physiological efficiency recorded in Basacote high K 6 M + hydrospeed CaB-Max plants. Indication of greater B content in Basacote high K 6 M + hydrospeed CaB-Max leaves (65. 686 ppm) when compared to organic CRF + hydrospeed CaB-Max (40. 596 ppm). This is within the optimal range for the growth of plants (20 -100 ppm) as per (9). B levels are significant in the synthesis of the cell wall and reproductive organs as well as in carbohydrate metabolism (21). Since there was higher B content in the plants treated with Basacote high K 6 M + hydrospeed CaB-Max the overall structural development and growth of the plants may have been enhanced. Basacote high K 6 M + hydrospeed CaB-Max plants were found to contain relatively greater Fe content than organic CRF + hydrospeed CaB-Max (25589. 12 ppm) as against 15512. 779 ppm Fe in organic CRF + hydrospeed CaB-Max plant species. It was demonstrated that iron is the most important micronutrient used in chlorophyll manufacture and electron transportation procedures in photosynthesis (22). The Basacote high K 6 M + hydrospeed CaB-Max plants contain higher Fe levels that imply with the SPAD values and the increased rate of photosynthesis. Zinc content was found to be maximum in Basacote high K 6 M + hydrospeed CaB-Max leaves with the value of 12,584. 38 ppm while the minimum value was recorded in organic CRF + hydrospeed CaB-Max with the value of 9. 612 ppm. Auxin metabolism and protein synthesis and activation of enzymes are some of the functions assisted by zinc (23). That higher concentration of Zn in Basacote high K 6 M + hydrospeed CaB-Max plants can play a role in enhancing the total metabolic rates and co-ordinate growth. The



Pearson's correlation coefficient matrix for morphophysiological parameters *Philodendron erubscens*. Pn is the photosynthetic rate, E is the transpiration rate, C is the stomatal conductance.

increase in the content of Mg, Fe and Zn in Basacote high K 6 M + hydrospeed CaB-Max plants is in direct proportion that is reflected to the increase in photosynthetic rate of 11.46 μmol/m^2/sec. Such a nutrient dependency implies that these substances are crucial for the assembly of chlorophyll and efficient function of photosynthetic equipment in plants (24). As observed in Basacote high K 6 M + hydrospeed CaB-Max plants, the Mg and Fe concentration is also high and compatible with the higher SPAD value of 47. 143 (Table 6) indicating better chlorophyll contents. It enhances the relationship between the availability of nutrients and the synthesis of chlorophyll (13). Basacote high K 6 M + hydrospeed CaB-Max plants also show a higher K content with a stomatal conductance of 30. 97 mmol m^{-2} s^{-1} and transpiration rate of 1 mmol/m^2/s. This is in complete accordance with the previous studies confirming the role of K in controlling stomatal activity and water metabolism (25). The superior performance of the Basacote high K 6 M + hydrospeed CaB -Max treatment across multiple parameters suggests that this CRF formulation could be an effective fertilization strategy for commercial production of *Philodendron erubescens*. The improved growth rates, enhanced root development and better physiological performance indicate that plants may reach marketable size more quickly and with better quality characteristics. From Table

Table 7. Pearson's correlation coefficient for *Philodendron erubescens.*

Morpho-physiological parameters							
	SPAD	**Height**	**Length**	**Breadth**	**Pn**	**E**	**C**
SPAD	**1.000**	0.984	0.932	0.939	0.995	0.996	0.851
Height	0.984	1.00	0.974	0.974	0.985	0.983	0.918
Length	0.932	0.974	1.000	0.995	0.940	0.933	0.981
Breadth	0.939	0.974	0.995	1.000	0.949	0.942	0.973
Pn	0.995	0.985	0.940	0.949	1.00	0.998	0.863
E	0.996	0.983	0.933	0.942	0.998	1.000	0.851
C	0.851	0.918	0.981	0.973	0.863	0.851	1.000

Pearson's correlation coefficient for *Philodendron erubscens* for Basacote high K 6 M + hydrospeed CaB-Max, organic CRF + hydrospeed CaB-Max and control. Pn is photosynthetic rate, E is the transpiration rate, C is the stomatal conductance.

7 it is summarised that Strong overall correlations between morphological and physiological data. All variables show high positive correlations (0.85-1.00), indicating strong relationships between the measured characteristics of the plant. Moreover, the use of CRFs could potentially reduce fertilizer application frequency and minimize nutrient runoff, aligning with sustainable horticultural practices (5). The economic implications of faster growth and potentially reduced labor costs for fertilizer application should be considered in future cost-benefit analyses of CRF use in commercial setting.

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